Legal Qualification of the Risks and Consequences of Permafrost Degradation: From Negative Impact to Legally Cognizable Harm

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Abstract

The aim of this article is to develop a systematic approach to the legal qualification of negative impacts resulting from permafrost degradation in the Arctic. The relevance of the research is determined by growing climate-related threats to infrastructure, ecosystems, and social stability, which necessitate a shift from fragmented regulatory responses to comprehensive legal regulation. Based on interdisciplinary and comparative legal analysis, the article reveals the fragmented nature of existing legislation in Arctic countries, which remains largely oriented toward addressing consequences rather than preventive risk management.

A key contribution of the study is the proposed classification of negative impacts, which conceptualizes permafrost as an independent object of legal protection rather than merely a source of secondary risks. This reconceptualization is essential for moving from reactive regulation to preventive risk governance, as it justifies the imposition of mandatory adaptation measures at the stage of risk identification, prior to the occurrence of harm. On this basis, the article substantiates a two-tier regulatory model comprising preventive measures (monitoring, standards, zoning) at the risk stage and liability mechanisms (compensation and restoration) once legally cognizable harm has materialized.

The findings of the study provide a foundation for the differentiated and equitable distribution of responsibility among states, business actors, and financial institutions, and may inform the development of a Model Law "On the Protection and

Sustainable Management of Permafrost" as a legal instrument for advancing proactive Arctic risk management and national adaptation strategies.

Keywords: Permafrost degradation; Negative impacts; Climate risk; Legally cognizable harm; Arctic; Allocation of responsibility; Environmental monitoring; climate adaptation; Compensation for harm.

Resumen. *Calificación jurídica de los riesgos y las consecuencias de la degradación del permafrost: del impacto negativo al daño jurídicamente relevante*

El objetivo de este artículo es desarrollar un enfoque sistemático para la calificación jurídica de los impactos negativos derivados de la degradación del permafrost en el Ártico. La relevancia de la investigación viene determinada por el creciente aumento de las amenazas climáticas para las infraestructuras, los ecosistemas y la estabilidad social, lo que exige una transición desde respuestas regulatorias fragmentadas hacia una regulación jurídica integral. Sobre la base de un análisis jurídico interdisciplinar y comparado, el artículo pone de manifiesto el carácter fragmentado de la legislación vigente en los países árticos, que sigue estando orientada en gran medida a la reacción frente a las consecuencias, más que a la gestión preventiva del riesgo.

Una aportación central del estudio es la clasificación propuesta de los impactos negativos, que conceptualiza el permafrost como un objeto autónomo de protección jurídica y no meramente como una fuente de riesgos secundarios. Esta reconceptualización resulta esencial para avanzar desde una regulación reactiva hacia una gobernanza preventiva del riesgo, en la medida en que justifica la imposición de medidas obligatorias de adaptación en la fase de identificación del riesgo, con anterioridad a la producción del daño. Sobre esta base, el artículo fundamenta un modelo regulatorio de dos niveles, que comprende medidas preventivas (monitoreo, estándares y zonificación) en la fase de riesgo y mecanismos de responsabilidad (compensación y restauración) una vez que el daño jurídicamente relevante se ha materializado.

Los resultados del estudio sientan las bases para una distribución diferenciada y equitativa de las responsabilidades entre los Estados, los actores empresariales y las instituciones financieras, y pueden servir de referencia para la elaboración de una Ley Modelo "Sobre la protección y la gestión sostenible del permafrost" como instrumento jurídico destinado a impulsar una gestión proactiva de los riesgos en el Ártico y las estrategias nacionales de adaptación.

Palabras clave: Degradación del permafrost; Impactos negativos; Riesgo climático; Daño jurídicamente relevante; Ártico; Asignación de responsabilidades; Monitoreo ambiental; Adaptación climática; Compensación del daño.

Resum. *Qualificació jurídica dels riscos i de les conseqüències de la degradació del permafrost: de l'impacte negatiu al dany jurídicament rellevant*

L'objectiu d'aquest article és desenvolupar un enfocament sistemàtic per a la qualificació jurídica dels impactes negatius derivats de la degradació del permafrost a l'Àrtic. La rellevància de la recerca ve determinada per l'augment creixent de les amenaces climàtiques sobre les infraestructures, els ecosistemes i l'estabilitat social, fet que exigeix una transició des de respostes reguladores fragmentades cap a una regulació jurídica integral. A partir d'una anàlisi jurídica interdisciplinària i comparada, l'article posa de manifest el caràcter fragmentari de la legislació vigent als països àrtics, que continua orientada en gran mesura a la reacció davant les conseqüències, més que no pas a la gestió preventiva del risc.

Una aportació central de l'estudi és la classificació proposada dels impactes negatius, que conceptualitza el permafrost com un objecte autònom de protecció jurídica i no merament com una font de riscos secundaris. Aquesta reconceptualització és essencial per avançar des d'una regulació reactiva cap a una governança preventiva del risc, en la mesura que justifica la imposició de mesures obligatòries d'adaptació en la fase d'identificació del risc, amb anterioritat a la producció del dany. Sobre aquesta base, l'article fonamenta un model regulador de dos nivells, que comprèn mesures preventives (monitoratge, estàndards i zonificació) en la fase de risc i mecanismes de responsabilitat (compensació i restauració) un cop el dany jurídicament rellevant s'ha materialitzat.

Els resultats de l'estudi estableixen les bases per a una distribució diferenciada i equitativa de les responsabilitats entre els Estats, els actors empresarials i les institucions financeres, i poden servir de referència per a l'elaboració d'una Llei model "Sobre la protecció i la gestió sostenible del permafrost" com a instrument jurídic destinat a impulsar una gestió proactiva dels riscos a l'Àrtic i les estratègies nacionals d'adaptació.

Paraules clau: Degradació del permafrost; Impactes negatius; Risc climàtic; Dany jurídicament rellevant; Àrtic; Assignació de responsabilitats; Monitoratge ambiental; Adaptació climàtica; Compensació del dany.

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1. RELEVANCE OF THE PROBLEM

1.1. Physical, Economic, and Technological Dimensions of Permafrost Degradation

Permafrost degradation is recognized as one of the most significant systemic threats to the stability of infrastructure, the economy, and the traditional way of life in the Arctic region, affecting the USA (Alaska), Canada, Denmark (Greenland), Russia, and the Scandinavian countries (hereinafter referred to as the "Arctic countries"). Processes of permafrost degradation or thawing of perennially frozen ground (this phenomenon is used synonymously in scientific discourse as a designation for the cryolithozone), accelerated by warming in the Arctic 2–4 times faster than the global average, lead to the loss of bearing capacity of foundations and mass deformations of buildings and engineering structures. According to international expert estimates, up to 70% of Arctic infrastructure could be in the high-risk zone by 2050 (Hjort *et al.*, 2018).

The economic consequences of this process are reaching catastrophic proportions. The total projected damage to infrastructure facilities in Arctic countries by 2050 is estimated at hundreds of billions of US dollars. For the Russian Arctic, expert estimates range from 50 to 70 billion dollars, with annual costs for maintaining the stability of road infrastructure potentially exceeding 300 million dollars. In Canada, expenditures on adapting infrastructure to permafrost changes amount to billions of dollars, while in Alaska, cases of relocating entire settlements due to loss of ground stability have been documented (Rajendran *et al.*, 2021) (*BBC News*, 2021).

The systemic nature of the threat is confirmed by the increasing frequency and scale of technological accidents. The 2020 accident in Norilsk, which led to a spill of over 20 thousand tons of diesel fuel, became a clear illustration of how permafrost

degradation can trigger environmental disasters with transboundary consequences. Similar incidents are recorded in other Arctic jurisdictions: destruction of roads and airports in Alaska, building deformations in the Canadian Arctic, damage to pipeline infrastructure in Scandinavia (Langer *et al.,* 2023).

1.2. Risk Assessment and the Limits of Positive Effects

For completeness, it should be noted that several studies report potential local positive effects of warming at high latitudes, including a lengthening of the growing season, partial enhancement of vegetation, improved access to mineral resources, and seasonal navigation. However, their scale and sustainability are recognized as disproportionately small compared to the cumulative risks (destabilization of infrastructure, increased methane emissions, irreversible landscape transformations, threats to Indigenous peoples). Consensus estimates from the Intergovernmental Panel on Climate Change (IPCC) and Arctic Monitoring and Assessment Programme (AMAP) confirm the unconditional priority of preventive regulation, adaptation, and harm compensation (Smith & Levasseur, 2021).

1.3. Legal Relevance and Systemic Challenges

The key unresolved legal problem remains the absence of holistic mechanisms for qualifying, preventing, and compensating for harm related to permafrost degradation. Existing approaches are characterized by fragmentation: they focus on the consequences of degradation but do not treat permafrost as an independent object of legal protection. The lack of uniform methodologies for damage assessment, criteria for distinguishing between natural and anthropogenic factors, and a clear allocation of responsibility between public and private actors creates a legal vacuum that undermines effective risk management. Against this background, the relevance of this research is underscored by the following systemic challenges:

(i) **The transboundary nature of permafrost degradation**. Permafrost degradation is not confined by national borders; it affects global climate processes through greenhouse gas emissions, the transboundary transport of pollutants via Arctic river systems, and large-scale ecosystem degradation. Addressing these impacts requires coordinated legal and regulatory approaches among all Arctic states within the framework of the Arctic Council and other international cooperation mechanisms (Melvin *et al.*, 2017). Particular relevance is added by the Advisory Opinion of the International Court of Justice of 21 May 2024, in which the Court confirmed the existence of states' obligations under international law in relation to climate change, including the duty to exercise due diligence to prevent transboundary environmental harm.

Permafrost degradation represents one of the most visible manifestations of such harm in the Arctic (WMO, 2024).

(ii) **Accumulated environmental risks**. Thawing permafrost leads to the release of historically accumulated pollutants. The Arctic cryolithozone[1] hosts thousands of industrial facilities and waste disposal sites containing toxic substances that, upon thawing, can migrate into aquatic systems and surrounding ecosystems. Current estimates suggest that by the end of the century between 1,100 and 5,200 contaminated sites in the Arctic will be located within zones of active permafrost thaw (AMAP, 2021) (Langer *et al.*, 2023).

(iii) **Social consequences for Indigenous peoples**. Permafrost degradation poses a direct threat to the traditional livelihoods of more than 500,000 Indigenous peoples in the Arctic. These impacts include damage to settlement infrastructure, disruption of animal migration routes, and degradation of pasture lands essential for subsistence activities (CSA Group, 2014).

Taken together, these challenges highlight the complexity of the legal qualification of permafrost degradation, which is exacerbated by the need to distinguish between natural climatic processes and anthropogenic impacts, particularly in the context of transboundary effects. At present, international law lacks objective, legally enshrined criteria for determining the transition from physical environmental impact to legally cognizable harm.

Addressing these deficiencies necessitates the development of a systematic legal regulatory framework, grounded in recognition of the specific conditions of the Arctic and the cumulative, multi-layered nature of the risks associated with permafrost degradation.

2. STATE OF THE ART

The contemporary scientific paradigm for studying permafrost degradation is grounded in consensus assessments from the Intergovernmental Panel on Climate Change (IPCC) and the Arctic Monitoring and Assessment Programme (AMAP), which view this phenomenon through the lens of systemic negative impacts.[2]

Physical-geographical and geocryological research identifies three main categories of impacts associated with permafrost degradation. First, geomechanical

[1] The term *cryolithozone* is widely used in Russian and Eurasian scientific literature to denote the permafrost zone and is employed here as a synonym of *permafrost zone*.

[2] U.S. Government Accountability Office. (2009). *Alaska Native villages: Limited progress has been made on relocating villages threatened by flooding and erosion* (Report No. GAO-09-551). https://www.gao.gov/products/gao-09-551

changes involve the loss of bearing capacity of frozen ground, resulting in deformation and failure of buildings, roads, pipelines, and other critical infrastructure. By 2050, up to 70% of Arctic facilities may fall within a high-risk zone (Novikova, 2024).

Second, biogeochemical processes include substantial emissions of carbon dioxide (CO_2) and methane (CH_4) from thawing organic deposits, generating positive feedbacks that intensify global warming. Arctic permafrost stores approximately 1,700 Gt of carbon—almost twice the amount currently present in the atmosphere (CSA Group, 2019).

Third, landscape-ecological transformations encompass the development of thermokarst (Standards Council of Canada, 2024), thermal coastal erosion (reaching up to 20 m per year in some areas), widespread waterlogging, and the irreversible degradation of unique Arctic ecosystems (Alfred Wegener Institute, 2023). In addition, large-scale northward forest expansion into tundra regions has been observed, leading to a reduction in tundra extent; the implications of this process for ecosystem stability and the global carbon cycle remain insufficiently understood (Hjort *et al*., 2018).

These effects generate multiple risks and lead to the emergence of systemic harm from permafrost degradation. However, existing research remains predominantly focused on technical and natural-scientific dimensions, while their legal qualification remains fragmented and reactive (AMAP, 2021).

At the same time, permafrost degradation should not be understood as a merely local geotechnical issue, but rather as a systemic transboundary challenge of global scale, contributing to the emergence of a new legal reality and necessitating a shift from reactive engineering fixes to proactive legal governance (Haeberli *et al.*, 2021); (CSA Group, 2014). The accelerated pace of climate change in the Arctic necessitates a shift from fragmented response measures toward the development of a comprehensive architecture of international responsibility that integrates legal principles, financial instruments, and institutional frameworks into a coherent system of risk management.

The scientific novelty of this research lies in moving beyond the descriptive analysis of physical processes toward their systematic legal qualification. A central contribution of the study is the development of a conceptual framework that structures the transition from the observation of natural phenomena to the activation of legal mechanisms.

Within this framework, legally cognizable harm does not arise from any physical change per se, but only when the consequences of permafrost degradation: (i) reach thresholds established by law, and (ii) affect specific legally protected interests, including public safety, property integrity, the right to a favorable environment, and the preservation of cultural heritage. It is this transition that triggers legal mechanisms such as permitting procedures, technical standards, liability regimes, and adaptation measures.

The proposed methodology demonstrates how this transition operates in practice across different jurisdictions. For example, deformation of a building's foundation becomes legally cognizable harm once permissible limits established by

construction standards are exceeded (e.g., CSA S501 in Canada), thereby triggering obligations for remediation or suspension of operation. Similarly, changes in hydrological regimes acquire legal significance when they require special permits for impacts on water bodies (e.g., under the Clean Water Act in the United States, 1972) (Svalbard Environmental Protection Act, 2001).

A further element of scientific novelty is the classification of impacts according to their direction of influence: impacts *on* permafrost—as an independent natural object requiring preventive legal protection—and impacts *from* degrading permafrost on associated systems such as infrastructure, ecosystems, and society, which require reactive regulatory measures. This distinction provides the conceptual foundation for a two-tier system of legal regulation (Global Affairs Canada, 2024).

Methodology. The research is based on an interdisciplinary approach combining: (i) comparative legal analysis of legislation in Arctic states (Russia, Canada, the United States, and Norway); (ii) the formal-legal method applied to normative acts, technical standards, and enforcement practices; (iii) analysis of data from both background (state) and facility-level (corporate) monitoring systems, including the Norilsk Nickel monitoring system and the emerging Russian state network; and (iv) synthesis of findings from international scientific assessments to provide empirical support for the proposed legal model (AMAP, 2025; Woodwell Climate Research Center, 2025).

Legal significance and practical applicability. The study contributes to the formation of a legal basis for recognizing permafrost as an object of special legal protection and for introducing mandatory standards governing design, monitoring, and operation within the cryolithozone. The development of mechanisms for early risk detection, adaptation standards aimed at prevention, and a fair allocation of responsibility for addressing accumulated damage among states, businesses, and the international community is fully consistent with the International Court of Justice's interpretation of states' obligations of due diligence.

The article addresses these interconnected challenges through a structured analysis presented across ten substantive sections of the article.

3. LEGAL CHALLENGES AND REGULATORY GAPS IN PERMAFROST DEGRADATION REGULATION

3.1. Fragmentation of the Legal Qualification of Permafrost Degradation

The conducted research has revealed that, despite the obvious scale and systemic nature of the consequences of permafrost degradation, the legislation of Arctic countries lacks a single, formally defined term "negative impact associated with permafrost degradation". Instead of a holistic legal institution, only a set of individual consequences falling within the scope of general and special norms of environmental,

land, and urban planning law acquires legal significance. This fragmented approach is a key legal challenge requiring urgent resolution.

3.2. Existing Approaches to Legal Regulation and their Limitations

The existing legal qualification of this complex phenomenon is revealed through three main approaches, each covering only part of the problem field and demonstrating fundamental regulatory incompleteness:

3.2.1. Response to Classical Environmental Harm

The first approach is based on treating permafrost degradation as a factor provoking traditional types of harm—pollution of water, air, and soil resulting from accidents. This approach, underlying acts like the U.S. Clean Water Act, is activated only *post facto* and does not cover slowly developing processes, such as greenhouse gas emissions from thawing grounds. A telling example is the 2020 accident in Norilsk, where the collapse of a diesel fuel storage tank led to a release of about 21,000 tons of oil products due to ground subsidence from permafrost thaw (OECD, 2024).

3.2.2. Regulation Through Technical Standards

The second approach focuses on the regulation of the consequences of permafrost degradation (ground subsidence, thermokarst) become the object of specialized construction norms aimed at ensuring the safety of structures. An example is the Canadian standard CSA S501-14 (later updated as CSA S501:21), which defines measures to mitigate the effects of permafrost degradation for existing building foundations. However, this approach protects the *object from permafrost*, not permafrost itself as a protected ecosystem component. These standards do not prevent landscape changes, ecosystem degradation, or greenhouse gas emissions beyond the specific construction site (United Nations Environment Programme, 2012).

3.2.3. Establishing Causation in Court

The third approach serves as a basis for assigning liability, but its effectiveness is severely constrained due to the difficulty of proving a direct link between the actions of a specific entity and local permafrost degradation against the backdrop of global warming. This leaves a vast number of cases of “diffuse” or cumulative harm without legal protection, as it is impossible to identify a single responsible party (Heller, 2025).

3.3. Systemic Regulatory Gaps and the Need for an Integrated Legal Framework

This fragmentation gives rise to a number of systemic legal challenges that require comprehensive resolution:

(i) **Lack of a conceptual foundation**. Existing approaches ignore the need to protect permafrost itself as an independent natural object. The classification proposed in this study of impacts on permafrost (preventive regulation) and from permafrost (reactive measures) creates the basis for the necessary two-tier system of legal response (Langer *et al.*, 2023).

(ii) **Gaps in harm assessment and liability**. There is a lack of unified methodologies for damage assessment, especially under combined natural and anthropogenic factors. The problem of accumulated environmental damage is particularly relevant. As research shows, there are between 13,000 and 20,000 contaminated industrial sites in the Arctic located in permafrost zones, where traditional approaches to liability qualification are ineffective. Operating organizations assumed that permafrost would "reliably and permanently" isolate toxic substances, hence did not take adequate measures for their disposal (Christensen, 2024).

(iii) **Institutional incoherence of monitoring**. The research has shown the necessity of legislatively establishing a two-tier model: background (state) monitoring for mapping regional risks and facility-specific (geotechnical) monitoring as a mandatory condition for infrastructure operation. This will develop legal criteria for distinguishing between risk and harm. According to world practice, background monitoring tracks the natural state and spatiotemporal variability of conditions at background observational sites, while geotechnical monitoring represents a complex of routine instrumental observations of the state of capital construction projects and ground masses in their foundations (Yukon Environmental and Socio-economic Assessment Act, 2003)

(iv) **Heterogeneity of national approaches**. Comparative legal analysis confirms that the heterogeneity of national approaches hinders the creation of an effective system for managing transboundary risks. The Canadian standard CSA S501 focuses on technical aspects of foundation stabilization and monitoring; the U.S. Clean Water Act provides a permitting regime and liability mechanisms for water pollution; the Norwegian Svalbard Environmental Protection Act implements a preventive model considering cumulative impact on ecosystems. The goal of the latter is to preserve the virtually untouched environment of Svalbard, taking into account wilderness areas, landscapes, flora, fauna, and

cultural heritage, while allowing for environmentally safe activities. However, the fragmentation of these regimes necessitates the development of a universal legal approach applicable across all Arctic jurisdictions (Arbitration Court of the Republic of Sakha, Yakutia, 2022)

3.4. Interim Conclusions: Limits of the Existing Legal Model

Thus, the existing legal system creates an illusion of control but is in fact fragmented and ineffective. It responds to individual symptoms (accidents, destruction) but does not treat the underlying "disease"—the process of permafrost degradation. The key gap lies in the non-recognition of risk as an independent object of preventive legal impact, which prevents the construction of a holistic system of proactive management and leaves the law always one step behind irreversible climate changes.

4. FROM PRACTICAL QUALIFICATION TO THEORETICAL MODEL

Building on the identified gaps in the legal regulation of permafrost degradation, we begin with a systematic transition from describing physical processes to developing mechanisms for their legal qualification. At the core of this transition lies the conceptual chain "impact → risk → harm → legally cognizable harm" through the analysis of specific manifestations of degradation and corresponding legal mechanisms operating in Arctic jurisdictions. The typology of legally significant consequences of permafrost degradation constitutes the first step in solving this task. Various manifestations of permafrost degradation undergo a complex transformation: from initial physical processes through intermediate stages of risk and general harm to legally significant consequences that activate specific legal response mechanisms.

The typology presented below systematizes this transition across five key areas of impact associated with permafrost degradation, each characterized by its own specifics of legal qualification and requiring a differentiated regulatory approach.

(i) **Deformations and Subsidence of Infrastructure**. Physical impact, such as ground subsidence, creates a risk of violating the bearing capacity of foundations and failure of facilities. The realization of this risk leads to general harm—damage to buildings, roads, and pipelines. This becomes a legally significant consequence when permissible deformation limits are exceeded, a threat of collapse arises, or conditions for safe operation are violated. At this stage, specific legal mechanisms are activated, for example, the Canadian standard CSA S501, which prescribes obligations for monitoring, repair, or suspension of operation.

(ii) **Changes in Relief and Development of Thermokarst**. This impact generates a risk of loss of territory stability and ground displacement. General harm is the loss of agricultural land and destruction of the natural landscape. Legal qualification occurs when established land plot boundaries are violated, a threat to neighboring objects arises, or a change in land category becomes necessary. A preventive legal instrument here is, for example, the Norwegian Svalbard Environmental Protection Act, which prohibits or strictly restricts economic activities leading to irreversible landscape changes.

(iii) **Greenhouse Gas Emissions (CO_2, CH_4).** Gas emissions from thawing permafrost create a risk of accelerating global warming and disrupting the climate balance. General harm manifests in the intensification of the greenhouse effect and atmospheric pollution. These emissions become legally significant when established standards are exceeded, allowing them to be qualified as a source of environmental harm. Regulatory responses include mechanisms like the U.S. Clean Air Act, which establishes a permitting regime and emission standards for industrial facilities.

(iv) **Changes in Hydrological Regime**. This impact carries a risk of disrupting water balance, intensifying erosion, and damaging aquatic ecosystems. General harm includes waterlogging or desiccation of territories, coastal erosion. The process acquires legal significance when a negative impact on water bodies occurs, requiring coordination, or when water protection zone regimes are violated. At this juncture, norms like the Russian Water Code come into force, which mandates obtaining a permit for any impact on water bodies.

(v) **Damage to Natural and Cultural Complexes**. Permafrost degradation creates a risk of irreversible loss of biodiversity and destruction of heritage sites. General harm is expressed in the destruction of ecosystems and archaeological sites. Legally significant harm is established upon the destruction or damage of objects with special protected status (e.g., within protected areas), which violates the corresponding legal regimes. Key protective roles are played by international instruments like the UNESCO World Heritage Convention, providing legal grounds for preserving sites of outstanding value.

(vi) **Cultural and Social Harm to Indigenous Peoples**. Permafrost degradation results in the destruction of archaeological sites, sacred places, and traditional land-use territories as a consequence of coastal erosion and thermokarst processes. The loss of reindeer pastures, hunting grounds, and migration routes undermines food security and, in many cases, leads to the forced relocation of Indigenous communities. From a legal perspective, these impacts are qualified as violations of the collective rights of Indigenous peoples to preserve their

cultural identity and traditional ways of life, as enshrined in the *United Nations Declaration on the Rights of Indigenous Peoples* (2007) and the *UNESCO Convention for the Protection of the World Cultural and Natural Heritage* (1972). Legal responses include compensation and adaptation measures such as managed retreat programmes, targeted funding for cultural and community centres, and the designation of alternative territories for the continuation of traditional practices.

Thus, the legally significant specificity of impacts, risks, and harm presupposes, first and foremost, their clear articulation in legal terminology within the relevant regulatory context. To this end, this study develops and substantiates a set of interrelated legal definitions that structure the transition from physical processes to legally operative categories.

(1) **"Negative impact associated with permafrost degradation"** is defined as a set of natural and/or anthropogenic changes that form risks or directly cause harm both to permafrost itself (a specially protected natural object) and to systems connected with it—infrastructure, ecosystems, cultural heritage, and society. Such impact requires special legal measures for identification, control, prevention, adaptation, as well as restoration and compensation at different stages of manifestation.

This definition encompasses a wide spectrum of consequences—from geocryological processes to complex environmental, infrastructural, and social effects—and ensures that impacts both on permafrost and from its degradation are taken into account. It also integrates natural and anthropogenic factors within a single legal framework. The introduction of this definition into national and international practice provides a basis for the precise allocation of legal duties, the improvement of compensation mechanisms, and the integration of adaptation standards into Arctic and environmental legislation.

The analytical differentiation between negative impact and risk associated with permafrost degradation allows not only for the refinement of traditional approaches to harm qualification, but also for the identification of previously underestimated forms of damage, including accumulated environmental harm. A particularly illustrative example is the problem of waste disposal and long-term contamination in permafrost zones, discussed below. This definition further enables the legal assessment of transboundary harm.

(2) **"Legally cognizable risk"** is defined as an independent legal category representing a scientifically substantiated and measurable probability of harm to legally protected interests—such as the environment, infrastructure, human life, or cultural heritage—arising from negative impacts associated with permafrost degradation.

Within the legal system, risk performs a dual function. On the one hand, it serves as an intermediate link between impact and harm, delineating the boundary between preventive regulation and liability. On the other hand, it constitutes an autonomous object of preventive legal intervention. Although risk does not yet amount to realized damage, it represents a manageable threat whose legal significance lies in creating grounds for state intervention and for imposing obligations on economic actors prior to the occurrence of actual harm. This enables a shift from a reactive model of regulation toward proactive risk management.

(3) **"Legally cognizable harm associated with permafrost degradation"** is defined as damage to legally protected interests—life, health, property, the environment, or cultural heritage—that simultaneously meets the following criteria: (a) it reaches an established normative threshold (e.g., exceeding maximum permissible pollutant concentrations or deformation limits for structures); (b) it has a demonstrable causal link with a specific negative impact associated with permafrost degradation; (c) it is quantifiable and capable of monetary assessment using approved methodologies; and (d) it results from an unlawful act or omission by a specific subject, such as a violation of standards or a failure to fulfil monitoring obligations.

It is precisely upon the simultaneous presence of these criteria that the physical consequence of permafrost degradation acquires legal status and entails legal consequences in the form of liability, compensation obligations, or the application of coercive measures.

5. COMPARATIVE LAW ENFORCEMENT APPROACHES TO PERMAFROST DEGRADATION

5.1. Convergence of Regulatory Approaches and Threshold-Based Legal Significance

Comparative analysis of law enforcement practice demonstrates that, notwithstanding substantial differences in normative instruments and institutional frameworks, Arctic jurisdictions exhibit a gradual convergence in their regulatory approaches. Manifestations of permafrost degradation become legally relevant once they exceed certain threshold levels, thereby triggering specific legal consequences, ranging from permitting requirements and mandatory expert assessments to obligations to implement adaptation measures and provide compensation for resulting harm.

In addition, this analysis identifies a number of priorities that are central to the conceptual framework of this study. To ensure comprehensive regulation of processes related to permafrost degradation, it is necessary to determine the relative significance of different categories of consequences from the perspective of their impact on the legal system

and the sustainability of Arctic territories. For this purpose, a hierarchy of legal priorities makes it possible to systematize regulatory directions—from environmental protection and infrastructure security to the provision of social and economic guarantees—and to structure regulatory responses according to the scale and urgency of emerging threats.

5.2. Hierarchy of Legal Priorities in the Regulation of Permafrost Degradation

Grouping the legal consequences of permafrost degradation according to regulatory priority makes it possible to identify which aspects of this phenomenon have already received, or require, independent enshrinement in national and international legal frameworks. The proposed hierarchy reflects not only the current state of legislation but also the objective logic of its development under conditions of accelerating climate change.

- **First Priority: Environmental Safety and Prevention of Large-Scale Pollution.** Regulation of risks associated with greenhouse gas emissions (methane, CO_2), as well as the prevention of soil and water pollution resulting from accidents at infrastructure facilities, is already enshrined in national environmental legislation in Norway, Canada, and the United States, as well as within the system of international climate obligations. The precautionary principle and enhanced control over emission sources occupy the highest position in this hierarchy, since the prevention of irreversible consequences and the fulfillment of global climate goals depend directly on the effectiveness of these measures.

- **Second Priority: Infrastructure Resilience and Safety Standards.** Mandatory regulation of deformation and subsidence processes affecting buildings, roads, and pipelines is embedded in urban planning, construction, and operational standards applicable to regions of perennially frozen ground. Examples include the Canadian standard CSA S501, regulations of the Alaska Department of Transportation, and regional legislation of the Republic of Sakha (Yakutia). This regulatory direction is assigned high priority due to the direct threat posed to public safety and the significant economic consequences associated with infrastructure failure (Alaska Department of Transportation & Public Facilities, 2022) (Standards Council of Canada, 2021) (Novikova, 2024).

- **Third Priority: Monitoring and Management of Hydrological Changes**. Mandatory coordination of changes in water flow, waterlogging, desiccation, and other hydrological shifts that pose risks to aquatic ecosystems is addressed through permitting procedures under water protection and land-use legislation. In this context, fishery licensing systems in Alaska and contemporary water protection regimes in Russia and Norway are of particular importance.

- **Fourth Priority: Preservation of Natural and Cultural Heritage.** Regulation of damage related to the loss of Arctic ecosystems, peatlands, and cultural heritage sites remains comparatively less institutionalized, but is nonetheless reflected in special protection regimes and restrictions on economic activities in the absence of prior environmental impact assessment. Such approaches are characteristic of, in particular, the Svalbard archipelago and northern regions of Scandinavia.

- **Fifth Priority: Socio-Economic Guarantees and Compensation**. Regulation of risks affecting the traditional ways of life of Arctic Indigenous peoples, as well as issues related to relocation and compensation for lost land and infrastructure potential, remains at an early stage of development. Nevertheless, these issues are increasingly addressed through regional initiatives and pilot projects.

Taken together, the proposed hierarchy reflects the objective logic of the evolution of legal regulation: environmental and infrastructure-related risks occupy the highest positions, since the prevention of catastrophic scenarios, compliance with international climate obligations, and the protection of public safety depend on the effectiveness of their regulation. In this regard, the prioritization of the rights of vulnerable communities and ecosystems most affected by climate change—recognized in international judicial practice—directly applies to Arctic Indigenous peoples and unique Arctic ecosystems.

5.3. From Negative Impact to Legally Cognizable Harm: A Conceptual Triad for Legal Regulation

In light of the priorities outlined above, a conceptual triad—*Negative Impact → Risk → Harm*—may be articulated. The broad range of negative impacts generated by permafrost degradation encompasses diverse consequences, from ecosystem destruction and biodiversity loss to large-scale infrastructure deformation and the deterioration of living conditions for Arctic populations. These impacts generate risk, while the realization of such risk results in general harm, understood as a cumulative set of adverse changes affecting the natural environment, infrastructure, and socio-economic systems.

From a legal perspective, however, only those consequences that infringe legally protected interests and contain the elements of an offense—unlawfulness, fault, and causation—acquire the status of legally cognizable harm. It is precisely such consequences that give rise to specific legal regimes, including compensation mechanisms, adjustments to construction standards, and measures aimed at protecting natural and cultural heritage.

Only the establishment of a proven causal link between degradational impacts and the occurrence of legally cognizable harm allows the relevant event to be qualified

as a basis for legal response, whether in the form of liability, enhanced monitoring, or the tightening of regulatory standards. In this way, the transition from a general assessment of negative impacts to the legal qualification of specific, legally significant facts is ensured, thereby bringing such phenomena within the scope of state and corporate regulatory control.

6. ON THE LEGAL SIGNIFICANCE OF THE RISK CATEGORY

As shown above, the existing fragmented approach in Arctic jurisdictions does not allow building a holistic and effective risk management system, as it leaves without due attention the key element of modern legal regulation—the category of risk as an independent object of preventive impact. Therefore, the inclusion of the risk category in the definition of "negative impact" became fundamental.

Risk here acts as an intermediate link, characterizing the probability of occurrence and potential scale of negative consequences. Precisely risk management is the main vector of modern legal regulation in the sphere of environmental safety and sustainable development. The higher the assessed risk of causing serious harm (e.g., large-scale oil product spill, critical disruption of the hydrological balance of a territory), the earlier—at the planning and design stage—mechanisms of preventive control, mandatory monitoring, and adaptation measures should be activated.

Thus, the following logical chain of legal qualification can be identified. An initial negative impact (such as ground deformation, greenhouse gas emissions, or changes in the hydrological regime) generates risk, understood as the probability of adverse events, including infrastructure failure, environmental accidents, and loss of biodiversity. The realization of such risk leads to general harm in the form of specific material, environmental, and social losses. Only harm that meets the criteria established by law—namely, the significance of the consequences, a provable causal link with the violation of legally protected rights and interests, and the existence of a legally protected object—acquires the status of legally cognizable harm, thereby giving rise to legal consequences in the form of liability, compensation obligations, the introduction of stricter regulatory standards, and the establishment of special activity regimes.

Such a systematic approach allows for transitioning from fragmented response to already occurred consequences to holistic management of risks associated with permafrost degradation. Distinguishing between adaptation measures (applied at the stage of risk identification and assessment) and liability measures (applicable upon actual causation of legally cognizable harm) is a key condition for developing effective legislation, in particular the proposed draft international Model Law "On the Protection and Sustainable Management of Permafrost" (working title), intended to harmonize the approaches of all Arctic states to this critically important problem (proposed formulations are presented below) (Arbitration Court of Khanty-Mansi Autonomous Okrug–Yugra, 2021).

Therefore, adaptation measures are preventive in nature and become mandatory based on risk assessment, before harm occurs. Liability, conversely, represents a reactive mechanism applied post facto, when the risk has already materialized, and legally cognizable harm has been caused. Such a distinction eliminates legal uncertainty and ensures the necessary balance between preventive protection of Arctic territories and fairness in imposing the burden of liability.

Therefore, "risk" is understood here as an intermediate, but independent object of legal regulation and preventive impact, not merely as a characteristic of harm probability. The "risk category" is an object of preventive impact (Kozyr & Novikova, 2024). The legal significance of the risk category lies in the fact that even before material damage occurs, the legal system gains grounds for intervention—for example, to restrict activities, issue permits, or adjust design norms.

7. MONITORING AS THE CONNECTING LINK BETWEEN RISK AND HARM

7.1. Monitoring as a Legal Instrument of Risk Prevention and Control

Monitoring of the state of perennially frozen ground serves as a key connecting link between the stage of risk assessment and the prevention of legally cognizable harm. Its legal significance is revealed through a two-circuit model of background and facility-specific monitoring. Background (state) monitoring forms part of the environmental monitoring system and provides long-term data series on ground temperatures, active layer thickness, thermokarst dynamics, and related hydrological processes. Its functions include hazard zoning, the establishment of threshold values, and informational support for territorial planning, environmental impact assessment, and permitting procedures. Facility-specific (geotechnical) monitoring is established as a legal obligation of the right holder of a specific facility (building, road, or pipeline), inextricably linked to the right to its construction and operation. It includes the installation of specialized sensors, geodetic control of deformations, the maintenance of observation logs, and the mandatory implementation of corrective actions when established thresholds are exceeded.

As regulatory practice in Arctic countries demonstrates (Shuvalev, 2024), the legal regime governing permafrost monitoring operates through a three-level regulatory system that combines permitting, operational, and supervisory mechanisms. Its establishment is of key importance for law-enforcement practice, as it serves not only as a tool for preventing environmental risks (CSA Group, 2019) but also as a source of evidentiary data for the legal qualification of harm (Etzelmüller *et al.*, 2023).

- **The first level—permissive conditions and design-construction standards.** Capital construction projects located in the cryolithozone (Landers & Streletskiy, 2023) cannot be put into operation without a functioning

monitoring system incorporating both background and geotechnical circuits. The obligation to create and maintain such a system should be included in the mandatory requirements of project documentation and permit conditions. Exceedance of established temperature, deformation, and filtration thresholds entails an obligation to take corrective measures, including restrictions on operational modes or the temporary suspension of activities (Vincent *et al*., 2017).

- **The second level—information provision and data exchange.** The results of facility-specific observations are subject to transfer to the state register of permafrost monitoring, which forms part of the unified state environmental monitoring system. Background indicators recorded in national observation networks (similar to the Roshydromet network) establish normative thresholds that are incorporated into enterprise operational regulations, urban-planning documentation, and assessment criteria for the issuance of environmental permits.

- **The third level—supervision and enforcement.** Failure to perform monitoring duties, concealment of data, or untimely transfer of information is qualified as a violation of permit conditions. Depending on the level of risk involved, administrative measures may be applied, including injunctions, fines, suspension of operations, conservation, or demolition of facilities (Ford *et al.*, 2016).

Background data serve as the basis for assessing regional climatic and geocryological risks, while facility-level monitoring confirms the operator's good faith or, conversely, establishes a causal link between violations of operational norms and the occurrence of harm. In this way, monitoring functions as the legal boundary between the "impact/risk" stage and the moment at which legally cognizable harm arises.

7.2. Monitoring Data as a Basis for Adaptation Measures and Harm Qualification

Monitoring data provide the basis for both the application of adaptation measures and the legal qualification of harm. The transition from preventive risk management to the legal qualification of harm is based on objective and measurable indicators derived from monitoring systems. These indicators are typically grouped into geophysical and environmental criteria, including increases in the average annual temperature of frozen ground to critical values (approaching 0 °C), greater seasonal thaw depth, growth in unfrozen water content, exceedance of background levels of methane and

carbon dioxide emissions, as well as the acceleration of coastal erosion and the expansion of thermokarst formations.

In addition, infrastructure-related criteria are applied, including exceedance of design thresholds for foundation and support deformations, reductions in ground bearing capacity, and increases in the frequency and cost of repairs, as confirmed by engineering surveys and statistical data. Socio-economic criteria may further include disruptions in the functioning of essential life-support systems of settlements, reductions in territories available for the traditional use of natural resources by Indigenous peoples, and increased expenditures required to ensure the safe operation of infrastructure.

8. FROM MONITORING TO LEGAL CONSEQUENCES: CRITERIA

8.1. Monitoring Data as Legal Triggers for Regulatory Intervention

Monitoring data, recording increases in ground temperature, accelerated erosion, or infrastructure deformation, are not merely technical indicators. In a legal sense, they represent an evidential base that allows triggering the mechanism of legal qualification. It is on the basis of these objective and measurable criteria that the transition from preventive risk management to the application of specific legal measures is carried out.

Formalizing these geophysical, infrastructural, and socio-economic criteria in legislation allows using them as legal triggers: reaching or exceeding threshold values becomes a sufficient ground for adjusting administrative decisions, including urban planning, environmental, and, importantly, land legal relations. Thus, monitoring data directly substantiate the necessity of changing the legal status of lands, revising permits, and introducing restrictive regimes.

8.2. Legal Consequences of Permafrost Degradation for Land Use

The legal consequences of permafrost degradation manifest most distinctly in the sphere of land relations, where cryogenic processes directly influence the stability of land possession, use, and disposal regimes. When monitoring results record the achievement of critical infrastructural or geophysical thresholds (e.g., exceeding design foundation deformations or irreversible change in microrelief), a legal necessity arises for reassessing the status of land plots and associated rights. This circumstance forms new legal grounds for changing or terminating previously issued permits, cadastral characteristics, or licenses, as well as for imposing additional obligations on land users regarding adaptation and reclamation.

8.3. Comparative Models of Adaptive Land Regulation

International practice confirms this tendency, employing different legal instruments depending on the applicable institutional and regulatory model. In Canada, this approach is implemented through the Yukon Environmental and Socio-economic Assessment Act (YESAA), which introduces permafrost impact assessment as a mandatory legal condition for project approval. Where an unacceptable level of risk is identified, the legislation provides either for the denial of a permit or for the imposition of obligations on the applicant to ensure systematic monitoring and the implementation of an adaptation action plan.

In effect, this framework renders land-use rights conditional and dynamic: they remain valid only insofar as the relevant land plot does not exceed permissible thresholds of cryogenic stability. In practice, YESAA applies principles of geo-ecological zoning, whereby areas with a high probability of permafrost degradation are classified as subject to limited or temporary use regimes. Through this mechanism, Canadian legislation has developed a legal analogue of land-rights revision, in which the physical parameters of the cryolithozone operate as a direct and legally relevant factor (Farquharson *et al.*, 2019).

In the USA (Alaska), this transformation has found more radical expression in the form of the managed retreat mechanism. The case of relocating the Newtok village is considered a classic example of the legal implementation of the resilience relocation principle—relocation upon loss of cryogenic stability of a territory. Based on monitoring data confirming coastal erosion and foundation deformations, federal authorities decided to terminate land use rights on the former territory and allocate new land funds. From a legal point of view, this means not merely termination of possession but forced relocation of property rights due to a recognized natural risk. This approach effectively forms a new subcategory of spatial rights—adaptive land rights, where land ownership is not absolute but limited by the climatic resilience of the plot. In US administrative practice, such decisions are justified by the "public safety priority" principle and interpreted as a preventive measure under conditions of realized climate risk (Hjort *et al.*, 2018).

In Norway (Svalbard), a preventive, strictest model of land use regulation is in effect. According to the Svalbard Environmental Protection Act, construction and operation of facilities are permitted only in specially defined planning zones. Any potential impact on permafrost is considered a threat to the ecological balance and can become sufficient grounds for denying a permit, even in the absence of actual harm. The law thereby enshrines the principle whereby risk assessment has the legal force of a prohibition—a regime of "preemptive management" of land use is formed. Upon identification of signs of soil degradation, changes in hydrological regime, or vegetation, the territory can be transferred to a specially protected status or restricted for exploitation. This creates a precedent where not the fact of destruction, but the high probability of its occurrence terminates economic activity (AMAP, 2021) (Ministry of Justice and Public Security, 2024).

Thus, the legal consequences of permafrost degradation in international practice are expressed in the dynamic nature of land rights, their dependence on climatically determined stability criteria based on monitoring data. A general principle operates in all considered jurisdictions: land use loses stability upon loss of cryogenic stability of the foundation, and the state is obliged to respond through instrumental mechanisms such as monitoring, adaptation, or relocation.

8.4. Judicial Practice and the Dynamic Nature of Land Rights

When monitoring data confirm the achievement of critical thresholds (e.g., an infrastructural criterion like exceeding design deformations or a geophysical criterion like irreversible change in relief), a mechanism for reassessing the legal status of land plots is triggered. Previously issued construction permits, licenses, and cadastral characteristics may become obsolete, and land users' rights—subject to revision.

For instance, Russian judicial practice already demonstrates how these criteria become the basis for legal decisions:

- **Case No. A58-1023/2022 (Arbitration Court of the Republic of Sakha (Yakutia)**: the trigger was the achievement of a socio-economic criterion—a threat to the life-support facilities of a settlement caused by thermokarst processes. On this basis, the court recognized the termination of the lease right under Clause 2, Article 54 of the Land Code of the Russian Federation as lawful, due to the impossibility of further safe use of the land plot.

- **Russian commercial courts:** have upheld suspensions of construction works where supervisory authorities demonstrated risks of ground instability and environmental harm, relying on geotechnical investigations and state monitoring data (see, e.g., decisions summarised in *EcoStandard.journal's* review of soil-damage case law). Court suspends construction of a logistics centre in Kraskino (reported by Gorod, 17 October 2025).[3] In such cases, the documented ground-subsidence risks (an infrastructural criterion) in state monitoring materials have served as a basis for suspending construction works, and the courts have held that these measures are consistent with the precautionary principle.

- **Case No. A75-6675/2021 (Arbitration Court of KhMAO-Yugra)**: a direct causal link between foundation degradation and the fulfillment of an environmental criterion—soil pollution—was established. This allowed the

[3] Available at: https://vladivostok1.ru/text/gorod/2025/10/17/76079066/

court to qualify the situation as legally cognizable harm and to apply measures of compulsory termination of property rights.

These examples demonstrate that, irrespective of the specific legal system, monitoring data and the criteria derived from them function as a universal language for substantiating legal consequences. In this way, permafrost degradation is transformed from a scientific and technical phenomenon into a legally relevant ground for the application of liability measures and the restructuring of land-use regimes.

Looking ahead, the accumulation of such practice supports the need to enshrine in international law a distinct adaptive legal institute of "climate risk lands." This category would be subject to special adaptive legal regimes based on the continuous analysis of climatic and geocryological data. Such an approach reflects a fundamental shift in legal consciousness—from the classical conception of land plots and land rights as stable and immutable to a model of adaptive land use shaped by climate-related risks (Abanin, 2024) (Akhtar, S. *et al*., 2023).

9. CRITERIA FOR THE LEGAL QUALIFICATION OF HARM RESULTING FROM PERMAFROST DEGRADATION

9.1. General Grounds for the Legal Qualification of Harm

On this basis—objective and measurable monitoring criteria—the qualification of harm caused as a result of general negative impact associated with permafrost degradation must be based. Legally cognizable harm can be distinguished from general negative impact and entail liability and/or compensation obligations. During legal qualification, four cumulative grounds must necessarily be present. First, a proven cause-and-effect relationship must be established and confirmed—through expert assessment, monitoring data, and scientific evaluation—demonstrating a direct link between a specific negative impact associated with permafrost degradation (e.g., ground subsidence resulting from anthropogenic thermal influence) and the adverse consequences that have occurred. Second, the scale of harm must reach a legally significant threshold, which, as a rule, is established where such harm exceeds permissible or background levels and affects legally protected interests. Third, the unlawfulness of the act or omission must be established through evidence of non-compliance with applicable legal norms, including construction standards, monitoring obligations, or operational requirements. Fourth, the harm must be imputable to the responsible subject, meaning that the causal chain is not broken by force majeure and that the damage results from manageable and foreseeable risks rather than uncontrollable natural processes.

9.2. Materiality of Harm: Environmental, Infrastructural, and Social Criteria

Assessment of the materiality of harm is carried out according to objective indicators in the following spheres. With respect to environmental harm, this is exceeding established pollution standards (MPC); reduction of the habitat or population of species listed in the Red Book; destruction or degradation of ecosystems over a measurable area; infrastructural harm: physical destruction or damage to objects (cracks, deformations, collapses) requiring restoration costs; complete or partial loss of object functionality; reduction of its market value; social harm: direct threat to the life or health of the population, confirmed by medical or expert opinions; necessity for evacuation or relocation of people; disruption of life support systems.

9.3. Specificities of Harm to Cultural Heritage Objects

Harm to cultural heritage objects is formally also assessed through the presence of physical damage or destruction of archaeological, historical, or cultural monuments located in the permafrost zone. However, it has its own specificities. The quantifiability (possibility of economic assessment) of the extent of harm in monetary terms based on approved damage calculation methodologies or actual costs necessary for restoring the disturbed state is problematic. The legal qualification of such harm requires a comprehensive approach, combining quantitative methods (assessment of the area of lost territories, number of affected population) with qualitative criteria (cultural significance, spiritual value, reversibility of damage). Key is the recognition that cultural harm cannot always be compensated financially—in a number of cases, the loss is irreplaceable, which requires applying the precautionary principle and the priority of preventive measures at the risk stage.

9.4. Unlawfulness, Proof, and the Limits of Force Majeure

Unlawfulness of the act (or omission) of the harm-doer is established by the fact of violation of specific legal norms: non-compliance with construction standards, ignoring requirements for geotechnical monitoring, violation of object operation rules, failure to comply with supervisory authority injunctions. Only in the presence of evidence for these criteria does the physical consequence of permafrost degradation transition into the category of legally cognizable harm, which becomes the basis for applying measures of civil, administrative, or even criminal liability (Etzelmüller *et al.*, 2023).

It is important to note that the specificity of proof consists in the necessity to clearly distinguish liability for damage caused by specific actions (or inaction) of economic entities from damage due to global climate changes, as well as regulatory flexibility—as a constant revision of standards and norms considering new scientific data and monitoring data.

An important caveat —the availability of reliable monitoring data to subjects radically determines the legal assessment of their actions and omissions. From a legal point of view, if an operator (state, company, municipality) possesses systematic observations recording increases in ground temperature, foundation deformation, or other signs of permafrost degradation, the impact cannot be recognized as force majeure. Monitoring ensures predictability and manageability of the process, and hence—excludes the criterion of "unpreventability" (*essentia casus*). In other words, the availability of information and opportunities for preemptive measures (including those enshrined in operational standards) transfers the situation from the sphere of chance to the sphere of manageable risk. Therefore, "casus" or force majeure are applicable only in rare cases where the consequences are caused exclusively by natural processes of a global scale, not amenable to forecasting and control, for example, cascade climatic effects (anomalous atmospheric circulations, sudden degassing of underground methane, and similar phenomena of a biospheric level). For all other cases, the presence of monitoring entails an obligation for proper response and excludes exemption from liability.

10. OBJECTS AND SUBJECTS OF NEGATIVE IMPACT FROM PERMAFROST DEGRADATION

10.1. Permafrost Degradation as an Object of Legal Regulation

The definition of negative impact associated with permafrost degradation, in a comprehensive manner, covers the subject-object aspect, as "a set of natural and/or anthropogenic changes that form risks or directly cause harm both to permafrost itself (a specially protected natural object) and to systems connected with it". Thus, a model of legal harm qualification is formed, taking into account the stages "on" and "from" permafrost.

The approaches and criteria presented above also allow, accordingly, to distinguish the objects of negative impact. Firstly, permafrost itself becomes an object of protection when the negative impact is directed at it. Secondly, degraded permafrost as a source negatively impacts other, connected objects protected by law. Consequently, it is proposed to build regulation in the legislation of Arctic countries according to the "object of impact" criterion in two interconnected planes:

10.2. Impact on Permafrost and Preventive Regulatory Measures

When responsible subjects and the state are obliged to prevent the degradation of permafrost itself as a component of the environment and an engineering-geological foundation, priority measures are monitoring, standardization, and establishment of special design and operational standards.

This approach is reflected in best Arctic practices, which combine special technical standards (such as CSA S501), mandatory geotechnical and environmental monitoring, public registers of permafrost conditions, and stricter environmental coordination procedures for projects in weakened zones (Oliver, 2023).

For illustration: in the construction and operation of road infrastructure and airfields on permafrost (Alaska, Canada, Russian Arctic), the category of foundation vulnerability is assessed, diagnostics are conducted, and individual engineering and adaptation measures are selected, up to partial demolition or constant monitoring of stability risks. For natural and cultural objects (e.g., in Svalbard), a strict permitting regime is in effect, prohibiting works outside approved planning zones and requiring assessment of cumulative impact not only on ecosystems but also on the landscape as a component of cultural heritage.

Comparative legal analysis of impact on permafrost itself as a protected component of the environment and an engineering-geological foundation of territories is reflected in the norms of legislation of Arctic countries, which are directly aimed at preventing thermal disturbances, managing permafrost degradation risks, and preventing the transformation of negative impact into legally cognizable harm. Let us consider some of them:

- **Canada:** the national standard CSA S501 enforces mandatory requirements for the operation of existing buildings on permafrost. This includes management of surface and ground waters, regulation of snow retention, subfloor ventilation, thermal insulation, application of passive foundation cooling systems, continuous temperature monitoring, and planned preventive maintenance. As extreme measures, site conservation or object demolition are permitted (Nordregio, 2024). These requirements legally operate at the "impact/risk" stage, reducing the likelihood of harm occurrence and setting verifiable obligations for the owner.

- **USA, Alaska:** design and organizational measures, regulated by "northern" guides for roads and airfields, prescribe excluding excessive thermal disturbances of the foundation, considering climate scenarios, and incorporating solutions that preserve the thermal balance of the ground (thermal insulation, cold-resistant embankments). These requirements are enshrined in technical assignments and permit conditions, transferring risk management into the plane of mandatory conditions for activity admission (Heller, 2025).

- **Norway (Svalbard):** legislation prohibits or strictly restricts construction outside planning zones to block the very risk of anthropogenic permafrost degradation. Priority is given to a preservation strategy and cumulative impact assessment (Alfred Wegener Institute, 2024).

- **Finland, Sweden, Greenland:** state standards require mandatory analysis of climate scenarios, state monitoring, and zoning of vulnerable territories. For high-risk zones, the application of special engineering solutions (thermal insulation, embankments, snow retention) is provided (United Nations Environment Programme, 2012).

- **Iceland:** when designing geothermal facilities, particular importance is attached to the mandatory assessment of influence on permafrost zones and landscape. Legislation requires mandatory expert assessment of degradation risk: projects posing environmental threats may be rejected or obliged to implement compensatory measures (Alaska Department of Transportation & Public Facilities, 2022).

These examples prove that managing permafrost degradation risks is only possible within a system where, when impacting on the object (permafrost), preservation standards and strict zoning regimes are applied. Thus, the legal consequences of negative impact are distinguished by object. If the object is permafrost itself, then requirements for projects, operation, and monitoring are established to preserve the thermal regime, including specific technical solutions and control procedures, with mandatory enforcement through standards and permit conditions (Ministry of Justice and Public Security, 2024).

10.3. Impact from Degraded Permafrost and Legal Consequences

When permafrost degradation is already causing harm to other protected interests (life, health, infrastructure, ecosystems, cultural heritage), the main measures are compensation for harm, ensuring operational resilience, and restricting economic activity.

In the case of negative impact from degraded permafrost as a source, obligations for engineering and environmental protection, monitoring of consequences, compensation, and restoration apply. If the object of negative impact is infrastructure, nature, or heritage, then liability for harm, territory protection regimes, and activity restrictions are applied, as well as engineering measures for adaptation and restoration, proportionate to the vulnerability and purpose of the object (Icelandic National Energy Authority, 2023).

Best practices integrate both regulatory directions—risk-oriented adaptation at an early stage and legal liability for harm "downstream"—and complement them with economic and social guarantees for people and nature. Hence, the Arctic model demonstrates a differentiated and comprehensive response system that can serve as the basis for the proposed Model Law "On the Protection and Sustainable Management of Permafrost."

10.4. Subjects of Negative Impact and Distribution of Responsibility

The classification of subjects of negative impact on permafrost and the allocation of responsibility enables the targeted application of regulatory and liability measures among different actors—from the state to private companies and financial institutions—thereby creating a preventive framework for managing emerging risks. Within the systematic approach developed in this study, impacts may be both direct and local (e.g., the construction of a facility) and indirect and global (such as greenhouse gas emissions).

Below is a classification of subjects by their role in each of both scenarios and the nature of influence (see Table 1).

Table 1. Classification of Subjects of Negative Impact on Permafrost

Subject	Impact on Permafrost	Legal Responsibility
Natural-Climatic Factors	Global warming, natural processes	Collective global responsibility
Public Authorities	Regulatory gaps, ineffective monitoring	Direct (state) & indirect (private) liability
Business	Thermal impact, accidents, violations	Direct responsibility (polluter pays)
Financial Institutions	Financing high-risk projects	Indirect ESG/insurance responsibility
Scientific & Design Community	Outdated designs and norms	Professional/reputational liability
Local & Indigenous Peoples	Minimal localized impact	Rights to compensation (as an injured) and to participation

Source: Author's own elaboration.

11. DISTRIBUTION OF RESPONSIBILITY FOR PERMAFROST DEGRADATION

11.1. System of Subjects and Principles of Responsibility Distribution

The systematization of subjects allows transitioning from abstract discussion of the problem to concrete mechanisms of legal responsibility distribution. It clearly shows that for effective management of permafrost degradation consequences, a combination of global climate initiatives, state oversight, corporate responsibility, financial incentives, and scientific support is necessary. Accordingly, such a comprehensive approach will adequately distribute the burden of adaptation and harm compensation among all participants. Let us proceed to consider the specific duties and regulatory tools arising for key groups of subjects.

The system of subjects and distribution of responsibility can be represented by three main groups.

11.2. Public and Private Subjects: Differentiation of Primary Responsibility

A. Public subjects (state and public authorities)

The state bears the primary responsibility for creating the legal and institutional basis for managing permafrost degradation risks. This role is realized through the following functions:

- Development and updating of legislation on permafrost protection, construction codes, and technical standards, considering climate change and regional specifics.
- Creation and support of a state system for monitoring the state of permafrost for timely risk identification and informing all interested parties.
- Ensuring compliance with established norms by all economic entities through environmental and technical inspections.
- Responsibility for the safe operation and adaptation of state infrastructure (roads, airports, social objects), which is also subject to permafrost degradation risks (CSA Group, 2014).
- Participation in global climate initiatives and exchange of best practices with Arctic Council countries to develop common approaches to risk management (Kozyr & Novikova, 2024).

B. Private subjects (business entities)

Primarily, business bears direct responsibility for the impact of its projects on permafrost and for the consequences of this impact. This responsibility is realized through:

- The obligation to build and operate objects in strict accordance with current norms and apply the best available technologies to minimize negative impact.
- Implementation of geotechnical monitoring systems at their facilities to prevent accidents and timely respond to changes in ground conditions.
- Property liability is imposed on private subjects in the form of compensation for harm caused to the environment and third parties in full, according to the "polluter pays" principle.

A further legal challenge concerns the need to distinguish between anthropogenic and natural impacts. The legal qualification of an environmental polluter's conduct within tort law is complicated by the difficulty of disentangling natural climatic processes from human-induced effects. In a number of cases, damage resulting from permafrost degradation is framed as a legal *casus* arising from natural causes, such as global warming and cascading effects, which tends to blur the attribution of responsibility to specific actors.

However, the core legal problem lies in the fact that existing, so-called “classical” approaches fail to account for the transboundary nature of impacts generated by the carbon-intensive economy and the energy sector. Global CO_2 emitters, whose activities accelerate warming and, consequently, permafrost degradation, should not fall outside the sphere of legal responsibility. Since permafrost degradation affects global climate processes through greenhouse gas emissions and pollutant migration, it requires coordinated regulatory responses among all Arctic states.

11.3. Financial Institutions and Indirect Responsibility Mechanisms

The financial sector currently plays the role of a "filter" and stimulator, directing capital towards more sustainable and less risky projects (OECD, 2024). Its participation is expressed in risk assessment during lending: projects with high non-compensated risks may not receive financing or receive it on less favorable terms. It also manifests in insurance: insurance companies can develop products covering damage from permafrost thaw, which economically motivates business to adapt. The role of the financial sector in the context of adaptation will be explored more deeply within a separate study.

11.4. Accumulated Harm in the Cryolithozone: A Case Study of Landfills

The problem of landfills and accumulated harm on permafrost vividly illustrates the applicability of the proposed model of legal qualification. This problem is typical for all Arctic countries:

- **Canada and USA (Alaska):** hundreds of "abandoned" landfills and village dumps, placed without considering geocryological risks, are already showing signs of thawing, intensifying pollutant migration into rivers and tundra (WMO, 2024) (Arctic Monitoring and Assessment Programme, 2025).

- **Greenland and Norway (Svalbard):** old industrial storage facilities, remnants of military infrastructure, and tailings ponds, operated on the "frozen storage" principle, are becoming subjects of special inventories (Hjort *et al.*, 2018).

- **Russia:** the problem is most acute due to the scale of Soviet industrial heritage and the extent of permafrost zones (CSA Group, 2014). Within key international research, an assessment of the number of contaminated sites in the Arctic is provided. According to it, the Russian Arctic contains about 70% of all industrial objects and associated contaminated sites in the Arctic permafrost zone, amounting to between 9,100 and 14,000 objects. The article directly states that historical industrial practices and the assumption of permafrost's eternal

stability led to the accumulation of this legacy (U.S. Department of Transportation & Federal Highway Administration, 2021).

This case study clearly demonstrates how the duality of impact ON/FROM permafrost transforms into a complex chain of legal consequences. On one hand, landfills are a source of direct anthropogenic impact on permafrost (local heating). On the other hand—a catalyst for secondary impacts from degrading permafrost (release and migration of toxicants). A clear gradation by risk stages is also obvious: "impact"—waste placement and thermal load on frozen ground; "risk"—onset of thawing, creating probability of pollutant release; "harm"—actual pollution of water objects and soils; "legally cognizable harm"—damage to legally protected objects (population health, natural complexes), requiring legal response and compensation (Woodwell Climate Research Center, 2025).

Therefore, the landfill case confirms that traditional norms of environmental and land law, not accounting for the specifics of a "floating" object of protection permafrost, are insufficient (Arctic Council, 2025).

This substantiates the necessity of developing special legal mechanisms: specific monitoring standards, damage assessment, and distribution of responsibility for accumulated anthropogenic harm. The necessity for preventive regulation becomes obvious, as territory pollution is detected only post facto, confirming the critical importance of transitioning from reactive to preemptive legal response.

12. CONCLUSION: FROM QUALIFYING NEGATIVE IMPACT TO AN ARCHITECTURE OF CLIMATE RESPONSIBILITY

12.1. From Physical Degradation to Legally Cognizable Harm

In the conducted research, we have shown that permafrost degradation is not a local geotechnical problem but a systemic, transboundary challenge of a global scale, shaping a new, integrative legal reality. At the same time, the key legal complexity is the absence of holistic mechanisms for qualifying, preventing, and compensating for harm associated with permafrost degradation. To solve this task, a transition from physical phenomena to the activation of legal mechanisms was structured. Within this logic, legally cognizable harm occurs when the consequences of degradation reach a threshold established by law and affect protected interests, such as citizen safety, property integrity, and the right to a favorable environment. For this reason, the creation of a holistic architecture of international responsibility is proposed instead of disparate response measures. Such a system could integrate legal principles, financial mechanisms, and institutional formats into a unified risk management system. At this stage, we transition from diagnosis to the main question: what should be an adequate, fair, and coordinated response from the world community? Such a response lies in creating a comprehensive architecture of international responsibility, consisting of

legal, financial, and institutional elements of a single, effective system for managing climate risks.

12.2. Rethinking the Core Principles of International Environmental Law

At this point, it will be necessary to start with an evolutionary rethinking of the classical principles of international environmental law, namely:

- **"Polluter pays" requires an expansive interpretation**. The "polluter" is recognized not only as an individual industrial facility but as the entire carbon-intensive model of the global economy, which necessitates the creation of fair responsibility distribution mechanisms, taking into account the historical contribution of states to emissions and the direct impact of corporations on Arctic ecosystems.

- **"Precautionary principle".** This principle is affirmed as a legal imperative, providing legitimate grounds for introducing preventive restrictions on economic activities in vulnerable zones.

- **"No harm principle" acquires special significance.** The transboundary nature of permafrost degradation, expressed in greenhouse gas emissions and pollutant migration, falls under the purview of this principle, as confirmed by the position of the International Court of Justice. This creates legal grounds for harmonizing the approaches of all Arctic states and holding accountable subjects whose activities outside the Arctic contribute to its degradation.

12.3. Financial Architecture: The International Fund for Permafrost Protection

Financial instruments as the economic core of the entire system ensure stable financing at all stages of negative impact manifestation. As a central element, the creation of an International Fund for Permafrost Protection can be proposed, the capitalization of which is ensured from diversified sources. For instance, these could be targeted contributions from states, calculated according to a formula considering their historical and current carbon footprint. Mandatory deductions from rental incomes for mineral extraction in the Arctic (at a rate of 2–5% of the value), funds from global carbon levies, as well as voluntary contributions from corporations implementing carbon neutrality strategies. The financial model of the Fund should be flexible, combining non-repayable financing for critically important social and environmental projects (up to 60% of funds) with repayable financing for commercially viable initiatives (up to 40%) through subordinated loans and guarantees.

12.4. Priority Funding Areas and Risk Allocation

The priority funding directions are clearly structured, in particular:

- Creation and support of a global permafrost monitoring network (with a budget of at least $150 million annually) for risk forecasting.
- Co-financing of critical infrastructure adaptation on a 50/50 principle with national governments and the private sector.
- Full coverage of expenses for managed retreat programs for Indigenous and local communities from zones of irreversible destruction, where the cost of relocating one settlement can reach $50–100 million.
- Projects for reclamation of disturbed lands and rehabilitation of key Arctic ecosystems.

12.5. Market and Insurance-Based Climate Risk Instruments

An ecosystem of market and insurance instruments should be built around the Fund. Issuance of targeted "permafrost bonds" with state guarantees will attract long-term capital from institutional investors. Creation of an international pool for insuring climate risks in the Arctic with reinsurance mechanisms will distribute the financial burden. The development of derivative financial instruments (derivatives), analogous to catastrophe bonds (cat bonds), for hedging the most acute risks associated with permafrost thaw is of particular importance. This entire financial construction must be legitimized and integrated into the United Nations Framework Convention on Climate Change (UNFCCC) framework, for example, through the creation of a specialized financial window in the Green Climate Fund, which will ensure its global recognition and access to existing financing mechanisms. The proposed architecture of climate responsibility, including the International Fund for Permafrost Protection, finds powerful support in the Advisory Opinion of the International Court of Justice, which calls on states to cooperate and adopt the most effective measures to protect the rights of people and ecosystems from climate change.

12.6. Institutional Anchoring and Normative Consolidation

The institutional support of the proposed system could be provided by existing international structures, such as the Arctic Council as a platform for developing unified

monitoring standards, and the European Union as a coordinator, utilizing the potential of initiatives like the European Green Deal[4] and the "Fit for 55" package.[5]

The synthesis of the aforementioned elements requires their consolidation in a single normative act—the Model Law "On the Protection and Sustainable Management of Permafrost". This law should ensure international recognition of permafrost as an independent object of legal protection and a critical climate regulator, supporting this status with effective financial-legal mechanisms. Its development and implementation will mark a tectonic shift in legal consciousness: from perceiving permafrost as a passive geological object to recognizing it as an active planetary climate asset, on the stability of which the future of not only the Arctic but the entire global climate system directly depends.

12.7. Final Concluding Remarks

The problem of permafrost degradation is transitioning from the realm of natural sciences to the realm of law and governance. The proposed systematic approach and concrete legal instruments represent the basis for transitioning from emergency response to proactive and coordinated risk management in the Arctic. The development and implementation of the Model Law will mark a shift in legal consciousness: from perceiving permafrost as a passive geological object to recognizing it as an active planetary climate asset, on the stability of which depends the future not only of the Arctic but of the entire global climate system.

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[5] Fit for 55: a legislative package of the European Union, presented in 2021, aimed at reducing net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels, as part of the implementation of the European Green Deal.

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