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Analysis of the Dilemmas and Development Pathways of China's Glacier Protection System

Wang Ni[1] & Shan Yan[1]

[1] Department of Maritime Law and Humanities Dalian Ocean University, Heishijiao Street, Shahekou District, Dalian City, Liaoning Province

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Abstract

This paper comprehensively examines the severe and increasingly deteriorating situation confronting glacier protection in China, while systematically identifying the inherent deficiencies and structural gaps in the country's current legal and regulatory framework governing glacial resources. It emphasizes the urgent and pressing need to address the cascading ecological crises and water resource shortages triggered by accelerating glacier ablation, a phenomenon that has been exacerbated by global climate change over the past few decades. Although a handful of existing national laws, local regulations, and policy documents in China touch upon certain aspects of glacier conservation, there remains a conspicuous absence of specialized, comprehensive legislation explicitly dedicated to the protection of glaciers as unique and irreplaceable natural assets. By conducting an in-depth comparative analysis of domestic legislative practices (including recent local initiatives in Tibet Autonomous Region and Xinjiang Uygur Autonomous Region) and international legislative models for glacier protection (such as the pioneering frameworks in Argentina and Kyrgyzstan), this study proposes a set of targeted recommendations. These include advancing the legislative process for a specialized national Glacier Protection Law, establishing four fundamental legal institutions for glacier conservation, and refining the regulatory system to ensure the comprehensive, systematic, and science-based protection of glacier resources. The ultimate goal of these measures is to promote the sustainable development of glacial ecosystems, safeguard critical water supplies for ecological and socioeconomic needs, and provide a robust legal foundation for China's efforts to address the challenges of climate change in the cryospheric domain.

Keywords

Glacier protection, Legislation, Environmental protection, Legal system, Cryospheric conservation, Sustainable development

1. Introduction

The current state of glacier protection in China is far from optimistic, as the country's legal and regulatory framework for safeguarding these vital cryospheric resources remains incomplete, fragmented, and inadequately responsive to the emerging threats posed by global warming. Since the dawn of the 21st century, the issue of global climate change has intensified at an unprecedented rate, with average global temperatures rising steadily and extreme weather events becoming more frequent and intense. This accelerating trend has led to a significant increase in the rate of glacier melting and retreat worldwide, and China's glaciers have been no exception. The ablation of glaciers not only contributes to global sea-level rise but also triggers a range of region-specific natural disasters, including glacial lake outburst floods (GLOFs), debris flows, landslides, and sudden changes in river runoff patterns, all of which pose severe threats to ecological stability, human settlements, and socioeconomic development.

To illustrate the severity of the situation, take the glaciers in the Mount Everest Nature Reserve as a case study. According to scientific monitoring data, the total glacier area in this reserve has been shrinking year by year between 1990 and 2020. Specifically, the glacier area decreased from 1,306.31 km^2 in 1990 to 1,059.15 km^2 in 2020, representing a net retreat of 247.16 km^2 and a cumulative area change rate of -18.92% (Ji, Q., Zhang, C. L., Ding, Y. K. et al., 2023, pp. 1591-1601). This translates to an average annual retreat rate of approximately 8.24 km^2 per year, a figure that is significantly higher than the global average for mountain glaciers. Similar worrying trends have been observed in other major glaciated regions across China, such as the Himalayas, Tianshan Mountains, Qilian Mountains, and Kunlun Mountains, where glaciers are experiencing accelerated retreat due to rising temperatures, altered precipitation patterns, and other climate change-induced factors. In the Himalayan region, for example, studies have shown that the average rate of glacier retreat has doubled over the past two decades compared to the previous century, with small glaciers (those less than 1 km^2 in area) disappearing at an even faster pace.

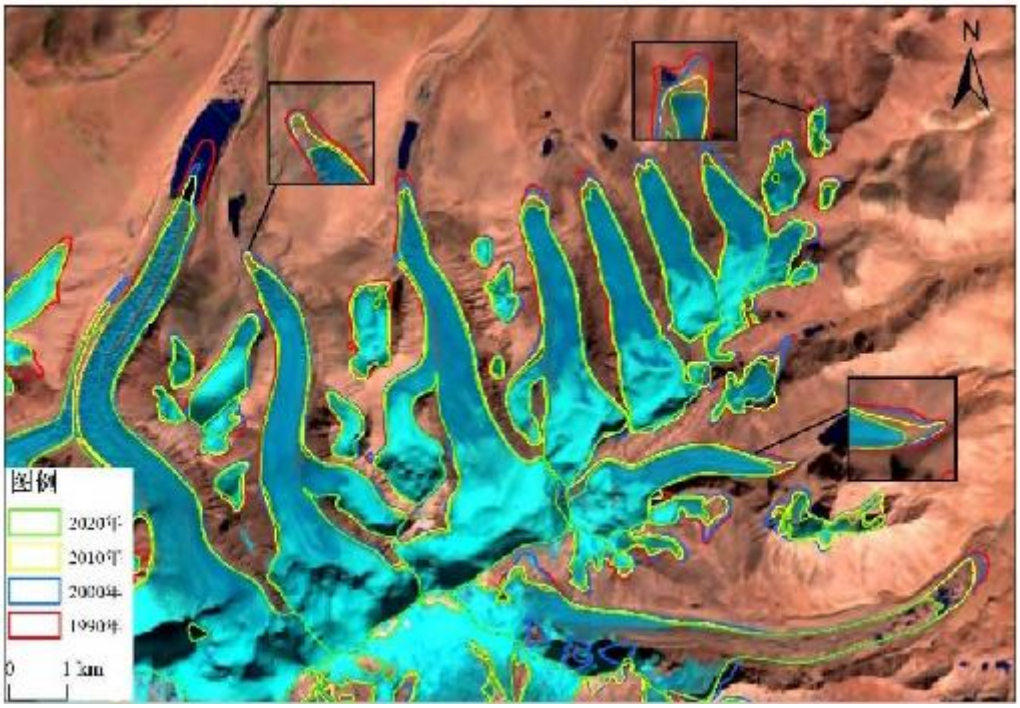

Figure 1. Glacier Area Changes in the Mount Everest Nature Reserve (1990-2020)

In response to these challenges, local governments across China have introduced a series of policies, regulations, and administrative measures aimed at protecting glacial resources within their jurisdictions. However, despite these efforts, the issue of specialized legislation for glacier protection has long been neglected at both the national and local levels. For decades, glacier protection has been treated as a secondary concern within broader environmental protection frameworks, with no dedicated legal instruments to address the unique ecological characteristics, conservation needs, and management challenges of glaciers.

A significant turning point occurred in 2023 when the National People's Congress and its Standing Committee enacted the Ecological Protection Law of the People's Republic of China for the Qinghai-Tibet Plateau (hereinafter referred to as the Qinghai-Tibet Plateau Protection Law), which includes specific provisions explicitly targeting the protection of glaciers within the plateau region—the core area of China's glacial resources. This landmark legislative development has brought the issue of glacier protection back into public discourse and marked an important step toward institutionalizing cryospheric conservation in China. Article 62 of the Qinghai-Tibet Plateau Protection Law clearly stipulates that provinces, autonomous regions, and prefecture-level cities involved in the Qinghai-Tibet Plateau may formulate specific measures for ecological protection in light of local actual conditions, including targeted provisions for glacier conservation. Furthermore, the Notice of the Ministry of Ecology and Environment on Publicizing and Implementing the Ecological Protection Law of the People's Republic of China for the Qinghai-Tibet Plateau (Huan Fa Gui [2023] No. 41) explicitly proposes to "accelerate the formulation of supporting documents" and "actively cooperate

with local standing committees of people's congresses, governments, and their relevant departments to do a good job in local legislative work and institutional supporting construction."

Building on this national legislative foundation, on July 31, 2024, the Tibet Autonomous Region promulgated the Tibet Autonomous Region Glacier Protection Regulations, becoming the first provincial-level administrative region in China to introduce a comprehensive local regulation specifically dedicated to glacier protection (Wang, S. K., 2023, pp. 29-32). This proactive response demonstrates the region's commitment to addressing the challenges of glacier conservation and provides a valuable model for other glaciated regions in China. Nevertheless, despite these positive developments, China still lacks a unified, specialized national legal framework for glacier protection. The existing legal provisions related to glacier protection remain fragmented across various environmental laws and policies, often marginalized and overshadowed by other environmental protection priorities. Many of these provisions are principle-based, vague, and lack operational specificity, making them difficult to enforce effectively in practice. This paper aims to address these legal challenges by conducting a systematic study of the current status, dilemmas, and development pathways of China's glacier protection system, with the ultimate goal of promoting the legalization and institutionalization of glacier protection in China.

2. The Necessity of Glacier Protection

Glaciers possess unique and inherent advantages as natural freshwater reservoirs, playing an indispensable and irreplaceable role in maintaining the balance of the global water cycle and supporting human survival and development. As one of the largest repositories of freshwater on Earth—second only to the polar ice caps—glaciers store approximately 69% of the world's freshwater resources, making them critical "water towers" for many regions, particularly in arid and semi-arid areas where alternative water sources are scarce. Glacial meltwater serves as the primary source of many major rivers, ensuring stable river flows that are essential for agricultural irrigation, municipal drinking water supplies, industrial production, and hydropower generation. In China, glaciers cover an area of approximately 59,406 km², distributed primarily across the Qinghai-Tibet Plateau and its surrounding mountain ranges, and provide water for more than 1.6 billion people living in the basins of major rivers such as the Yangtze, Yellow, Lancang (Mekong), Nu (Salween), and Yarlung Zangbo (Brahmaputra) rivers.

In arid and semi-arid regions of Northwest China, glacial meltwater is the lifeline for local ecological systems and socioeconomic development. Take the glaciers in the Qilian Mountains as an example: the Taolai River Basin, located in the Hexi Corridor of Gansu Province, relies primarily on meltwater from Qilian Mountain glaciers as its main water source, which constitutes a major component of surface runoff in the basin. This glacial meltwater ensures the continuous water supply for industrial and agricultural activities in the region, supporting the irrigation of over 1.3 million hectares of farmland and the operation of numerous industrial enterprises. However, in recent years, the reduction in glacial

runoff caused by accelerated glacier retreat has led to severe water shortages in the Hexi Corridor, exacerbating ecological degradation, desertification, and land degradation (Dou, C. M., 2009, pp. 91-95). Prolonged drought conditions, intensified by reduced glacial meltwater, have also resulted in a significant decline in biodiversity in the Qilian Mountains. Native vegetation communities, including ancient and tall tree species such as Qinghai spruce (Picea crassifolia) and Qilian juniper (Juniperus przewalskii), have been adversely affected by water stress, with many trees dying or declining in health. This vegetation loss, in turn, has triggered a cascade of negative ecological effects, including increased soil erosion, reduced carbon sequestration capacity, and declines in the populations of dependent wildlife species such as the snow leopard (Panthera uncia) and Tibetan antelope (Pantholops hodgsonii).

At the same time, glaciers also hold significant economic value beyond their hydrological functions. Their majestic, awe-inspiring landscapes—characterized by towering ice cliffs, blue ice caves, and vast snowfields—attract millions of domestic and international tourists each year, driving the development of glacier-based tourism industries that generate substantial economic income for local communities. In addition to tourism revenue, glacier tourism also promotes cultural exchange and dissemination, enhancing the visibility and influence of local cultures. Notably, many glaciers in the Qilian Mountains Nature Reserve and other glaciated regions in China are located in economically underdeveloped areas, where glacial resources serve as a key pillar for local economic development, supporting industries such as tourism, aquaculture, and handicrafts. For example, in the Yulong Snow Mountain Scenic Area in Yunnan Province, glacier tourism generates annual revenues exceeding 1 billion yuan, supporting thousands of local jobs and contributing to poverty alleviation and rural revitalization efforts.

Environmental issues related to glaciers often have far-reaching and cascading effects, as changes in glacial conditions can impact not only the immediate vicinity but also downstream regions that depend on glacial meltwater. The retreat of glaciers and the subsequent reduction in freshwater availability can disrupt the delicate balance of ecosystems, affect agricultural productivity, and even trigger social and economic conflicts in water-scarce regions. Therefore, the protection of glacial resources is not merely an ecological imperative but also a critical socioeconomic necessity that requires urgent attention and action. Failure to address the challenges of glacier retreat could have severe and long-lasting consequences for ecological stability, water security, and sustainable development in China and beyond.

3. Current Status of Glacier Protection Legislation in China

The existing legal and regulatory framework for glacier protection and management in China can be broadly categorized into two types, each reflecting different levels of legislative attention, specificity, and enforcement capacity.

3.1 Legislation That Does Not Designate Glaciers as Specialized Protection Objects

The first category includes national and local laws and regulations that address glacier protection incidentally but do not designate glaciers as specialized protection objects. These legal instruments typically include glaciers within broader categories of natural resources or ecosystems, without providing targeted protection measures or specific regulatory requirements.

At the national level, the earliest legal provision related to glacier protection can be found in the Environmental Protection Law of the People's Republic of China, promulgated in 1989. This law stipulates that people's governments at all levels shall take measures to protect representative natural ecosystem areas and prohibit destruction, including glacial relics with significant scientific and cultural value. Building on this foundation, the Regulations on Nature Reserves of the People's Republic of China, enacted in 1994, further proposes the establishment of nature reserves to provide special protection for glaciers with major scientific and cultural value. Subsequent revisions to national legislation, such as the revised Environmental Protection Law of the People's Republic of China (2014) and the revised Regulations on Nature Reserves of the People's Republic of China (2017), also mention glacier protection in passing, reaffirming the importance of safeguarding these natural assets.

At the local level, provinces and autonomous regions with significant glacial resources—such as Sichuan, Yunnan, Gansu, Qinghai, and Xinjiang—have incorporated references to glacier protection in their local environmental protection regulations. For example, the Sichuan Provincial Environmental Protection Regulations, Yunnan Provincial Environmental Protection Regulations, and Gansu Provincial Environmental Protection Regulations all mention glaciers as part of the natural resources that require protection. Additionally, autonomous prefectures within Gansu Province, such as Linxia Hui Autonomous Prefecture and Sunan Yugur Autonomous County, have enacted autonomous regulations that include provisions related to glacier conservation, such as the Regulations of Linxia Hui Autonomous Prefecture of Gansu Province and the Regulations of Sunan Yugur Autonomous County of Gansu Province. However, most of these legal provisions merely mention the term "glaciers" in passing, without specifying concrete protection measures, management requirements, enforcement mechanisms, or legal liability for damage. As a result, these provisions are largely symbolic and lack practical operability, failing to provide effective legal safeguards for glacier protection.

3.2 Legislation That Designates Glaciers as Protection Objects and Specifies Concrete Protection Content

The second category consists of local laws and regulations that explicitly designate glaciers as specialized protection objects and outline specific protection measures, responsibilities, and

enforcement mechanisms. These regulatory instruments represent a significant advancement in glacier protection legislation, addressing the limitations of the first category by providing targeted and operational guidance.

The most prominent example of this type of legislation is the Tibet Autonomous Region Glacier Protection Regulations, promulgated in 2024. This regulation comprehensively addresses issues related to glacier protection within the region, clarifying the scope of responsibilities of people's governments at all levels, encouraging the development of financial projects dedicated to glacier protection, and establishing a sound complaint and reporting system for illegal activities that harm glaciers. It is currently the most comprehensive provincial-level local regulation on glacier protection in China, providing a valuable model for other regions.

In the Xinjiang Uygur Autonomous Region, the Measures of the Xinjiang Uygur Autonomous Region for the Implementation of the Water Pollution Prevention and Control Law of the People's Republic of China explicitly stipulates that people's governments at or above the county level shall take measures to protect glaciers and delineate protected areas where pollution-causing activities are prohibited. Furthermore, the Standing Committee of the 14th People's Congress of the Xinjiang Uygur Autonomous Region has included the formulation of the Glacier Protection Regulations of the Xinjiang Uygur Autonomous Region in its five-year legislative plan, aiming to introduce a comprehensive regulatory framework for glacier protection across the region. However, despite these efforts, Xinjiang currently lacks supporting local administrative regulations and autonomous prefecture-level rules for glacier protection. To date, only the Ili Kazakh Autonomous Prefecture has enacted the Regulations on the Protection and Management of Glacier Water Resources in the Sawuer Mountains of Jeminay County, leaving a gap in regional-level legislation for glacier protection. This absence of unified regional-level legislation hinders the effective legal protection of glaciers in Xinjiang and highlights the uneven development of glacier-related laws across China.

More importantly, the legal concept of "glacier" remains undefined in most Chinese legislation related to glacier protection. To date, only the Tibet Autonomous Region Glacier Protection Regulations provides a clear legal definition: "For the purposes of these Regulations, a glacier refers to a natural ice mass that exists on the Earth's surface, is formed by the accumulation and evolution of snowfall or other solid precipitation, and is in a flowing state." Clarifying the legal concept of "glacier" is essential for defining the scope of protection objects, ensuring the consistency and coherence of the legal framework, and enhancing the enforceability of glacier protection laws. Without a standardized legal definition, there is a risk of ambiguity and inconsistency in the application of laws and regulations, leading to gaps in protection and challenges in enforcement. Therefore, it is imperative to explicitly define the legal concept of "glacier" in national and local legislation to lay a solid foundation for the construction of a comprehensive and effective glacier protection legal system.

4. Legal Issues in Glacier Protection in China

4.1 Fragmented Legislative System

Currently, China lacks a specialized national law dedicated to glacier protection, resulting in a fragmented legislative system where provisions related to glacier protection are scattered across various environmental laws, regulations, and policies. These include the Qinghai-Tibet Plateau Protection Law, the Yellow River Protection Law of the People's Republic of China, the revised Regulations on Nature Reserves of the People's Republic of China (2017), and the revised Environmental Protection Law of the People's Republic of China (2014), among others.

For example, the Yellow River Protection Law of the People's Republic of China stipulates that "the state shall strengthen the protection of water source conservation areas in the Yellow River Basin and increase efforts to protect snow-capped mountains, glaciers, permafrost, alpine meadows, grasslands, wetlands, deserts, spring areas, and other ecological features in the source regions of the main stream and tributaries of the Yellow River." This provision mentions glaciers incidentally as part of the broader effort to protect water source conservation areas in the Yellow River Basin, rather than focusing specifically on the protection needs of glaciers themselves. Similarly, the Environmental Protection Law of the People's Republic of China stipulates that "people's governments at all levels shall take measures to protect representative natural ecosystem areas of various types, natural distribution areas of rare and endangered wild animals and plants, important water source conservation areas, natural relics with significant scientific and cultural value (such as geological structures, famous karst caves, and fossil distribution areas, glaciers, volcanoes, and hot springs), as well as cultural relics and ancient and famous trees, and prohibit destruction." This provision is clearly a principle-based statement that lacks specific, constructive content related to glacier protection, providing little practical guidance for enforcement.

As a result, China's legal framework for glacier protection is incomplete and inadequate. There is no specialized national law dedicated to glacier protection, and the existing provisions related to the protection, rational utilization, and liability for damage or restoration of glaciers are fragmented and lack specificity. Most of these provisions exist in the form of local regulations with low legal hierarchy, and there is no unified, systematic regulatory system at the national level. This fragmented legislative approach makes it difficult to address the complex and interrelated challenges of glacier protection effectively, leading to inconsistencies in enforcement, gaps in coverage, and inadequate legal safeguards for glacial resources. Therefore, there is an urgent need to formulate a specialized, systematic national Glacier Protection Law that can integrate and harmonize existing scattered provisions, provide a clear legal basis for glacier protection, and establish a comprehensive regulatory framework for the conservation and management of glacial resources.

4.2 Lack of Specificity in Legislative Content

Most legal provisions related to glacier protection in China are principle-based, vague, and lack operational specificity, resulting in weak practical applicability and enforceability. For example, the

Qinghai-Tibet Plateau Protection Law includes six articles related to glaciers, five of which are general principle-based statements. Take Article 8 as an example: "The state encourages and supports scientific investigation and research on the Qinghai-Tibet Plateau, strengthens research on major scientific and technological issues in fields such as climate change, biodiversity, ecological protection and restoration, hydrology and water resources, snow-capped mountains, glaciers, and permafrost, soil and water conservation, desertification control, evolution of rivers and lakes, geological environments, monitoring, early warning, and prevention and control of natural disasters, development, utilization, and protection of energy and climate resources, and ecosystem carbon sinks on the Qinghai-Tibet Plateau, promotes the construction of major scientific and technological infrastructure, and advances long-term research work to grasp the ecological baseline and its changes on the Qinghai-Tibet Plateau." This provision focuses on the overall ecological environment of the Qinghai-Tibet Plateau, with glaciers merely being one component of this broader ecosystem. It does not provide specific, actionable measures for glacier protection, such as monitoring requirements, land-use restrictions, or enforcement mechanisms.

Local regulations also suffer from the problem of excessive principle-based provisions. Take Gansu Province as an example: Article 22 of the Regulations of Gansu Province on Ecological Protection and High-Quality Development of the Yellow River Basin stipulates that "the people's government of the province shall strengthen the protection of water source conservation areas in the Yellow River Basin, take measures to increase efforts to protect snow-capped mountains, glaciers, permafrost, alpine meadows, grasslands, wetlands, deserts, spring areas, and other ecological features in the source regions of the main stream and tributaries of the Yellow River." Article 32 of the Gansu Provincial Environmental Protection Regulations stipulates that "people's governments at all levels shall take measures to protect representative natural ecosystem areas of various types, natural distribution areas of rare and endangered wild animals and plants, important water source conservation areas, natural relics with significant scientific and cultural value (such as geological structures, famous karst caves, and fossil distribution areas, glaciers, volcanoes, and hot springs), as well as cultural relics and ancient and famous trees, and prohibit destruction." Both of these regulations mention "glacier protection" but fail to specify concrete measures for how to protect glaciers, such as defining prohibited activities, setting monitoring standards, establishing penalty mechanisms, or allocating funding for conservation efforts.

Principle-based provisions are often highly general and abstract, providing directional guidance for the formulation and implementation of specific rules but failing to address practical issues directly. Therefore, to ensure the effective implementation of principle-based provisions, it is necessary to establish supporting mechanisms, detailed implementation rules, and operational standards. Without such operational clarity, principle-based provisions risk becoming mere declarations of intent rather than effective instruments for promoting change. This gap between policy intent and practical implementation undermines the credibility and effectiveness of glacier protection efforts, perpetuating regulatory inefficiencies and failing to provide adequate legal safeguards for glacial resources.

4.3 Low Legal Hierarchy

Most legal provisions related to glacier protection in China exist in the form of local regulations enacted by provinces, autonomous regions, or autonomous prefectures. These local regulations have limited legal hierarchy and lack universal applicability across the country, making it difficult for them to provide sufficient legal basis for regulating activities related to glacier protection on a national scale.

For example, in 2016, the Standing Committee of the People's Congress of Ili Kazakh Autonomous Prefecture formulated the Regulations on the Protection and Management of Glacier Water Resources in the Sawuer Mountains of Jeminay County. This regulation explicitly stipulates that the county people's government shall establish a Glacier Water Resources Management Committee, composed of relevant administrative departments, resident departments, and units, to exercise unified leadership and management over the ecological protection of glaciers and define specific responsibilities. Following the enactment of the Qinghai-Tibet Plateau Protection Law in 2023, the Tibet Autonomous Region actively responded to the call, adhered to the basic concepts of the law, and formulated the Tibet Autonomous Region Glacier Protection Regulations. This regulation, combined with the actual conditions of the autonomous region, clarifies the specific responsibilities of people's governments at all levels and ecological and environmental departments at all levels, and stipulates the implementation of a target responsibility system and performance evaluation system for glacier protection. These local initiatives undoubtedly provide valuable references and insights for China's glacier protection legislation, helping to promote the development of glacier-related laws and regulations.

However, due to their low legal hierarchy, these local regulations can only be applied within their respective administrative regions and cannot provide comprehensive protection for China's glacial ecosystems on a national scale. Furthermore, local regulations often lack effective supervision mechanisms, and there may be conflicts or inconsistencies between the provisions of different regions, leading to problems such as inconsistent enforcement standards and ineffective implementation. For example, a local regulation in one region may prohibit certain activities near glaciers, while a neighboring region may have no such restrictions, creating a "regulatory arbitrage" phenomenon where harmful activities simply shift to regions with weaker legal protections. Additionally, the low legal hierarchy of local regulations makes it difficult to coordinate glacier protection efforts across administrative boundaries, which is particularly problematic given that many glacier systems span multiple provinces or autonomous regions. Without a unified national legal framework, it is challenging to address cross-regional issues such as transboundary water management, coordinated climate change adaptation, and unified monitoring and enforcement.

Elevating the legal hierarchy of glacier protection provisions by formulating a specialized national Glacier Protection Law would help to address these limitations. A national law would have universal applicability across the country, ensuring consistent protection standards and enforcement mechanisms. It would also provide a strong legal basis for coordinating cross-regional glacier protection efforts,

resolving conflicts between local regulations, and ensuring that glacier protection is given priority in national environmental policy and decision-making.

4.4 Inadequate Public Participation Mechanisms

Glaciers are valuable natural resources that hold significant economic value for local communities, particularly in regions where tourism, aquaculture, and other industries rely heavily on glacial resources. However, some stakeholders may prioritize short-term economic interests over long-term ecological sustainability, leading to overexploitation of glacier resources and contributing to glacier retreat. Currently, glacier protection efforts in China rely primarily on local governments, with limited opportunities for residents—who are the direct stakeholders and beneficiaries of glacial resources—to participate effectively in decision-making and supervision processes related to glacier protection.

This lack of adequate public participation mechanisms makes it difficult to resolve conflicts between environmental rights and economic interests, as the voices and concerns of local communities are not fully heard or considered in policy and decision-making. Local residents, particularly indigenous communities and those whose livelihoods depend directly on glacial resources, often possess valuable traditional knowledge and insights about glacier ecosystems, their changes, and their importance. However, existing legal frameworks rarely incorporate these perspectives, resulting in top-down policy approaches that may not align with local needs or priorities.

Effective public participation mechanisms are essential for ensuring the legitimacy, effectiveness, and sustainability of glacier protection policies. By involving local residents, environmental organizations, scientists, and other stakeholders in decision-making processes, it is possible to develop more inclusive and balanced policies that address both ecological protection and socioeconomic development needs. Public participation can also enhance public awareness and understanding of glacier protection issues, foster a sense of ownership and responsibility among local communities, and improve compliance with environmental regulations.

Mechanisms for enhancing public participation in glacier protection could include public hearings and consultations for major projects or policies that may affect glaciers, community-based monitoring programs that engage local residents in tracking glacier changes and reporting illegal activities, transparent information disclosure systems that provide the public with access to data on glacier conditions and protection efforts, and legal provisions that allow environmental organizations to file public interest lawsuits to enforce glacier protection laws. By establishing these mechanisms, China can ensure that glacier protection policies are more responsive to local needs, more effective in practice, and more sustainable in the long term.

5. Insights from International Glacier Protection for China

5.1 Argentina's Glacier Protection Law: A Pioneering Model

Argentina's glacier protection legislation, enacted in 2010, is the world's first specialized national law dedicated exclusively to glacier protection. This landmark legislation has significant implications for glacier protection globally, providing a valuable model for other countries facing similar challenges. The law recognizes glaciers as public goods that are essential for ecological balance, water security, and sustainable development, and it prohibits all activities that could interfere with the natural state of glaciers, including mining, oil and gas exploration, construction, and waste disposal.

A key provision of Argentina's Glacier Protection Law requires the government to conduct a comprehensive inventory of all glaciers in the country within 180 days of the law's enactment, with priority given to glacial regions where economic activities are already underway. This national glacier inventory serves as the foundation for effective glacier protection and management, providing detailed information on the location, size, type, and ecological characteristics of each glacier, as well as an assessment of the threats facing them. By establishing a national glacier inventory, Argentina has been able to develop targeted protection measures, monitor changes in glacial conditions, and enforce the law more effectively.

The law also establishes strict liability for damage to glaciers, requiring any person or entity that causes harm to glaciers to compensate for the damage and restore the affected area to its original state. Additionally, the law includes provisions for public participation, requiring public consultations and hearings for major projects or policies that may affect glaciers, and ensuring that the public has access to information on glacier protection efforts. Argentina's experience demonstrates the importance of specialized, comprehensive legislation for glacier protection, as well as the value of establishing clear legal definitions, strict prohibitions on harmful activities, and effective monitoring and enforcement mechanisms.

5.2 Kyrgyzstan's Glacier Law: Strengthening Liability for Damage

In 2014, the Parliament of Kyrgyzstan adopted its own Glacier Law, which builds on Argentina's model and introduces additional provisions to strengthen liability for glacier damage. Like Argentina's law, Kyrgyzstan's Glacier Law prohibits the development and exploitation of glacier resources, but it goes further by detailing the legal liability for damage to glaciers and establishing specific compensation requirements. The law clarifies that individuals or entities engaged in the extraction of natural resources covered by glaciers shall be held liable for any damage caused to the glaciers, and the amount of compensation for such damage shall be determined by the government based on the extent of the harm.

This provision not only effectively prevents the development and destruction of glaciers but also provides an incentive for the government to enforce the law, as it can recover compensation for damages caused by illegal activities. However, some scholars argue that while Kyrgyzstan's Glacier Law is a positive step, it came too late to prevent significant damage to glaciers from previous mining

activities. For example, the Kumtor Gold Company has been operating near the Kumtor Glacier in the Tien Shan Mountains since 1992. Between 1994 and 2011, the company removed 39 million cubic meters of glacial ice to access gold deposits and dumped industrial waste on the remaining glacier, causing severe pollution to the glacier and surrounding water sources. Despite the subsequent enactment of the Glacier Law, the damage already done to the Kumtor Glacier is irreversible, highlighting the importance of enacting glacier protection legislation before harmful activities occur, rather than attempting to remediate damage after it has been inflicted.

Kyrgyzstan's experience underscores the need for timely legislative action to protect glaciers, as well as the importance of establishing strict liability and compensation mechanisms to deter harmful activities. It also demonstrates that even well-intentioned laws may be ineffective if they are not supported by adequate enforcement resources and political will.

5.3 Key Insights and Lessons for China

The international experiences of Argentina and Kyrgyzstan, as well as other countries with glacier protection policies, offer several key insights and lessons for China as it seeks to strengthen its own glacier protection legal framework:

1) Specialized National Legislation: The development of a specialized national Glacier Protection Law is essential for providing a unified, comprehensive legal basis for glacier protection. Such a law should clearly define glaciers as specialized protection objects, establish strict prohibitions on harmful activities, and outline specific protection measures, management requirements, and enforcement mechanisms.

2) Clear Legal Definitions: Explicitly defining the legal concept of "glacier" is critical for ensuring the consistency and coherence of the legal framework, avoiding ambiguity in enforcement, and providing a clear basis for identifying protected objects.

3) National Glacier Inventory: Establishing a national glacier inventory based on scientific data is essential for effective glacier protection and management. The inventory should include detailed information on the location, size, type, ecological characteristics, and threats facing each glacier, and it should be regularly updated to reflect changes in glacial conditions.

4) Strict Liability and Compensation: Establishing strict liability for damage to glaciers and requiring compensation for harm caused by illegal activities can serve as a strong deterrent to harmful behavior. This includes not only requiring the restoration of damaged glaciers but also compensating for ecological and socioeconomic losses resulting from glacier damage.

5) Timely Legislative Action: Enacting glacier protection legislation before significant damage occurs is far more effective and cost-efficient than attempting to remediate damage after it has been inflicted. Timely action can prevent irreversible harm to glaciers and ensure the long-term sustainability of these vital resources.

6) Public Participation: Incorporating effective public participation mechanisms into glacier protection legislation can enhance the legitimacy and effectiveness of policies, ensure that local

community needs are considered, and foster a sense of ownership and responsibility among stakeholders.

7) Enforcement and Supervision: Strong enforcement mechanisms and adequate supervision resources are essential for ensuring that glacier protection laws are effectively implemented. This includes establishing clear enforcement responsibilities, providing adequate funding and technical support for enforcement agencies, and developing effective monitoring systems to track compliance.

By drawing on these international experiences and adapting them to China's specific national conditions, China can develop a robust, effective legal framework for glacier protection that addresses the unique challenges facing its glacial resources.

6. Feasible Pathways for Improving Glacier Legislation in China

6.1 Advance the Legislative Process for a Specialized National Glacier Protection Law

Glaciers possess unique ecological characteristics and play critical roles in water conservation, climate regulation, and biodiversity protection, making them distinct from other natural resources. As a result, they require a specialized legal protection system tailored to their specific needs. Relying solely on general environmental laws such as the Environmental Protection Law or the Water Law is insufficient to capture the complexity of glacier ecosystems or address their unique protection requirements.

China should therefore integrate existing scattered provisions related to glacier protection, draw on international legislative models, and formulate a specialized national Glacier Protection Law that reflects China's specific national conditions and glacier protection needs. This law should establish a comprehensive legal framework for glacier protection, including provisions for the definition of glaciers, the establishment of a national glacier inventory, specific protection measures, rational utilization guidelines, liability for damage, and restoration requirements. A specialized national law would not only provide a clear legal basis for regulating activities that may affect glaciers but also ensure the comprehensive, systematic protection of glacial resources, promoting the restoration and sustainable development of glacial ecosystems.

The legislative process for the Glacier Protection Law should involve extensive research, consultation, and participation from a wide range of stakeholders, including glaciologists, ecologists, environmental lawyers, local communities, indigenous peoples, and relevant government departments. This multidisciplinary and inclusive approach can ensure that the law is based on scientific evidence, reflects diverse perspectives, and addresses practical challenges, enhancing its feasibility and effectiveness in practice.

6.2 Establish Fundamental Legal Institutions for Glacier Protection

To complement the specialized national Glacier Protection Law, China should establish four fundamental legal institutions for glacier protection, providing operational mechanisms to implement the principles and provisions of the law:

1) Environmental Impact Assessment (EIA) System for Glacier-Related Projects

The Environmental Impact Assessment (EIA) system is a key tool for preventing or mitigating the adverse environmental impacts of development projects. For projects that may affect glaciers—such as mining, construction, tourism development, and infrastructure projects—a rigorous EIA should be mandatory. This assessment should include a comprehensive analysis of the potential impacts of the project on glaciers, including changes in glacial meltwater runoff, soil erosion, habitat destruction, and pollution. It should also involve public hearings to solicit the opinions and concerns of local communities, environmental organizations, and other stakeholders. Based on the results of the EIA, projects that are likely to cause significant damage to glaciers should be prohibited, while those with acceptable impacts should be required to implement strict mitigation measures to minimize harm. The EIA system should also include post-project monitoring to track actual environmental impacts and ensure that mitigation measures are effectively implemented.

2) Glacier Planning System

The glacier planning system involves the development of comprehensive protection plans by competent authorities, based on the ecological characteristics of glaciers and the socioeconomic development needs of local regions. These plans should define the responsibilities of different government departments, clarify the ownership and management of glacial resources, and establish zoning systems for glacier protection. For example, glacial regions could be divided into core protection zones, buffer zones, and experimental zones, each with different levels of restrictions on human activities. Core protection zones would be strictly protected for scientific research and ecological conservation, with no development activities allowed. Buffer zones would permit limited, low-impact activities such as scientific monitoring and ecotourism, while experimental zones would allow for more intensive but sustainable development, subject to strict environmental regulations. The glacier planning system should also incorporate spatial planning tools, such as zoning maps and land-use plans, to guide development decisions and minimize conflicts between conservation and economic development.

3) Rational Utilization System for Glacial Resources

For economically underdeveloped regions that rely on glacial resources for economic development, a rational utilization system should be established to balance conservation with sustainable development. This system should be based on an assessment of the environmental carrying capacity of glacial regions, ensuring that the utilization of glacial resources does not exceed the capacity of the ecosystem to recover (Wang, S. J., He, Y. Q., He, X. Z. et al., 2008, pp. 38-43).

Specifically, the rational utilization system could include the following measures:

- **Zoning for Utilization**: Dividing glacial regions into different zones based on their ecological sensitivity and carrying capacity, as outlined in the glacier planning system. Core zones would be reserved exclusively for scientific research, with no commercial or recreational activities allowed. Buffer zones would permit limited tourism activities, such as guided glacier tours, with strict limits on the number of visitors and the types of activities allowed to minimize environmental impacts.

Key development zones, located in glacier runoff areas, would allow for more intensive economic activities but would be subject to strict regulations to ensure that they do not harm glaciers or their ecological functions.

- **Regulation of Utilization Methods**: Clearly defining the permitted methods of utilizing glacial resources through legislation. For example, tourism activities in buffer zones could be limited to non-motorized transportation, and the construction of tourist facilities would be prohibited within a certain distance from glacier margins. Any changes to the permitted utilization methods would require prior approval from competent authorities, and the applicant would be required to pay compensation for any potential environmental impacts.
- **Sustainable Tourism Management**: Developing sustainable tourism practices in glacial regions, such as promoting low-carbon tourism, limiting visitor numbers, and requiring tourists to follow designated trails to minimize damage to glacial ecosystems. Revenue generated from tourism could be used to fund glacier protection efforts and support local community development.

4) Ecological Compensation System for Glaciers

The ecological compensation system for glaciers aims to address the conflicts between glacier protection and local economic development by providing economic incentives for conservation. Glaciers not only have ecological value but also provide important socioeconomic benefits, such as supporting tourism and agricultural activities. However, the protection of glaciers often imposes economic costs on local communities, such as restrictions on development activities. The ecological compensation system seeks to balance these interests by providing financial support to local communities and governments that engage in glacier protection.

China already has a relatively well-developed ecological compensation framework, including mechanisms such as fiscal transfers from the central government to local governments in ecologically important regions, payments for ecosystem services (PES), and green financing. These existing mechanisms can be leveraged and adapted to support glacier protection. For example:

- **Fiscal Transfers**: The central government could provide additional fiscal transfers to provinces and autonomous regions with significant glacial resources, to compensate for the economic costs of implementing strict glacier protection measures and to support local ecological conservation efforts.
- **Payments for Ecosystem Services**: Establishing a PES system where beneficiaries of glacial ecosystem services—such as downstream water users, hydropower companies, and tourism operators—pay compensation to upstream communities that protect glaciers. This would internalize the ecological value of glaciers into economic decision-making and provide a sustainable source of funding for glacier protection.
- **Green Financing**: Encouraging the development of green financial products, such as glacier protection funds and green bonds, to attract private investment in glacier conservation projects. This could include funding for glacier monitoring, restoration of degraded glacial ecosystems, and sustainable development projects in local communities.

By establishing an effective ecological compensation system, China can ensure that the costs of glacier protection are shared equitably among all stakeholders, while providing economic support to local communities to promote sustainable development that is compatible with glacier conservation.

7. Conclusion

Glacier resources are mostly distributed in remote mountainous areas and snowfields far from human settlements, seemingly distant from our daily lives and having little direct impact on our routines. However, despite their remote location, glaciers are an indispensable part of Earth's natural resources and play a critical role in maintaining the global ecological balance and supporting human sustainable development. As "water towers of the world," glaciers provide essential freshwater resources for billions of people, regulate global climate patterns, support unique biodiversity, and offer valuable economic opportunities through tourism and other industries. They are not only natural treasures but also key elements for sustaining the delicate balance between humanity and nature.

Facing the severe challenges of glacier ablation, ecological degradation, and water resource shortages caused by global climate change, strengthening the legal framework for glacier protection is not only a matter of respecting the laws of nature but also a responsibility to safeguard humanity's own future. Through the formulation of a specialized national Glacier Protection Law and the establishment of fundamental legal institutions for glacier protection, China can provide a robust legal foundation for the comprehensive, systematic, and science-based protection of glacial resources. This will not only help to mitigate the adverse impacts of climate change on glaciers but also promote the sustainable development of glacial ecosystems, ensure water security for ecological and socioeconomic needs, and contribute to global efforts to address climate change and protect biodiversity.

Furthermore, specialized glacier protection legislation can help to foster a culture of environmental protection and respect for nature across society, promoting the widespread recognition of the importance of glaciers and encouraging public participation in conservation efforts. By establishing clear legal obligations and responsibilities for governments, enterprises, and individuals, the law can drive behavioral change and ensure that glacier protection becomes an integral part of national development strategies and daily life.

We eagerly anticipate the emergence of a comprehensive, specific, and effective Glacier Protection Law in China. Such a law will not only safeguard the country's valuable cryospheric resources but also demonstrate China's commitment to global environmental governance and sustainable development. The journey toward effective glacier protection requires the collective efforts of governments, scientists, environmental organizations, local communities, and all members of society. By learning from international experiences, drawing on scientific research, and engaging in inclusive decision-making, China can develop a world-class glacier protection legal system that serves as a model for other countries and contributes to the preservation of these vital natural resources for current and future generations.

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