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# Mountain Cryosphere Landscapes in South America: Value and Protection

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**Abstract:** Mountain landscapes support hydric and biodiversity potential under different ownership and land use perspectives. A focal point justifying their preservation is often the legislation's ethical endorsement. Yet, when scales for assessment diverge without a common analytical purpose, the protective measures may become either ambiguous or insufficient. By considering that mountain cryosphere landscapes have both subjective and supply values, we focused on approaches to protect them and examined conceptual dissonances in their assessment. This ambiguity was examined by analyzing the hydric storage potential of the mountain cryosphere in semi-arid regions in the Andes. We reviewed the technical aspects of cryosphere hydrology and how current legislation aims to preserve freshwater supply and non-instrumental value. The analysis found a clash between instrumental and non-instrumental values and, most importantly, the neglect of a temporal dimension for landscape evolution. Particularly, landscape protection becomes suboptimal as scales of analysis for use and non-use values diverge. Therefore, we recommend analyzing mountain cryosphere landscapes as overlapped sub-units bearing a unified potential (future value) as a hydric resource. This analysis should fit the most inclusive scale on which transaction costs reflecting needs and insurance values reflecting management quality are optimal.

**Keywords:** mountain cryosphere; landscape protection; conservation; hydric potential; natural value; Central Andes

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## 1. Introduction

Protecting mountain environments entails different dimensions of value: water resource protection (consumption, utility, and human rights), biodiversity (intrinsic value), and landscape protection (non-use values and intrinsic value). As with a water tower, water security management design implies an inter-scale analysis [1] without a univocal moral philosophical procedural framework [2]; hence, it is prone to failure in attaining optimal scopes of protection. For example, underground mining interventions might affect an aquifer's hydrological connectivity while (apparently) not altering the cryosphere elements thereon.

Attempts to protect different resource value types appeared in the New Zealand Resource Management Act of 1991, which defined intrinsic value in relation to ecosystems and their constituent parts, including their biological and genetic diversity and the essential characteristics that determine an ecosystem's integrity, form, functioning, and resilience [3]. In this sense, other indirect ways of addressing more complex systems are "ensuring" baseline ecosystem conditions, e.g., a minimal "ecological" streamflow (Decree-Law 71 in Chilean Law).

We could frame these challenges/shortcomings in legislation because of endorsing landscape "as a mere viewshed" in Environmental Impact Assessments when additional factors of the landscape/individual interaction often consider physical, artistic, and psychological attributes of the landscape [4,5]. Neglecting such attributes will often result in a failure of adequate representation in citizen discussions and the prioritization of the development of more updated policies.

Further simplifications of where landscapes emerge may also overlook several types of economic transformations (fragmentation and loss of integrity) and changes in terms of incremental welfare due to their protection [6]. Additionally, landscape appraisal in protected regions often relates to perception-based valuations of aesthetic value [7], remaining relatively detached from the temporary changes in society (the valuation time-scale) as symbolic representations of non-artificiality or non-interference. Hence, it is the government's predicament to guarantee this sort of idealized "permanence" of unspoiled nature.

Nevertheless, in any given landscape, the intrinsic characteristics of many nonliving objects (resource value) as well as living objects (biodiversity value) are inextricably linked to their mobility and growth, requiring an understanding of the boundaries of complex systems and the linkages and flows into and out of these systems [3]. Not only complex systems but complex scales of comparison may describe the structure of concerns (supply or cultural value), but not the methods to establish a baseline for resource change. For example, until the beginning of the 20th century, most of the (alpine) mountain peaks did not have names; it was common to describe the borders of alpine pastures with neighbors, cardinal points, or mountain peaks [8]. Even today, with geographic information systems and high-resolution inventories, not all glaciers or cryosphere-related structures are accounted for, detected, and monitored. Therefore, a challenge in understanding cryosphere environments is knowing their "latent" potential as a freshwater supply and their "platform" for multiple intersections of value.

High-altitude cryosphere landscapes entail services for human well-being [9], such as being a strategic freshwater supply in dry areas [10], but they also possess historical links and concerns to society [11] and "social arrangements" [12]. Hence there is difficulty in establishing a fair welfare trade-off for cryosphere objects as the resource use value (freshwater supply) is inherently tied to ecosystem functioning [13]. Therefore, a co-production perspective should be required in the adaptive management of, e.g., glacier ecosystem services, aimed at ensuring demand and supply management [14]. Nevertheless, ensuring supply implies anticipating the change in a cryosphere element bound to a specific demand, despite the unavoidable uncertainty in scientific predictions and estimates [15]. For example, challenges for legislation may range from anticipating legal and environmental conflicts to the evolution of objects due to climatic variations [16]. These challenges are essential when asking about, and calculating scales of benefits derived from resource exploitation, damage, or destruction [17]. Hence, a crucial issue concerning imminent mountain cryosphere degradation is the lack of juridical tools considering the long-term evolution of their value and the scales of either local or regional concern [18].

As a terrestrial solid water structure, the mountain cryosphere is a sine qua non component of the high Andes, often located within protected areas [19]. Its degradation is caused by changing precipitation patterns, particularly in arid and semi-arid zones, such as the Dry Andes of South America [20]. Complex conditions, such as variable surficial sediments, vegetation cover, or shallow groundwater flow, influence heat transfer and the time scales over which changes occur and affect the mountain water flow path [21]. As such, the amount of ice content and potential water storage is critical in these areas [22], where intertwined ecological processes take place, expressing our being and culture [4,23].

This study aims to describe the legal values and knowledge interactions that highlight the shortcomings of the mountain cryosphere management design under current climate change. We focused on difficulties in the legislation of mountain-protected areas (Table 1) and examined incongruences relative to the assessment of natural assets. Landscape enters as a concept for analysis, able to capture the subjective valuation of cryosphere settings, where cultural ecosystem services play a role in its valuation.

**Table 1.** Categories within the Convention for the Protection of Flora, Fauna and Natural Scenic Beauty of the American Countries (1942).

| Category | Purpose | Implementation |
|---|---|---|
| National park | Protection and conservation of value | Park-specific |
| Natural reserve | Use and conservation (management) | The specific purpose of the reserve |
| Natural monument | Absolute protection | Restricted to research and state inspection |

## 2. Materials and Methods

### *2.1. Context for a Changing Mountain Cryosphere*

Millions of people depend on the freshwater provided by the mountain cryosphere along the Andean mountain range [24,25] and therefore are currently prone to systematic insecurity in terms of food resources [26] and physical/economic water scarcity [27].

This has been the essence of ongoing efforts to include cryosphere elements in action plans and legislation. For example, recently, at the Conference of Parties in Egypt (COP27), the Sharm el-Sheikh Implementation Plan included, for the first time, the integrity of all ecosystems […] including … the cryosphere. Additionally, at COP27, both Iceland and Chile, which are countries with important concerns about their extensive mountain cryosphere, signed a bilateral agreement called "Ambition on Melting Ice" (AMI), which was co-signed by 17 other countries. Hence, we expect impacts from such agreements on more local legislative commitments by each country involved, as they acknowledge more specific concerns on (mountain) cryosphere elements.

Nevertheless, there are sustained insecurities in vast mountainous areas under sustained glacier decline, such as the Andes mountains between 10 and 56°S [10], where permafrost is currently degrading [28–30]. This degradation is relevant considering that the estimation for the southern Andean permafrost area (probability = 1) is about 10,651 km$^2$ [31], representing 24.2% of the total area of the Andean permafrost region [32] in Argentina and Chile. Furthermore, the impact of the cryosphere decline on the water supply along the Andes is not uniform. Glacierized catchments in the low-latitude Andes of Bolivia [33] and Peru [34] reached peak water levels before 2019, while at 33°S, in the Andes of Argentina and Chile, the consistent glacial retreat [35,36] projects catchment runoff decreases in future scenarios (RCP4.5 and RCP8.5) starting in the year 2021 [37]. Furthermore, the central-southern Andean region (30–48°S) presented a declining precipitation trend over 1960–2016 [38] and is expected to have a snowpack loss of up to 75–85% by the year 2100 [39]. This factor becomes preponderant as snow-dominated catchments over the Western Andean Front (30–35° S) may have a more significant groundwater contribution to streamflow than pluvial basins [40].

Moreover, in addition to a projected surface warming expected to reduce snow cover, hence increasing glacier and permafrost retreat [41], snowmelt season contraction might also vary and change infiltration patterns [42], consequently affecting subsurface recharge [43]. Therefore, at higher altitudes, there could be a more critical role for frozen surfaces involved in infiltration processes and replenishment of groundwater supplies, which are elements often outside the scope of impact assessment baselines.

Nevertheless, Andean environments affected by seasonal freeze–thawing are still neglected by specific legislation, which fails to acknowledge their role in the hydrological cycle, thus reducing their contingency to overall runoff and omitting the mechanistic complexities occurring at different timescales. For example, a long-term (>100 years) groundwater resilience to drought would imply a strategic reserve to cope with precipitation deficits [44] but requires an understanding of precipitation–recharge relationships as essential for reliable predictions of impacts and adaptation (infrastructure) strategies [45]. Moreover, groundwater partitioning is still unknown in arid basins [46,47], as groundwater in (currently) hyper-arid regions may have been recharged in a wetter climatic regime in the past [48]. Hence, groundwater supply in water-scarce regions does not account for the long-term evolution of storage, and consequently, its resilience to depletion is uncertain. Therefore, robust assessments of the impact of climate change on hydrological drought [49] are necessary for long-term planning and understanding of the current baseline.

### *2.2. Formulation*

This study analyzed specific Andean cryosphere areas where current legal endeavors aim to limit land use and establish a protective framework upon the imminent development of human activities (mining, construction, gas pipelines). This contingency is framed in the balance between the long-term expectations for the water supply and the water management design of the mountain cryosphere in the Andes. For example, when considering future groundwater recharge as a subunit of cryosphere landscapes [50], which reshapes its value as a supply of fresh water, its scarcity should require a proactive legislature for the landscapes' protection [51].

The areas of study (Figure 1) correspond to the Dry Andes (central and desert Andes to the north) and the humid Andes (lake region and Patagonian Andes to the south), as classified by Lliboutry and Corte [5]. The northern subregion has precipitation as the most critical climatic indicator, whereas in the southern subregion, it is temperature; both are essential variables for the formation of glacial or periglacial ice. Therefore, variations in these climatic elements will impact the future presence of mountain ice. For example, by the year 2100, the annual runoff in one-third of the 56 large-scale glacierized catchments is projected to decline by over 10%, with the most significant reductions in Central Asia and the Andes [52].

We will show that mountain cryosphere systems have an underestimated value with no optimal management design nor tools to determine the mountain cryosphere's current and future value within widespread scarcity. The implication is that the mountain cryosphere's supply could change beyond the scope of the present-day legislative grasp.

We assessed the change in the value of a depleting freshwater supply under climate forcing by reviewing technical literature on mountain areas where strategic water supplies often overlap conservation and exploitation interests as a conflict of value. This concern appeared in the recommendations of the Sustainable Development Goals [53], local legislations, and the IPCC [20]. This analysis further investigated whether the description of legal values defines how cryosphere systems can manage shortcomings under imminent depletion. For this, we selected regulations (Table 2) dealing with climate change adaptation and the cryosphere [16] and other compilations from databases, such as the Grantham Research Institute on Climate Change and the Environment, the Observatory for the Climate Change Law in Chile, and historical agreements, such as the Convention for the Protection of Flora, Fauna and Natural Scenic Beauty of the American Countries.

We focused on the Andean regions near highly populated centers, where untimely legislation (in comparison with Alpine nations) delayed the implementation of an adequate water management design. We further assumed an underestimated mountain cryosphere hydric potential (freshwater supply) in the Chilean Andes, as probabilistic models establish a region of under 14,000 km$^2$ affected by perennially frozen ground (permafrost) conditions [32]. However, other models express a much larger surface, approximately 140,000 km$^2$, for all the South American Andean permafrost, mostly between Chile and Argentina [54]. These areas not only coexist with glacial environments but can also either represent freeze–thaw-affected environments (periglacial) or are indirectly linked to glacial influence [55]. This precedent means they belong to the terrestrial cryosphere and, as such, either contain surface or ground ice, perennial or seasonal snow, or are ultimately affected by perennial freezing or seasonal frost.

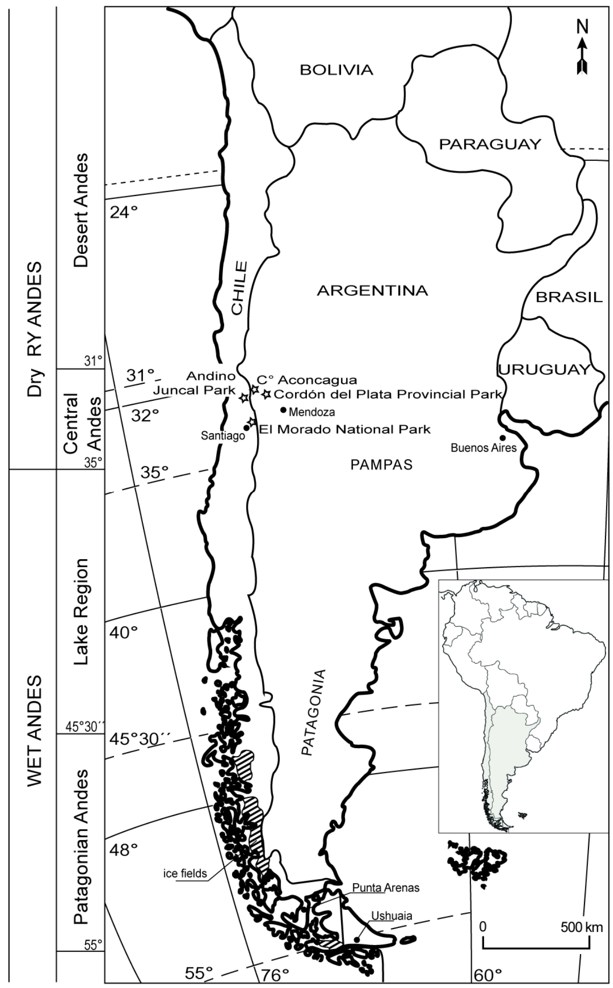


**Figure 1.** Selected areas of mountain cryosphere in the central Andes. Reprinted/adapted with permission from Ref. [5]. Copyright 1998, United States Geological Survey, Professional Paper 1386-I.

**Table 2.** Climate change and cryosphere regulations (Grantham Research Institute on Climate Change and the Environment and the Observatory for the Climate Change Law in Chile).

| Country | Type | Cryosphere Protection | Name | Year of Appearance |
|---|---|---|---|---|
| Austria | Law | Not included | 37th Federal Law for Climate and Energy funding | 2007 |
| Argentina | Law | Glacial and periglacial environments | Law 26639: "Minimal budgets for the preservation of glaciers and periglacial environment" | 2010 |
| Austria | Law | Not included | 106th Federal Law on Climate Protection | 2011 |
| Iceland | Passed | Not included | Act 70 on Climate Change | 2012 |
| Chile | Strategic plan | Included | National Climate Change Adaptation Plan | 2014 |
| Peru | Law | Mountain environments and glaciers | Law N° 30754 on Climate Change | 2018 |

| | | | | |
|---|---|---|---|---|
| Iceland | Strategic plan | Glaciers mentioned | Iceland's Climate Action Plan for 2018–2030 | 2018 |
| EU | Regulation in force | Not included | Regulation 842 | 2018 |
| EU | Strategic plan | Arctic and Boreal environments are mentioned | A Clean Planet for all | 2018 |
| Argentina | Law | Glacial and periglacial environments | Law 27520: "Minimal budgets for Adaptation and Mitigation to Global Climate Change" | 2019 |
| Chile | Law project | Not included | Climate change framework Law | 2020 |
| EU | Strategic plan | Indirectly mentioned through reference | Forging a climate-resilient Europe—the new EU Strategy on Adaptation to Climate Change | 2021 |

Finally, we discussed overlapping dimensions in environmental protection for land use (as property) within the grasp of current legislation and disentangled their spatial and temporal complexities for protection purposes in mountain cryosphere environments. This premise considers that headwater catchments generally overlap protected areas and both land use and conservation policies. The conservation policy issue involves rescuing both the intrinsic values and marginal utility of biodiversity and the hydric potential of mountain cryosphere landscapes under current climate forcing. This last part of our discussion focuses on the complexity of cryosphere environments when represented as landscapes with defined aspects [56].

Specific case examples on the hydrological relevance of headwater catchments and the mountain cryosphere intend to deliver insights into the evolution of landscape environmental protection in Argentina and Chile. We included Andean areas at 33°S, such as the "Mendoza River" in Argentina and the "Parque Andino Juncal Park" in Chile (Figure 2).

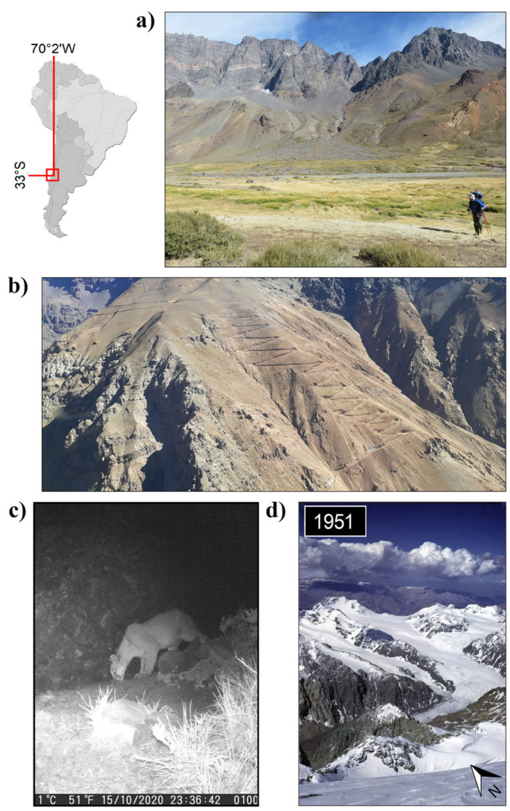


**Figure 2.** Intersected dimensions of landscape appraisal in Juncal Andino park, Central Andes of Argentina/Chile. (**a**) A RAMSAR site, (**b**) an aerial photograph of mining expansion within the

viewshed at 33°S, (**c**) a *Puma concolor* image from trap cameras within the park, and (**d**) a 1951 photograph (aiming at north-east) of the Chile/Argentina border at 33°S taken by Eberhard Meier. Figure adapted from Ruiz Pereira, 2021 [57].

## 3. Results

### *2.1. Shortcomings in Legislation*

We attested that a lack of time scales to measure the depletion of cryosphere elements (Table 2) overlooks the complexity of changing hydrological landscape schemes in many regions of the world and the Southern Andes (Table 3). For example, impacts due to the temperature evolution of groundwater [58] are neglected in a temporal dimension for protection, even though many areas represent protected habitats within parks and even present high-altitude wetlands in arid areas with unique biodiversity (RAMSAR site in Figures 2 and 3).

**Table 3.** Summary of landscape analyses (Adapted with permission from Reference [56], Copyright 1963, University of California publications in Geography).

| Aspects of Landscape | Description |
|---|---|
| A comprehensive view of nature and culture | Interaction of natural and/or cultural factors |
| Internal vs. external perspective | Areas, as perceived by people |
| Historical retrospection | Balance loss, fragmentation destruction, or transformation of landscape units |
| Forms and processes | Action and interaction, human factors |

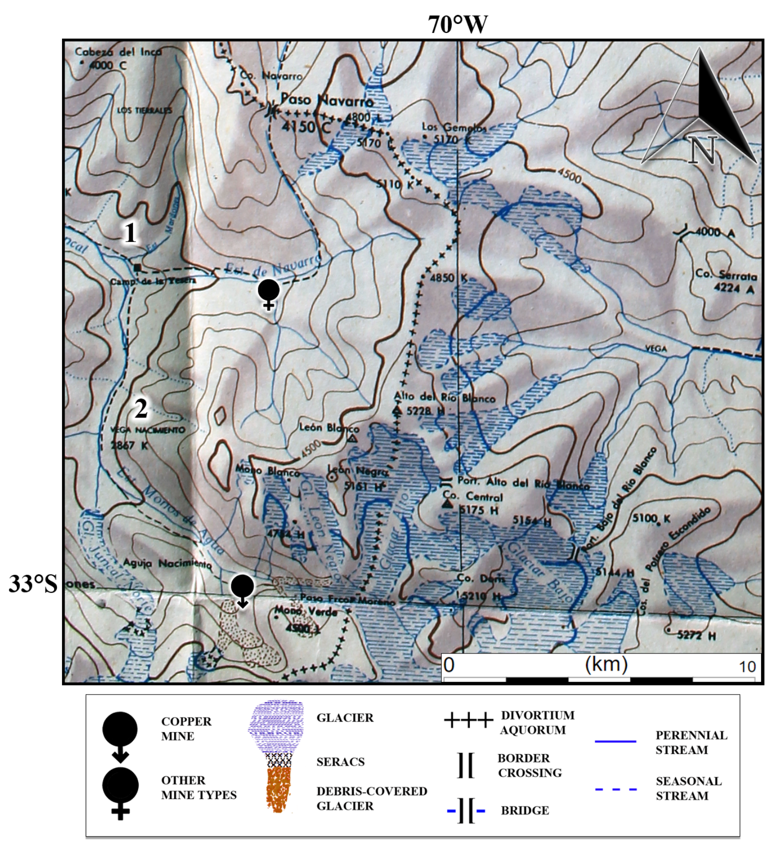


**Figure 3.** Historical map of mountain-protected areas in the Chilean central Andes (shown in Figure 1). Adapted from Nieves y Glaciares de Chile (Lliboutry, 1956), copyright 1956, Universidad de Chile Editions. (1) The "Juncal Andean" Park's entry point and (2) the RAMSAR site No. 1909 (2010).

Another issue of particular interest for the Andean cryosphere is the transboundary aquifers, which raise the issue of unpaired assessments as one country monitors and focuses on the aquifer changes while the other is under private assessment, such as mining consulting. Even though mentioned in international law [17], this issue is somewhat absent from legislation that protects the mountain cryosphere. For example, Chilean law officially prohibits activities in cryosphere areas under protection, but only through "hardened" laws controlling the operation. Meanwhile, the Glacial Law (No. 26,639, 2010) can stop activities in Argentina. Furthermore, in Chile, restricting exploitative activities comes only through protection under national monuments (Law 17,288, Chile 1970) and/or national parks (Law 18,362, Chile 1984).

Moreover, protecting cryosphere landscapes as natural "monuments" requires a multi-dimensional framework assessing various elements bound by the conceptual mission of a preservation purpose. For example, in the USA, the National Park Service (NPS) requires commercial use authorizations (CUA) for impacts if they are consistent with enacted legislation and complementary to a park's mission. That prerogative includes appropriate principles and practices, environmental goals, and avoiding unacceptable impacts, even though technical landscape definitions are missing [59].

Specifically, the moral prerogative for preserving certain features and functions of an area can be an analog to ecosystem service protection ranging from the non-instrumental "scenic" qualities to the instrumental freshwater supply dimension of an aquifer. In Chilean law, the protection of (natural) monuments has a share of this "mission" to sustain the unique character of landscapes and geological formations (Law 18,362, Art. 1 c–d, Chile 1984) but also to keep the productive quality of grounds to restore and improve scenic resources. These directions represent non-alteration categories (Table 2) for national parks, monuments, or nature reserves, also in compliance with the Convention for the Protection of Flora, Fauna and Natural Scenic Beauty of America (Washington, 1940), complied in Chile by Supreme Decree 531 (1967) and related to Law 1,939 (State Assets) and Law 1,9300. This convention (for protection) exhorts, in its Article III, that "the riches existing in them shall not be exploited for commercial purposes" and includes in its Article V the "extraordinary geological formations."

An example of upscaling protection was performed by the Ministry of National Assets (Chile) through Supreme Decree 2581 (modified by Decree 121, 2017). The Ministry reclassified the "El Morado" National Park (33°46′S, 70°04′W) as a Natural Monument to incorporate more geomorphological aspects (moraines) between its watersheds and lower limits, thus, granting protection to the whole sub-basin. These management categories for conservation imply the preservation of natural environments (fiscal property), cultural features (heritage and sports), and scenic (landscapes) features associated with them.

Even though mountain cryosphere objects can be redefined in their hydrological importance as supply resources, they still reside amidst different aspects of landscape units, as described in Table 3. Therefore, approaches to landscape protection often withhold moral prerogatives for preserving features through management. For example, "everyone is obliged to take care of the country's nature and show extreme caution so that it is not spoiled" is included in Paragraph 2, Art. 12 of the Conservation Law no. 44/1999, Iceland [60]. In 2022, the Swiss Confederation delivered statute 451 of the Federal Act on the Protection of Nature and Cultural Heritage (Article 78, paragraphs 2–5, Federal Constitution), discussing the necessary links between the management, protection, and preservation of landscapes and biodiversity. Along with supporting local management (cantons), the act promoted conservation, scientific research, and education for local landscapes. Furthermore, in Article 23 of statute 451, we can perceive the "clash" between instrumental and non-instrumental values of landscapes. In this sense, this act revitalizes the 1991 Water Protection Act (statute 1 February 2023), which established in Article 1-b a guaranteed water supply and in Article 1-e water as an element of the landscape, further defining the surface and underground scope of such supply in Article 2 and establishing the definition of shallow and groundwater in Article 4.

Overall, shortcomings in environmental legislation are amplified due to the normalized mistreatment/neglect of optimal management of natural assets. This issue may be rooted in a lack of familiarity or skills for the appraisal and protection of natural values per se, the recognition of the value, and even more, the future value, as technical notions on the spatiotemporal dimension of resources are neglected. Such factors interfere with the timely implementation of protective measures, considering that there are, as mentioned, enough legislative tools to circumvent the new challenges in conservation.

### *2.2. Landscape Protection in the Andes of Argentina–Chile?*

Other examples of management issues in protected areas are the Nahuel Huapi (created in 1922, 41°′ S, 71°30′ W) and Los Alerces (created in 1937, 42°48′ S, 71°53′ W) national parks in Argentina, which currently face unsupervised impacts as a consequence of unplanned (human) occupation. Further north, near the city of Mendoza (with around one million inhabitants), Argentina, the creation of the "Provincial Park Cordón del Plata" ensured the protection of mountain permafrost and rock glaciers, which are cryogenic indicators of underground ice and are little known for their hydrological importance. Here, not just cryoforms are protected (rock glaciers, protalus ramparts, or cryogenic sedimentary slopes), but the entire periglacial environment of the upper hydrographic basin, which is being transformed by environmental changes and climatic variability, including water recharge areas (which preserve the supply), glaciers, flora, and fauna of the Andean tundra (File No. 8372/C/9930091)[61].

In such settings, an overestimated spatial scale for protection often complies with the preservation of aquifer connections between the surface and the subsurface. Still, it is different from the "natural monument" protection explained in Chilean law (No. 18,362, 2014). The link between both protective approaches provides an understanding that different spatial scales for protection (basin and sub-basin units) can solve the purpose of preserving the same asset but through different ontologies of concern. For example, in Chile, the "Andino Juncal" park (33° S, 70°5′ W) has been private property since 1911: used from 1970–2000 for cattle raising and mining. It currently constitutes a conservation project facing transformative pressure (Figures 2b and 3) due to current surrounding (within the park's viewshed) mining activities, as private cement companies have extraction rights and have built roads to the sites. By 2003, the park's owners decided to prohibit any exploitative activity on their property, and by 2010, a RAMSAR site (No. 1909, 32°55′S, 70°03′W) within the park was designated. In this area, hydric resources (glacierized and permafrost-affected catchments) and mountain biodiversity (mountain lions, kodkods, guanacos, foxes, and marshlands) (Figure 2) are now protected.

Furthermore, the park's Environmental Impact Assessment declaration (2006–2007) stated a useful life span of twenty years for the "sustainable tourism" project, which does not necessarily coincide with the official authorization granted by the Environmental Assessment Service (SEA, Chile) as a final resolution. Nevertheless, as shown in Figure 2, the expansion of mining operations (Andina-Codelco, Chile) nearby this park (Juncal) started to affect one dimension of the scenic value in terms of the landscape as a viewshed. The mining project stated in the Chilean Official Gazette (No. 41.965, January 2018) that it involved several "voluntary environmental commitments" for impacts (on air quality, surface runoff, groundwater, and glaciers), support for the local water supply and sanitary systems, as well as maintenance of the international road. Yet, other problems entail the visual impacts of infrastructure expansion within the same viewshed of a conservation area (the park), a type of impact absent in the Glacial Law in Argentina (No. 26,639, 2010). Nevertheless, this type of impact appears as a Category-2 type in Scotland's guidelines for landscape and visual impact assessment of wind power infrastructure [62]. In Chile, attempts at assessing landscape value through Environmental Impact Assessments have considered it a "visual quality", possessing an inherent value that makes it "unique and representative" (Art. 9, Law 19,300, Chile).

## 4. Discussion

### *4.1. Cryosphere Value under Transformation*

Transformations of mountain cryosphere landscapes pose challenges for impact assessments as technical aspects translate to (subjective) values. Conservation, in this sense, requires qualitative shifts in human–nature relations [63] and ultimately a reformulation of the economic relations therein (property allocation). Nevertheless, as the mountain cryosphere becomes scarcer, its natural value increases. Yet, if a resource's value is considered in terms of its "unspoiled character" [64], its depletion faces the problem of providing present and future amenities. For example, as scarcity is a pervasive aspect of human life and is a fundamental precondition of economic behavior [65], the capacity of ecosystems to sustain its (hydrological) services [66] or to store a future supply, as is the case for long-term glacial storage [67], is also an economic formulation.

In essence, the context of future cryosphere decline and depletion entails the loss of balance, fragmentation, or destruction of landscape units by land use, e.g., from extraction to conservation. In Figure 3, a 1955 glaciological map describes areas of mining activities within glacial environments, such as in Juncal Park shown in Figure 2. In these cases, other value dimensions from historical retrospection or subjective appraisal (Figure 2) have an incremental welfare effect on scarcity derived from protecting management design. Moreover, regional atmospheric warming deepens the permafrost table in the dry Andes, enhancing ice-rich permafrost degradation [28,29], affecting regional connectivity between basins, and modifying the space–time trends in groundwater recharge and discharge [68]. Therefore, the whole hydrological scheme is undergoing a transformation while the appraisal of its value is missing.

In that sense, even though high-altitude catchments of the mountain cryosphere represent an essential input for dry regions, they still have plenty of unaccounted elements in their full extension. For example, rock glaciers (of the permafrost type) in upper valleys influence downstream flows and potentially constitute excellent aquifers [48,69]. Nevertheless, they were neglected in inventories and impact assessments until recent years. They became protected by the Glacial Law in Argentina, implemented in 2010, while such legislation is still in process in Chile.

Therefore, as elements of the mountain cryosphere landscapes constitute a dynamic configuration, they often surpass a reduced definition of landscape content (e.g., visual quality bound to water quality), which, if subdivided into partial systems, can be investigated with sufficient accuracy [70]. One possibility for grasping their complexity is addressing their hydrological potential, which modifies their future value. For example, suppose that mountain cryosphere elements undergo storage changes from the surface to the subsurface, affecting baseflow components. In that case, the prioritization of protection should aim for supply from different elements instead of one fixed element. This issue engages the insurance value of such natural assets and "integrates it into the disaster risk management agenda" [71] and fundamentally refers to (i) objective risks in terms of different possible states of nature, (ii) the decision maker's subjective risk preferences over these states, and (iii) a mechanism that allows mitigation [72] relating to the idea of future water insecurity [26].

Furthermore, if we were to focus on a valuation method [73], we would encounter the issue that experiences cannot be reduced to mere satisfaction (the present day) because natural value also possesses undesirable aspects [74] associated with its decline and depletion. However, hydric potential also requires the inclusion of the "risk potential" of natural disasters and justifies the notion of "insurance" (to depletion). Additionally, including time in economic theory requires the separate treatment of the time dispositions of the entrepreneur [75] if all market participants have homogenous expectations, are rational and risk-averse, and cannot influence prices [76]. For example, water-rights exchange in a drier world could be framed in decision-making rather than by the "market price" and within a different field of risk considerations and benefits [73]. Then, the cryosphere as an ecosystem and water/ice storage units associated with value concerns (Table 3) enter the water security context. This approach has been the protective framework for glacial/periglacial environments (Art. 15, Law No. 26,639) in Argentina and the predicament behind the Glacial Protection Law Project in Chile (Art. 1, Bulletin No. 11.876-12) but they still neglect methods to derive a transversal valuation frame for future scenarios.

### *4.2. Shortcomings in Policy Development*

Natural value appraisals usually face scale incompatibility when assessing water security (hydric resource-related risks), falling short when assessing overlapping dimensions in one object. This methodological challenge implies that there is no standard measure for accumulative knowledge, as comparisons may not follow fixed, definitive rules [77]. For example, value appraisal deals with analytical incommensurability because management options (transforming value) (i) cannot be compared, (ii) lack a particular scale, or (iii) the scaling procedure is sub-optimal [78]. For example, one option is guiding decision-making processes through a cross-scale approach that serves the best interests of all those in the river basin regarding transaction costs [79] at a hydrological-scale focus (an oversized spatial scale). Incorporating transaction costs could bring about commonly ignored issues by basing policy instruments on practices or some other easily observable factor [80].

However, the problem is that empirical analyses for baselines and impacts often misvalue such transactions when value is only a term that reflects a subject's ranking of goods [73] to a permissible level of needs [74] and a determined degree of supply as "welfare". In this sense, a non-static baseline would require the inclusion of a "permissible" timescale of appreciation and utilization within the temporal grasp of utility and containment of landscape value.

Another problem is how current legislation evaluates components, organization, and perceptions of permanence and change [81] without accepting landscape stability [82]. Stability is brought by the naivety of impermanence, not including internal processes (and depletion) of hydric potential within the landscape. Therefore, the protection of natural value can be interpreted from its nested causalities (of all overlapping dimensions) embedded in an evolving organization. For example, a RAMSAR marshland's lifespan includes several generational cycles of biological renewal while constituting a hydrological element affecting runoff and aquifer recharge.

The temporal scale issue is evident when considering that a system's evolution is also an evolution of its use. To maintain mountain landscapes as aesthetically attractive, land managers and policymakers must cope with both present landscape transformations and the effects of former land-use changes [7]. However, this is also an issue dealing with analytical incommensurability, as management options (transforming value) (i) cannot be compared, (ii) lack a particular scale, or (iii) the scaling procedure is sub-optimal [78]. This issue also coincides with the fact that expectations cannot be adequately expressed as a single end but only as a hierarchy of ends [83].

When risk and adaptation appraisals positively and significantly impact residents' intention to adopt climate change adaptation behaviors [84], then there might be adequate management timescales and valuation deadlines to project sustainability values [85]. Otherwise, a loss of future income could reflect monetary value: a price [86] carrying "conserving effects" as an amplified signal of scarcity and hence a higher value. Only after landscapes "emerge" is their value proposed (following a hierarchical, reference-based prioritization) and can assessments approach potential impacts. The difficulty in assessing such environments is that sometimes cryosphere elements lie outside legal definitions (Water Code of Law or specific laws) and are not "familiar" to the remaining off-surface elements (interstitial, segregation or ground ice, and glacial covered ice) [87]. The update on what (cryosphere) landscapes contain often requires hydrogeological and geophysical assessments/surveys, long-term monitoring, etc.

The previous examples represent utilitarian measures (resource optimization) seeking to maximize the welfare obtained from instrumental (water supply) and non-instrumental (e.g., scenic features) values. Nevertheless, natural areas' citizen appraisal (Figure 2) is often landscape as viewshed units or ensembles of primarily visual (surface) information. In contrast, we may approach landscapes as the integration of the different processes exhibited in Table 2. Therefore, we refer to the landscape as the retrieval of mountain cryosphere representative settings, not only a hydrogeological or technical aspect in the ecosystem service perspective (provision services). Seeking more functional protective strategies behind concepts such as landscape balance (*Landschaftshaushalt*) [88] requires scale compatibility to be the leading element in assessing landscape as a unified (ecosystem) service implemented at any order of magnitude. In that case, the association of landscape elements (cryosphere units and services) requires a common ground with the desired integrity (aspects to be preserved), for which baselines change in accordance with the available knowledge, following the previous analysis by M. Bütler [8].

## 5. Conclusions

Mountain cryosphere landscapes are protected under legislation that aims at management designs that lack depletion timescales as an account of their evolution. Therefore, the value appraisal of environmental elements often uses inappropriate or inconclusive scales of analyses constrained by pretensions of totality in their assessments.

In mountain cryosphere regions, environmental impact assessment strategies have overlooked the complexity of hydrological elements constituting landscapes, which are also bound to visual quality, uniqueness, and cultural values. Since cryosphere landscapes reflect different levels of human appropriation and value production, they are inevitably bound to management options. For the specific case of cryosphere landscapes, an overestimated spatial scale for protection often complies with the need to protect aquifers and hydrological connections between the surface and the subsurface more than for merely scenic protection (viewshed). Hence, legislation on the mountain cryosphere's long-term evolution is conceptually insufficient; consequently, its interpretation of freshwater supply resilience to depletion is equivocal and, therefore, has derived natural value.

A more functional framework requires a common ground with the desired integrity (aspects to be preserved), in which baselines change following the available knowledge. This means approaching nested analytical units able to grasp either process foci or purpose foci. For instance, links between spatial (character and scenic value) and functional (hydrological supply) protective approaches deliver an understanding that can resolve the purpose of preserving the same asset but through different strategies connecting "different" nested subunits within the same landscape unit. This approach requires that scale compatibility for resource use and protection be addressed beforehand to avoid legislative contradictions (conservation/exploitation) and seek efficiency (costs) and complementarity (representativity) instead.

For mountain cryosphere landscapes representing supply and subjective value, if sustainable development fails to overcome current assessments simplifying hydrological structures and water supply evolution, the feasibility of an adequate water management design for landscape conservation will be lost.

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## References

1. Bakker, K. Water security: Research challenges and opportunities. *Science* **2012**, *337*, 914–915.
2. Cook, C.; Bakker, K. Water security: Debating an emerging paradigm. *Glob. Environ. Change* **2012**, *22*, 94–102.
3. Nordstrom, K.F. Intrinsic value and landscape evaluation. *Geogr. Rev.* **1993**, *83*, 473–476.
4. Otero Pastor, I.; Martínez, M.A.C.; Canalejoa, A.E.; Mariño, P.E. Landscape evaluation: Comparison of evaluation methods in a region of Spain. *J. Environ. Manage.* **2007**, *85*, 204–214.
5. Lliboutry, L.; Corte, A.E. Glaciers of South America: Glaciers of Chile and Argentina. In *US Geological Survey Professional Paper*; U.S. Geological Survey, Information Services: Denver, CO, USA, 1998.
6. Tol, R.S.J. Comment on "Valuing or pricing natural and environmental resources" by Yaoqi Zhang and Yiqing Li, Environmental Science and Policy, 8, 189–190. *Environ. Sci. Policy* **2005**, *8*, 187–188.
7. Schirpke, U.; Timmermann, F.; Tappeiner, U.; Tasser, E. Cultural ecosystem services of mountain regions: Modelling the aesthetic value. *Ecol. Indic.* **2016**, *69*, 78–90. https://doi.org/10.1016/j.ecolind.2016.04.001.
8. Bütler, M. *Glaciers–Objects of Law and International Treaties. Alpine Space—Man & Environment*; Innsbruck University Press: Innsbruck, Austria, 2007; p. 19–31.
9. Su, B.; Xiao, C.; Chen, D.; Qin, D.; Ding, Y. Cryosphere services and human well-being. *Sustainability* **2019**, *11*, 4365.
10. Dussaillant, I.; Berthier, E.; Brun, F.; Masiokas, M.; Hugonnet, R.; Favier, V.; Rabatel, A.; Pitte, P.; Ruiz, L. Two decades of glacier mass loss along the Andes. *Nat. Geosci.* **2019**, *12*, 802–808.
11. Gagné, K.; Rasmussen, M.B.; Orlove, B. Glaciers and society: Attributions, perceptions, and valuations. *Wiley Interdiscip. Rev. Clim. Change* **2014**, *5*, 793–808.
12. Mill, J.S. *Principles of Political Economy*; Riley, J., Ed.; Oxford University Press: New York, NY, USA, 1994.
13. Therme, T. Les services d'usage indirect fournis par les écosystèmes marins et côtiers: L'exemple de la Guadeloupe (Indirect use services provided by marine and coastal ecosystems: The example of Guadeloupe). *Études Caribéennes* **2014**. https://doi.org/10.4000/etudescaribeennes.6790.
14. Cook, D.; Malinauskaite, L.; Davíðsdóttir, B.; Ögmundardóttir, H. Co-production processes underpinning the ecosystem services of glaciers and adaptive management in the era of climate change. *Ecosyst. Serv.* **2021**, *50*, 101342.
15. Norberg, J.; Blenckner, T.; Cornell, S.E.; Petchey, O.L.; Hillebrand, H. Failures to disagree are essential for environmental science to effectively influence policy development. *Ecol. Lett.* **2021**, *25*, 1075–1093.
16. Iribarren Anacona, P.I.; Kinney, J.; Schaefer, M.; Harrison, S.; Wilson, R.; Segovia, A.; Mazzorana, B.; Guerra, F.; Farías, D.; Reynolds, J.M.; et al. Glacier protection laws: Potential conflicts in managing glacial hazards and adapting to climate change. *Ambio* **2018**, *47*, 835–845. https://doi.org/10.1007/s13280-018-1043-x.
17. Funtowicz, S.O.; Ravetz, J.R. The worth of a songbird: Ecological economics as a post-normal science. *Ecol. Econ.* **1994**, *10*, 197–207.
18. Bertazzo, S. Los acuíferos y las aguas subterráneas en el Derecho internacional público (Aquifers and groundwater in public international law). *Rev. Derecho Adm. Econ.* **2019**, *27*, 41–66.
19. Kollmair. M.; Gurung, G.S.; Hurni, K.; Maselli, D. Mountains: Special places to be protected? An analysis of worldwide nature conservation efforts in mountains. *Int. J. Biodivers. Sci. Manag.* **2005**, *1*, 181–189.
20. Hock, R.; Rasul, G.; Adler, C.; Cáceres, B.; Gruber, S.; Hirabayashi, Y.; Jackson, M.; Kääb, A.; Kang, S.; Kutuzov, S.; et al. High Mountain Areas. In *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*; Cineca: Casalecchio di Reno, Italy, 2019.
21. Arenson, L.U.; Harrington, J.S.; Koenig, C.E.M.; Wainstein, P.A. Mountain Permafrost Hydrology—A Practical Review Following Studies from the Andes. *Geosciences* **2022**, *12*, 48.
22. Navarro, G.; MacDonell, S.; Valois, R. A conceptual hydrological model of semiarid Andean headwater systems in Chile. *Prog. Phys. Geogr. Earth Environ.* **2023**, 03091333221147649. https://doi.org/10.1177/03091333221147649.
23. Council of Europe. European landscape convention. *Eur. Treaty Ser.* **2000**, *176*, 1–7.
24. Barnett, T.P.; Adam, J.C.; Lettenmaier, D.P. Potential impacts of a warming climate on water availability in snow-dominated regions. *Nature* **2005**, *438*, 303–309.
25. UN Department of Economic and Social Affairs. *World Population Prospects: The 2012 Revision*; Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat: New York, NY, USA, 2013; Volume 18, pp. 620–626.
26. Wutich, A. Water insecurity: An agenda for research and call to action for human biology. *Am. J. Hum. Biol.* **2020**, *32*, e23345.
27. Mancosu, N.; Snyder, R.L.; Kyriakakis, G.; Spano, D. Water Scarcity and Future Challenges for Food Production. *Water* **2015**, *7*, 975. https://doi.org/10.3390/w7030975.
28. Trombotto Liaudat, D.; Bottegal, E. Recent evolution of the active layer in the Morenas Coloradas rock glacier, Central Andes, Mendoza, Argentina and its relation with kinematics. *Cuad. Investig. Geogr. Geogr. Res. Lett.* **2020**, *46*, 159–185.

29. Trombotto, D.; Borzotta, E. Indicators of present global warming through changes in active layer-thickness, estimation of thermal diffusivity and geomorphological observations in the Morenas Coloradas rockglacier, Central Andes of Mendoza, Argentina. *Cold Reg. Sci. Technol.* **2009**, *55*, 321–330. https://doi.org/10.1016/j.coldregions.2008.08.009.
30. Ruiz Pereira, S.; Marquardt, C.; Beriain, E.; Lambert, F. Permafrost evolution in a mountain catchment near Santiago de Chile. *J. South Am. Earth Sci.* **2021**, *109*, 103293.
31. Obu, J.; Westermann, S.; Kääb, A.; Bartsch, A. Ground Temperature Map, 2000–2016, Andes, New Zealand and East African Plateau Permafrost. University of Oslo 2019. Available online: https://doi.org/10.1594/PANGAEA.905512 (accessed on 19 February 2023).
32. Gruber, S. Derivation and analysis of a high-resolution estimate of global permafrost zonation. *Cryosphere* **2012**, *6*, 221–233. https://doi.org/10.5194/tc-6-221-2012.
33. Frans, C.; Istanbulluoglu, E.; Lettenmaier, D.P.; Naz, B.S.; Clarke, G.K.C.; Condom, T.; Burns, P.; Nolin, A.W. Predicting glaciohydrologic change in the headwaters of the Zongo River, Cordillera Real, Bolivia. *Water Resour. Res.* **2015**, *51*, 9029–9052.
34. Polk, M.H.; Young, K.R.; Baraer, M.; Mark, B.G.; McKenzie, J.M.; Bury, J.; Carey, M. Exploring hydrologic connections between tropical mountain wetlands and glacier recession in Peru's Cordillera Blanca. *Appl. Geogr.* **2017**, *78*, 94–103.
35. Bown, F.; Rivera, A.; Acuña, C. Recent glacier variations at the Aconcagua basin, central Chilean Andes. *Ann. Glaciol.* **2008**, *48*, 43–48. https://doi.org/10.3189/172756408784700572.
36. Ruiz Pereira, S.; Veettil, B.K. Glacier decline in the Central Andes (33° S): Context and magnitude from satellite and historical data. *J. South Am. Earth Sci.* **2019**, *94*, 102249.
37. Ragettli, S.; Immerzeel, W.W.; Pellicciotti, F. Contrasting climate change impact on river flows from high-altitude catchments in the Himalayan and Andes Mountains. *Proc. Natl. Acad. Sci. USA* **2016**, *113*, 9222–9227.
38. Boisier, J.P.; Alvarez-Garretón, C.; Cordero, R.R.; Damiani, A.; Gallardo, L.; Garreaud, R.D.; Lambert, F.; Ramallo, C.; Rojas, M.; Rondanelli, R. Anthropogenic drying in central-southern Chile evidenced by long-term observations and climate model simulations. *Elem. Sci. Anthr.* **2018**, *6*, 74.
39. Bozkurt, D.; Rojas, M.; Boisier, J.P.; Valdivieso, J. Projected hydroclimate changes over Andean basins in central Chile from downscaled CMIP5 models under the low and high emission scenarios. *Clim. Change* **2018**, *150*, 131–147. https://doi.org/10.1007/s10584-018-2246-7.
40. Alvarez-Garreton, C.; Boisier, J.P.; Garreaud, R.; Seibert, J.; Vis, M. Progressive water deficits during multiyear droughts in basins with long hydrological memory in Chile. *Hydrol. Earth Syst. Sci.* **2021**, *25*, 429–446.
41. Baraer, M.; Mark, B.G.; McKenzie, J.M.; Condom, T.; Bury, J.; Huh, K.-I.; Portocarrero, C.; Gómez, J.; Rathay, S. Glacier recession and water resources in Peru's Cordillera Blanca. *J. Glaciol.* **2012**, *58*, 134–150.
42. Musselman, K.N.; Clark, M.P.; Liu, C.; Ikeda, K.; Rasmussen, R. Slower snowmelt in a warmer world. *Nat. Clim. Change* **2017**, *7*, 214–219.
43. Condon, L.E.; Atchley, A.L.; Maxwell, R.M. Evapotranspiration depletes groundwater under warming over the contiguous United States. *Nat. Commun.* **2020**, *11*, 1–8.
44. Keys, P.W.; Porkka, M.; Wang-Erlandsson, L.; Fetzer, I.; Gleeson, T.; Gordon, L.J. Invisible water security: Moisture recycling and water resilience. *Water Secur.* **2019**, *8*, 100046.
45. Cuthbert, M.O.; Gleeson, T.; Moosdorf, N.; Befus, K.M.; Schneider, A.; Hartmann, J.; Lehner, B. Global patterns and dynamics of climate–groundwater interactions. *Nat. Clim. Change* **2019**, *9*, 137–141.
46. Cuthbert, M.O.; Taylor, R.G.; Favreau, G.; Todd, M.C.; Shamsudduha, M.; Villholth, K.G.; MacDonald, A.M.; Scanlon, B.R.; Kotchoni, D.O.V.; Vouillamoz, J.-M.; et al. Observed controls on resilience of groundwater to climate variability in sub-Saharan Africa. *Nature* **2019**, *572*, 230–234.
47. Gleeson, T.; Befus, K.M.; Jasechko, S.; Luijendijk, E.; Cardenas, M.B. The global volume and distribution of modern groundwater. *Nat. Geosci.* **2016**, *9*, 161–167.
48. Halla, C.; Blöthe, J.H.; Baldis, C.T.; Liaudat, D.T.; Hilbich, C.; Hauck, C.; Schrott, L. Ice content and interannual water storage changes of an active rock glacier in the dry Andes of Argentina. *Cryosphere* **2021**, *15*, 1187–1213.
49. Van Lanen, H.A.J.; Wanders, N.; Tallaksen, L.M.; van Loon, A.F. Hydrological drought across the world: Impact of climate and physical catchment structure. *Hydrol. Earth Syst. Sci. Discuss.* **2012**, *9*, 12145–12192.
50. Grenier, C.; Régnier, D.; Mouche, E.; Benabderrahmane, H.; Costard, F.; Davy, P. Impact of permafrost development on groundwater flow patterns: A numerical study considering freezing cycles on a two-dimensional vertical cut through a generic riverplain system. *Hydrogeol. J.* **2013**, *21*, 257–270. https://doi.org/10.1007/s10040-012-0909-4.
51. Cox, J. Finding a place for glaciers within environmental law: An analysis of ambiguous legislation and impractical common law. *Appeal Rev. Curr. L L Reform* **2016**, *21*, 21.
52. Langsdorf, S.; Löschke, S.; Möller, V.; Okem, A.; Officer, S.; Rama, B. *Climate Change 2022 Impacts, Adaptation and Vulnerability Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 2022*; Cambridge University Press: Cambridge, UK, 2022
53. Nino, F.S. *Sustainable Development Goals—United Nations*; United Nations Sustainable Development: Incheon, Republic of Korea, 2015.
54. Saito, K.; Trombotto Liaudat, D.; Yoshikawa, K.; Mori, J.; Sone, T.; Marchenko, S.; Romanovsky, V.; Walsh, J.; Hendricks, A.; Bottegal, E. Late Quaternary Permafrost Distributions Downscaled for South America: Examinations of GCM-based Maps with Observations. *Permafr. Periglac. Process.* **2016**, *27*, 43–55.
55. Ballantyne, C.K. Paraglacial geomorphology. *Q Sci. Rev.* **2002**, *21*, 1935–2017.

56. Sauer, C. The morphology of landscape. *Univ. Calif. Publ. Geogr.* **1963**, *2*, 19–54.
57. Ruiz Pereira, S.F. *Hydrological Role of Frozen Grounds near Santiago de Chile*; Instituto de Geografía, Pontificia Universidad Católica de Chile, Santiago, Chile, 2021.
58. Sjöberg, Y.; Jan, A.; Painter, S.L.; Coon, E.T.; Carey, M.P.; O'Donnell, J.A.; Koch, J.C. Permafrost promotes shallow groundwater flow and warmer headwater streams. *Water Resour. Res.* **2021**, *57*, e2020WR027463.
59. Pereira, S.R.; Fernández, J.; Herrera, J.; Olea, J. Assessment of landscape transformation in protected areas. *Environ. Impact Assess. Rev.* **2021**, *86*, 106472. https://doi.org/10.1016/j.eiar.2020.106472.
60. Óskarsdóttir, A.V. *Náttúruvernd, Hvítbók um Löggjöf til Verndar Náttúru Íslands* (Nature Conservation, White Book on Legislation for the Protection of Nature in Iceland); Umhverfisráðuneytið (Ministry of the Environment), Reykjavík, Iceland, 2011.
61. Trombotto, D.; Buk, E.; Hernández, J. Rock glaciers in the southern central Andes (approx. 33–34 S), Cordillera Frontal, Mendoza, Argentina. *Bamb. Geogr. Schr.* **1999**, *19*, 145–173.
62. Heritage, S.N. *Siting and Designing Wind Farms in the Landscape*; Scotland's Nature Agency, Inverness, Scotland, UK, 2017.
63. Washington, H.; Gomez-Baggethun, E.; Piccolo, J.J.; Kopnina, H.; Alberro, H. Harmony in Conservation. *Conservation* **2022**, *2*, 682–693.
64. Krutilla, J.V. Conservation reconsidered. *Am. Econ. Rev.* **1967**, *57*, 777–786.
65. Lynn, M. Scarcity effects on value: A quantitative review of the commodity theory literature. *Psychol. Mark.* **1991**, *8*, 43–57.
66. Batabyal, A.A.; Kahn, J.R.; O'Neill, R.V. On the scarcity value of ecosystem services. *J. Environ. Econ. Manage.* **2003**, *46*, 334–352.
67. Jansson, P.; Hock, R.; Schneider, T. The concept of glacier storage: A review. *J. Hydrol.* **2003**, *282*, 116–129.
68. Bense, V.F.; Kooi, H.; Ferguson, G.; Read, T. Permafrost degradation as a control on hydrogeological regime shifts in a warming climate. *J. Geophys. Res. Earth Surf.* **2012**, *117, F3*. https://doi.org/10.1029/2011JF002143.
69. Trombotto-Liaudat, D.; Sileo, N.; Dapeña, C. Periglacial water paths within a rock glacier-dominated catchment in the Stepanek area, Central Andes, Mendoza, Argentina. *Permafr. Periglac. Process.* **2020**, *31*, 311–323.
70. Haase, G.; Richter, H. Current trends in landscape research. *GeoJournal* **1983**, *7*, 107–119.
71. Bauduceau, N.; Berry, P.; Cecchi, C.; Elmqvist, T.; Fernandez, M.; Hartig, T.; Krull, W.; Mayerhofer, E.; Sandra, N.; Noring, L.; et al. *Towards an EU Research and Innovation Policy Agenda for Nature-Based Solutions & Re-Naturing Cities: Final Report of the Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities'*; Publications Office of the European Union: Brussels, Belgium 2015.
72. Baumgärtner, S.; Strunz, S. The economic insurance value of ecosystem resilience. *Ecol. Econ.* **2014**, *101*, 21–32.
73. Olbrich, M.; Quill, T.; Rapp, D.J. Business valuation inspired by the Austrian school. *J. Bus. Valuat. Econ. Loss Anal.* **2015**, *10*, 1–43.
74. Anderson, E. *Value in Ethics and Economics*; Harvard University Press: Cambridge, MA, USA, 1995.
75. Morgenstern, O. Das Zeitmoment in der Wertlehre. *Z. Natl.* **1934**, *5*, 433–458.
76. Quaas, M.; Baumgärtner, S.; De Lara, M. Insurance value of natural capital. *Ecol. Econ.* **2019**, *165*, 106388.
77. Sankey, H.; Hoyningen-Huene, P. Introduction: Incommensurability and related matters. *Boston Stud. Philos. Sci.* **2001**, *216*, 7–34.
78. Adler, M. Law and Imcommensurability: Introduction. *U. Pa. L. Rev.* **1997**, *146*, 1169.
79. Perry, J.; Easter, K.W. Resolving the scale incompatibility dilemma in river basin management. *Water Resour. Res.* **2004**, *40*. https://doi.org/10.1029/2003WR002882.
80. McCann, L. Transaction costs and environmental policy design. *Ecol. Econ.* **2013**, *88*, 253–262.
81. Green, N. Looking at the Landscape: Class Formation and the Visual. In *The Anthropology of Landscape: Perspective on Place and Space*; Hirsch, E., O'Hanlon, M., Eds.; Clarendon Press: Oxford, UK, 1995; pp. 31–42.
82. Bailey, D.W. *Impermanence and Flux in the Landscape of Early Agricultural South Eastern Europe*; Oxbow: Oxford, UK, 1997.
83. Hayek, F.A. *The Road to Serfdom*, 2nd ed.; Routledge: Abingdon, UK, 2001.
84. Xue, M.; Zhao, Y.; Wang, Z.; Zhang, B. Behavioural determinants of an individual's intention to adapt to climate change: Both internal and external perspectives. *Environ. Impact Assess. Rev.* **2021**, *91*, 106672. https://doi.org/10.1016/j.eiar.2021.106672.
85. Phillips, J. The Sustainability Dynamics Framework—A holistic approach to define and evaluate sustainability and unsustainability in the Anthropocene. *Environ. Impact Assess. Rev.* **2020**, *84*, 106436. https://doi.org/10.1016/j.eiar.2020.106436.
86. Rothbard, M.N. *For a New Liberty: The Libertarian Manifesto*; Ludwig von Mises Institute: Auburn, AL, USA, 2006.
87. Trombotto Liaudat, D.; Wainstein, P.; Arenson, L.U. *Guía Terminológica de la Geocriología Sudamericana*; Vazquez Mazzini: Buenos Aires, Argentina, 2014.
88. Volk, M.; Steinhardt, U. Landscape balance. In *Landscape Balance and Landscape Assessment*; Springer: Berlin/Heidelberg, Germany, 2001; pp. 163–202.