

**ADAPTING TO SHRINKING ANDEAN GLACIERS.
SCIENCE, POLICY AND SOCIETY IN POWER GAMES**
(Draft background paper)

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1. Introduction

This paper is an invitation to policy makers, scientists and science funding agencies to rethink their view of the science-policy interface in favor of glaciers protection. Having identified the risks being faced by glaciers, the paper presents some of the ecosystem services they provide as arguments for their conservation. It examines diverse approaches to glacier protection, drawing lesson from different cases. The analysis shows that, when informing policy making, scientists became part of turbulent social processes marked by power struggles between actors and interests. From this perspective, an effective science-policy interface requires a broader conception of research uptake and calls for renewed roles for scientists, policy makers and funding agencies.

2. Impact of climate change in Andeans glaciers, snow and ice.

The components of the Earth system in the frozen state are called cryosphere. It comprises snow, river and lake ice; sea ice; ice sheets, ice shelves, glaciers and ice caps, and frozen ground. (Vaughan et al, 2013:321). Glaciers form when climate conditions and topographic characteristics allow snow fallen in high altitudes to compress into ice masses. Snow should be able to accumulate over long periods for a glacier to be formed; however, they move imperceptibly downhill under gravity. Glaciers melt in lower and warmer areas as processes of ablation are stronger than accumulation, with subsequent runoff. Mass balance is directly linked to atmospheric conditions and is modified by topography (e.g., due to shading). Wind and avalanches re-distributing snow can contribute to accumulation or ablation.

Close to the melting point, glaciers are sensitive to changes in climate, especially temperature and precipitations. Global warming is especially pronounced at high altitudes (reference), and glaciers react with changes in length, area, volume and mass. Glaciers respond differently according to their characteristics, such as size, slope, elevation range, distribution of area/elevation, and its surface characteristics (e.g., the amount of debris cover). External factors such as nearby topography and the climatic regime also influence their transformation. These factors determine differences in changes from region to region but also among glaciers that are spatially close.

In spite of a variability related to different response times and local conditions, annually measured glacier terminus fluctuations from about 500 glaciers worldwide (WGMS, 2008) show a consistent trend in length reduction, which is confirmed by more regionally focused analyses. For the extratropical South America Andean glaciers, between ca. 17° and 55°S (Desert Andes, the Andes of central Chile and Argentina, and the North and South Patagonian Andes) Masiokas et al (2009) recognize a general pattern of glacier recession and significant ice mass losses. *[Add evidence from Lopez et al, 2010]*. Similar generalized observations have been made on glacier areas. The analysis of a large number of published studies on worldwide glacier area changes since IPCC AR4 reveal that total glacier area has decreased in all regions, especially in the recent past. The low latitudes,

including the tropical Andes, are identified among the areas with the highest loss rates (Vaughan et al, 2013:338). Glaciers volume and mass budgets are consistent with length and area observed changes. [Add evidence] almost all glaciers in the tropical Andes have been shrinking rapidly since the 1980s (Rabassa, 2009; Rabatel et al., 2013; Jiménez Cisneros et al, 2014: 236). Disappearing glaciers have been reported in the Andes...; Patagonia... Bolivia [references].

Glaciers respond to climate change, but their reaction is not immediate. The changes observed today are reactions to climatic changes in the past. It may take decades before they adjust in length, area, volume and mass balance to a temperature stimulus, reduce precipitations or changes in the Equilibrium Line Altitude (ELA). As glaciers are not in balance with the current climate, it is expected that they will continue to adjust in the future, especially in the case of bigger glaciers that have longer response times.

Projections for the 21st century (IPCC WGI AR5, Chapter 13) show continued mass loss from glaciers (Jiménez Cisneros et al, 2014: 243) but particular local situations are also expected.

3. The value of glaciers

Human well-being depends on the benefits that nature provides, as people's lives depend on ecosystem-based processes necessary to the creation of the products we use every day. These benefits that nature provides to people are called ecosystem services, "services" meaning that they are of value to someone.

The concept of ecosystem services has been used in the scientific field since the late 90's (Daily, 1997; de Groot et al., 2002), but its use extended to communities of policy makers, practitioners and decision makers in 2005, when the Millennium Ecosystem Assessment was published. The concept was well received by the non-scientific community because it offers a straightforward way to think about the complex interrelations between nature and society. When linking the capacity of nature to capture, accumulate, store and release water to everyday situations such as the wine we drink and the wellbeing while sitting in the shade of a tree on a hot day, for instance, the idea of ecosystem services reminds us about the true origin of the products and goods we use in every-day life. The concept also makes evident that human decisions and actions have an impact on nature that will ultimately affect the availability of the resources we use, eventually forcing us to find sometimes costly alternatives for what nature could otherwise provide to us. The relations between ecosystem process, services, and goods is complex, and every human action involves trade-off not easy to assess; still, the idea of ecosystem services is useful to showcase the need to conserve ecosystems and encourages more informed decisions across a wide range of human activities and sectors.

As a major mountain range with significant altitudinal gradients stretching along all latitudes, the Andes comprise several ecosystems and provide different types of ecosystem goods and services that form the basis for human security, basic material for good life, health, good social relations and freedom of choice and action of people:

- Provisioning services such as water, raw materials for construction and fuel including wood from wild and cultivated plant species, food from different types of agricultural systems, medicinal resources and energy. The provision of water is one of the most outstanding ecosystem services

and one to which glaciers relate directly. The Andes have been defined as a “natural water tower” capable of collecting, storing and distributing water from rain and melting snow (Messerli and Ives 1997; Viviroli et al. 2007, Vitale 1941). In the context of hydrology, the water tower image is used for mountain areas that supply disproportional runoff as compared to the adjacent lowland area. The water is used for human consumption, irrigation, industry and hydropower generation activities taking place in the mountainous regions, foothills and lower and flatter lands. Mountain slopes are places where aquifers recharge. This is of special importance in drylands where lowland surface water supply-demand gaps are filled by pumping, as in the Eastern and Western slopes of the central dry Andes. There are still many gaps of knowledge on ecosystem services related to mountain hydrology under climate change. Still, the hydrological highland-lowland linkages clearly show the role that mountain areas have in supporting downstream. The cryosphere is considered a key element for water provision.

- The Andes provide regulating services, contributing to regional and local climate regulation and air quality. Andean forests store and sequester greenhouse gases; healthy Andean ecosystems minimize extreme weather events and dampen environmental disturbances and natural hazards such as storms, avalanches, landslides and floods, reducing their impacts. Trees stabilize slopes of abrupt topographies; vegetation cover prevents soil erosion causing land degradation and desertification, especially in sloping areas; wetlands can soak up flood water. *[Andean examples, references]*

- The Andes also provide plenty nonmaterial benefits related to culture. Andean indigenous communities' lifestyles and knowledge systems are highly linked to ecosystems, and their spiritual and religious values are often incarnated in nature. Beyond the indigenous communities there is a diversity of social groups that nurture their inspiration, aesthetic values, social relations, sense of place and cultural heritage values in the Andean nature. Recreational and touristic sectors also make use of these cultural ecosystem services. *[Andean examples, references]*

- Finally, these ecosystem services are made possible by supporting ecosystem services related to production of atmospheric oxygen, nutrient cycling, soil formation, biomass production, and provisioning of habitat.

Ecosystem services have been extensively studied, although the mountainous regions have been approached from this perspective much later (references). Even rarer are studies of ecosystem services provided by the cryosphere, particularly by glaciers (references). It is not the intention here to save this gap, but to take inspiration from this way of understanding the relationship between society and nature to highlight the value of the glaciers in search of arguments for conservation. Beyond their intrinsic value, we are interested in highlighting the glacier's contribution to human welfare and the risks that they are facing. From a variety of ecosystem services provided by glaciers, we will focus on those whose benefits are more direct and immediate, and those being currently threatened by human activity taking place on a global and local level. This is fertile ground to examine the science-policy interface built around glaciers conservation.

Adding to snowmelt, glaciers contribute to water supply, their contribution to runoff varying according to regions, type of glaciers, and seasonal, annual and longer term variabilities, among other factors. They accumulate, retain and store water that will be used for human consumption,

agriculture, industrial and recreational uses downstream. Providing to water availability, glaciers are key elements in facing the “water supply crises”, one of the top five global risks identified by the 2013 World Economic Forum (reference). Soruco et al (2015) estimated that a 15% of the annual supply of water to La Paz city, Bolivia, between 1963 and 2006 originated in the 70 glaciers located within the drainage basins of La Paz. Two million people living in Quito city, Ecuador also depend on the Antizana and Cotopaxi glaciers supplying a significant fraction of the city’s water supply (Bartolone, 2006). Glacial contributions are also relevant to hydropower production in the tropical Andes, which accounts for approximately 71% of electricity generation in Colombia, 49% in Ecuador, 32% in Bolivia and 56% of energy in Peru (World Bank, 2010).

Glaciers are not only a source of water but - more importantly - they provide a water regulation service, as they contribute to the maintenance of ‘normal’ streamflow by buffering the low extremes in discharge of rivers. This glacier compensation effect (Lang, 1986) is important in drylands and regions with little summer precipitation, where meltwater from the ice is released when other sources such as snowmelt are depleted. The share of glacial water supplying La Paz shows strong seasonality. The contribution of 14% in the wet season is doubled to 28% in the dry one. Andean rivers are used for hydropower production, often competing with agricultural water uses, and are sensible to dry season shortage flows. Is the case in Peru, with an energy matrix highly dependent on hydropower (70%) (reference). In cases where there are no dams to regulate flow variability, glacial contributions are critical to ensuring power generation throughout the year. Moreover, reservoirs are useful to face water shortage problems in the short term, while glaciers contribute to increase diminished flows over several years.

Glaciers also contribute to aesthetic landscapes valued in associated with pristine natural environments. Also adding to the cultural services they provide, glaciers are part of landscapes that play an important role in traditional Andean lifestyles in which material and spiritual lives are entangled with the rhythms of the glaciers. Andean rituals include offerings made to the spirits residing in the highest mountain peaks (known as *apus*). The *apus* are mountain deities custodial of the eternal ices and snow and of the life-sustaining water. The ceremonies are conducted by *Misayoqs*, specialists in Andean rituals that are believed to possess the ability to communicate directly with the mountain spirits and natural forces (Bolin, 1998). Andean mountaintops were Inca’s shrines in which frozen mummies resulting from human sacrifices practices are being found these days found (Cerrutti, 2015). These cultural ecosystem services nourish a tourist activity that constitutes an important source of income for the highlands of the Andes.

Global and local threats to glaciers and the services they provide

Glacier hydrologic systems are among the most affected by climate change. Their global volume is projected to decrease by up to 85 per cent this century (IPCC, 2014). Locally and regionally differentiated changes in temperature, precipitation, snow-cover and glacier mass balance have repercussions in runoffs. Melting glaciers in search of a new balance cause a temporary increase in runoff that masks the underlying problem. Runoff at La Paz city between 1963 and 2006 did not change significantly despite the loss of 50% of the glacierized area, showing that increase in ice melt rates compensated for reduction in the surface area of the glaciers. (Soruco et al, 2015) But calculations that assume complete disappearance of the basin’s glaciers and no change in precipitation anticipate a runoff diminution of ~12% at an annual scale, 9% during the wet season and 24% during the dry season. Using data from Perú’s power system [Ministry of Energy and

Mines, 2005], Vergara et al (2007) estimated the impact of the reduction of glacial melt water on the power generation capacity of the Cañon del Pato hydropower plant on the Rio Santa, Peru. They conclude that a 50% reduction in glacier runoff would result in a decrease in annual power output of approximately 10% (from 1540 GWh (gigawatt hours) to 1250 GWh). Further, if glaciers melt water disappeared completely, annual power output would be reduced to 970 GWh. If the melting process is accelerate, runoff volume could increase, potentially encouraging new demands induced by this abundance of water that will not be sustained over time (Vuille, 2013).

Runoff timing is also altered. Snowmelt occurs earlier and so are river discharges in many glacial Andean rivers [*Examples from Andean cases, references*]. Agriculture and many other human activities downstream develop in sync with river discharge, and alterations in the hydrograph translate into water being abundant when demand is still low and lack of water in times of high consumption. Adaptive measures are then required, extending the supply period (e.g., building a dam) or operating on the water demand by changing to crop species or varieties that suit the new seasonality or are more resistant to variable flows. Overall, variability is to increase, making it harder water planning and preparedness for coping with extremes.

Global threats to glaciers are important for their impacts; but they are difficult to neutralize, and never in the short term. Human activities taking place locally - such as mining and tourism - have localized effects, but attract our attention because of the possibility of being managed in a way that they don't compromise glaciers conservation.

Mining impacts vary according to the different activities involved throughout projects. A first phase of prospecting and evaluation of a site includes construction of roads and land clearing areas that may alter deposit of snow or the same consolidated glaciers. Vans, trucks and heavy machinery transit raise dust. Exploration drilling requires building platforms for installing heavy equipment and drilling wells, with direct impacts in the glaciers surface or the surrounding topography. The exploitation phase brings more roads, construction of infrastructure and facilities, blasting, crushing and transportation in large trucks, with both direct and indirect impacts. Despite mitigation actions, these activities release particulate matter that is transported by the wind and deposits on snow accumulation areas or in the glaciers, darkening and increasing surfaces temperatures and favoring melting.

[3 lines describing risks from tourism]

4. Andean Countries Addressing Climate Change. Approaches to glacier conservation and lessons learned

Glaciers in natural parks conservation strategies

The early history of the protection of glaciers refers to general initiatives to protect nature. In 1940, representatives of countries of the Americas, under the USA leadership, agreed on the "Nature Protection and Wildlife Preservation in the Western Hemisphere" (Shainin, 1998) that promoted USA national park model throughout the continent. Although the mandate was focused on protecting and preserving representatives of all species and genera of native flora and fauna in their natural habitat, the committee of scientific and other experts from seventeen countries of the Americas also recognized the need to protect scenery of "extraordinary beauty, unusual and

striking geologic formations, regions and natural objects of aesthetic, historic or scientific value, and areas characterized by primitive conditions." The convention encouraged national conservation initiatives, and revitalized the attention paid to several parks that had been created before that protect cryosphere components. The binational Waterton-Glacier International Peace Park was established in 1932 by the union of the Waterton Lakes National Park in Canada and the Glacier National Park in the United States. Both parks were declared Biosphere Reserves by UNESCO and their union as a World Heritage Site. Argentina had created the The Glaciers Natural Park in 1937 (declared UNESCO World Heritage Site in 1980) preserving an extensive area of continental ice, cold forests, glaciers and glacial lakes. In Peru, the declaration of the Huascarán National Park (1975) as a World Heritage Site made by UNESCO in 1985 specifically protects 633 glaciers of this mountain range.

Except perhaps in the most recently created parks, the rationale of conservation focused on pristine or unique features or ecosystems, considered as testimonies that should be left as a legacy to future generations. Most modern parks combine conservation objectives with the development of low-impact human activities, especially those that provide for the subsistence of local communities. Parks evolve together with the concept of heritage, recognizing the culture of communities as intangible heritage and adopting an integrated view regarding preservation of the environment and sustainable development. Yet, this is a strategy feasible for relatively few selected areas.

National, provincial and even private parks are legitimate contributions to glaciers conservation, but the area that can be protected is limited, and most of the Andean glaciers remain outside them. This is precisely one of the points currently in dispute regarding the law of glaciers in Chile. The discussion is about whether the law should protect all glaciers or just those within national parks. In Chile, the most endangered glaciers are in the North of the country, where national parks are rare and where they share territory with mining reserves; in fact, some of them are within areas affected to mining concessions. Chilean environmental organizations argue that a law that does not protect glaciers outside the boundaries of national parks is absolutely insufficient. Mining interests base their arguments on the percentage of glaciers that would be protected or not. With these limitations, parks add to glaciers' conservation initiatives.

Global awareness on the value of the cryosphere

Much later, under the paradigm of sustainability and with climate change impacts already being a concern, the United Nations Conference on Environment and Development (UNCED) of 1992 places the mountains in the global environmental agenda. The "mountain agenda" became the core of 'chapter 13' of UNCED Agenda 21. Also in 1992 the UN Framework Convention on Climate Change proposed measures, mainly justified in applying the precautionary principle. Ten years later, the UN General Assembly declared 2002 as the 'International Year of Mountains', and the same year the World Summit on Sustainable Development (WSSD) at Johannesburg provided a further opportunity for world leaders to work on the implementation of the Agenda 21, which resulted in the 'Mountain Partnership', a voluntary alliance of partners dedicated to improving the lives of mountain people and protecting mountain environments around the world. In 2005 'The State of Knowledge Overview of Global Change and Mountain Regions' (Huber et al, 2005) presented the challenges of mountainous areas facing global environmental change including an ecosystem services perspective and giving full attention to paleoclimatology and cryospheric research. From 1990 to these days, the IPCC assessment reports and evaluation reports have

reviewed and assessed the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of the cryosphere under climate change. [Add (UNESCO, 2006)]

These initiatives have undoubtedly proved useful to better understand the processes that explain the behavior of the cryosphere, to know about the impacts observed and to raise awareness of its value. They also provide a basis on which to build feasible conservation strategies. Not least, these initiatives are necessary to generate social awareness levels necessary to sustain conservation laws and policies. Yet, the step of decision-awareness to effective protection is a way still to go. Effective science-policy links have a key role in achieving effective protection.

The legal approach

In several countries, glaciers are protected through water laws. In Colombia, the Title 1 of the Code of Natural Resources establishes the regulation of non-maritime waters, in all its forms, specifically including mountains and glaciers (Article 77, letter h). In Ecuador, the Water Law identifies glaciers as sources of water supply.

In 2010, Argentina became the first country in the world to have a law specifically protecting glaciers. The process started in 2008, when the Congress passed a national law which was vetoed by President Cristina Kirchner shortly after. Intense debates were held in both houses of Congress, in various areas of civil society and in the media. A new text – not very different from the original - was finally approved in September 2010. The law grew out of a long political and social process that included heated debates animated by environmentalist groups, scientists, actors from the mining sector and governmental representatives joining both sides of confronting arguments.

The passage of the Law 26.639 of “Preservation of Glaciers and Periglacial Environment” was a victory celebrated by those promoting conservation, but it soon became clear that there would be many obstacles to overcome in its implementation. One of the first mandates of the law is to make a national inventory of glaciers, to be developed jointly by the National Environment Secretariat (coordination, supervision) and the scientific sector (Instituto Argentino de Nivología y Glaciología, IANIGLA) (execution). The inventory aims at identifying, characterizing and monitoring all glaciers and other components of the cryosphere acting as strategic water reserves in Argentina, identifying environmental factors governing their behavior, and establishing the hydrological relevance of these icy bodies in the Andean runoff. The information provided by the inventory is an essential tool for the identification and delimitation of protected areas. The inventory advanced, not without problems [Brief description of main problems of implementation. Source: Ricardo Villalba, IANIGLA’s director].

A second contentious moment will take place when the information issued from the inventory is applied to the identification of the areas to be protected. The concept of protecting the parts of the glacier and periglacial system that contribute to the formation of river flows is written in the law text and not in question. But conflicts are expected when this general concept takes shape in a map delimitating the areas to be protected, where mining and other activities will be banned. The scientific sector will surely be under pressure in its function to determine which components of the cryosphere contribute to runoff in each case. We can anticipate a scenario in which science, with its "objectivity" and its prestigious social position acts as mediator between mining interests and

environmental groups, while different fractions of the state simultaneously support and play for and against the interests of the actors involved in the dispute.

The inventory comprises 37 basin and 79 sub-basin distributed in 12 Argentinean provinces (<http://www.glaciaresargentinos.gob.ar/>), but while in some provinces the work is finished, in others it is delayed, particularly in those where mining is more intense. This is related to another challenge being faced by the law: local resistance to its implementation. Argentina is a federal country in which the provinces have jurisdiction on their own natural resources. The law setting mandatory minimum levels of environmental protection is resisted, especially in provinces with big mining projects making the main contribution to the local economy. Some of these provinces have prompted lawsuits before the Supreme Court to resist the application of national law. In San Juan province, where Barrick Gold has the Pascua Lama and Veladero projects, a group of companies - including Barrick -, mining unions and chambers took action against the law, and achieved in 2010 a precautionary measure that suspended the application of the law in the territory of the province. The Argentinean Supreme Court revoked it in 2012 and reestablished the application of the law (Ventura, 2012), but the link between the federal government and the autonomous provinces leaves room to question jurisdictions. Other provinces such as Jujuy are dodging the national law by enacting their own provincial standards, more permissive (Jujuy al Momento, 2015).

Argentina also provides the example of a law aiming at protecting the headwaters, but not by promoting conservation but rather by specifically banning the activities that threaten them. Law 7722 from Mendoza province was enacted in June 2007, banning the use of cyanide and other toxic substances in mining. Cyanide mining technologies were also banned in the European Union in May 2010. Mendoza is a province adjacent to San Juan, but both have taken different positions regarding the recent development of the mining sector in Argentina. Perhaps because of more abundance of mineral resources and fewer other alternatives, San Juan has made mining the centerpiece of the provincial development of the recent years. Mendoza has remained committed to the wine industry and agro-industries, which add up at revenues from an oil industry in lowlands. The sanction of the law in Mendoza responded to claims of mass demonstrations in the streets and roadblocks in rejection of mining projects that sought provincial approval [*Photos*]. These demonstrations are renewed every time there is an attempt to revoke or amend the law.

Chile is currently in the process of enacting a law to protect glaciers. The first attempt dates back to 2006, in coincidence with the approval of the Pascua-Lama mining project (Barrick Gold) that threatened glaciers in the north of the country. The initiative failed and was filed in 2007. In May 2014, a new legal text was proposed by a group of congressmen. The proposal aimed to protect all glaciers in the Chilean territory, banning mining and other activities that might affect them. This initiative was resisted by mining and geothermal companies. The office of the president issued a counterproposal on March 2015. The revised version restricts the protection to the mass of glacier ice disregarding peri-glacial environments and permafrost, is permissive with glaciers outside national parks and – as reported by social and environmental civil organizations – is ambiguous and shows gaps that could be used in stratagems and subterfuges to intervene glaciers (Gonzales, 2015). These actors consider that the 2015 version of the law is “a political gesture in favor of mining companies” (Correa, 2015). On the other part, the Chilean Mining Council and Codelco also criticizes it as “it would mean restricting mining in many basins where there are mineral

resources and concessions related to new projects or expanding of the existing one" (Portal Minero, 2015). It is a negotiation process showing entrenched positions not easily reconcilable.

It is worth noting that the Chilean context is different from the Argentinean. Mining is the second most important sector of the Chilean economy after services. In 2006, it accounted for 21% of the national GDP (reference). Chile is the largest copper producer in the world, meeting 36% of the world market (reference). In 2009-2013 mining was the main destination for foreign direct investment, with 45% of the total (reference). Private actors of the Chilean mining sector include global companies like Barrick Gold. The State also participates in the activity and the state-owned company Codelco (1976) is the largest copper company in the world. Mining actors in Chile are many and powerful, and the style of development and politics in Chile has traditionally been inspired by private entrepreneurship, competition, profitability, and the rules of free markets. There is a tradition of considering environmental regulations as barriers for economic development.

These economic and political orientations have recently shown a twist. On the one hand, the conditions of the minerals international market, especially copper, and higher domestic energy and wage costs have caused a slowdown of mining. The 21% share of mining in the Chilean GDP was reduced by half in 2011. The deactivation of the binational Pascua Lama, one of the world's largest gold and silver resources, is an example of this. Pascua Lama is an open mine exploitation of gold, silver and copper at 4,500 meters on the Argentine-Chilean border. The project has significantly revitalized the economic sectors involved while growing in the most important mining conflict in the region. The project is resisted in both Argentina and Chile for the use of cyanide for gold extraction and the possibility of contamination of glaciers in close proximity to the extraction zone. After over 10 years of exploration, the project approved its environmental impact assessment. But the low price of gold, the costs of complying with environmental regulations and the need for a mining treaty that facilitates the exploitation of a binational reservoir led Barrick to suspend construction of the mine (Liezal, 2013; Trefis Team, 2014). Meanwhile, Chilean public agendas seem to be incorporating education, health, human rights and environmental social demands that hadn't had political space previously.

The economic and social context here is not a minor issue. The relative political openness along with the Argentinean precedent may represent a window of opportunity for the values of glaciers recognized by scientists and environmental groups to be considered in a major piece of legislation. A glaciers law would have been unthinkable in Chile 10 years ago. The possibilities of scientific knowledge to influence this process are less relevant than the incidence of the context. Regional, national and subnational initiatives should pay attention to the political and economic environments in which glaciers conservation strategies are being promoted.

These experiences allow extracting some lessons on the limitations of the legal approach to glaciers conservation. The Argentine case shows that law enforcement may be resisted by judicial proceedings. Even in the case where claims of unconstitutionality are rejected, judicial procedures delay the effective application of the law or limit its scope for a long time. Unlike a law that defines a national park with precise geographical limits, the Argentinean glaciers law - like many other land-use, territory and environmental planning laws - order procedures to be carried out, launching a process. Technical studies will require coordinating a set of human, technical, material, financial and administrative resources. Technical procedures such as identifying different

levels of protection for different areas will be subject controversies and disputes between actors with conflicting interests. The sanction of the law is the beginning of a process that will suffer the vicissitudes of the political and administrative lives of the country and provinces.

Also linked to political models and the balance of power between different interests, there is the possibility that the law is not effective in assuring the conservation of a common natural good. It may be a "bad law", permissive and permeable to economic interests. To some extent, scientific knowledge can provide some "rationality" to discussions about what is good and what is not, what to do and what to forbid. But ultimately, disputes are of political nature and are settled on social power games.

There is also an issue of governance. The effectiveness of a legal strategy to protect glaciers - or any other environmental good - varies from country to country, given the various governance schemes in the countries of the Americas. Chile is a country in which a neo-liberal economic policy inspired in economic liberalization, privatization, fiscal austerity, deregulation, agent's competition and free trade, favors a primary export oriented economy ruled by competition (Carruthers 2001). With a centralized administration and predictable procedures, the legal via has more chances to achieve effective protection. Argentina has an existing law, but the federal model and the political manipulation of justice conspire on their effective implementation. To a greater or lesser extent, in these and other countries of the Americas, political tides, traffic of influences and other turbulences of the political milieu also affect the efficiency of the legal protection strategies.

Styles of development also matter, particularly when involving indigenous communities or traditional cultures. *[Describe Bolivian governance, bottom-up decision making scheme and consuetudinary laws that sometimes clash with the scientific rationales and modern administration].*

Nonetheless, the legal approach is one of the strongest bases for a regulatory strategy tackling glaciers conservation and a solid base for conservation policies.

A law does not make a policy

A law is a good basis for a policy, but not enough.

[Elaborate on the components of a policy and the role of scientists: (a) principles and arguments that support it, where scientists and global environmental institutions play an important role; (b) instruments: law, financing, administration; (c) actions or services being carried out according to the principles proposed].

["Proyecto de Adaptación al impacto del acelerado retroceso glaciar en los Andes Tropicales" (PRAA) de Bolivia, Ecuador y Perú in the Andean Community: components of the project, advances. Presentation of the initiative as a strategy based on action rather than in regulation]

Social license

In addition to legal, scientific and technical considerations, the exploitation-vs-conservation kind of decisions are built upon social acceptance. Normally, the formal institutions of the state assure the common goods being preserved and the common interest being defended. Institutional structures also channel discrepancies from those who claim for rights are not being respected. But

when social discontent is major and formal institutions fail to drive it, there are no laws or authorizations that could make a mining project viable. A mining project that does not have some level of social acceptance will be seriously questioned, probably delayed, and its costs increased.

Mining conflicts have arisen in many countries and grow global, in parallel with the globalization of the mining sector. A long history of conflicts has led to lessons learned by the mining actors. Influence exerted on policy makers and regulatory frameworks to make them more permissive can backfire in social conflicts in opposition to projects. On the other hand, communities close the exploitation sites favorable to mining projects have proven to be the best allies when it comes to channel projects through the administration. Mining companies have identified the need of establishing and maintaining a social license to operate (Boutilier and Thomson, 2009; Moffat and Zhang, 2014). Social License to Operate (LSO) refers to the acceptance of mining companies and their projects in local communities. For a LSO it is necessary to develop good relations with all stakeholders, particularly with local communities (Moffat and Zhang, 2014). The idea is to instill credibility for building acceptance and approval, and to develop trust up to achieve the highest level of psychological identification (Thomson & Boutilier (2011a and b).

As a corporate self-regulation integrated into a business model, LSO is a kind of Corporate Social Responsibility practice that has a potential in integrating social, environmental, ethical and human rights concerns into mining companies operations. The principle is legitimate, but the terms of the relationship between a global company and a local community are most unequal. The smaller, more isolated and poorer a community is, the fewer options it has for improving living conditions, and the easier it will be to obtain a social license without really meeting the high objectives announced. Moreover, stakeholders are not limited to these local communities, and LSO strategies are more difficult to implement at broader scales. The idea of social license based on consensus building is valid, but it cannot be fabricated or bought.

To sum up, natural parks work as bubbles protecting selected environments; laws lay the foundation of the rules of the game, and often constitute the backbone of policies involving other components. Mining companies make efforts to get social approval, and promise autoregulation to minimize ecological damage. All tools add to conservation purposes. But finally, decisions on the conservation of glaciers - or any other natural common good - are the expression of a particular balance of power between actors who have conflicting interests. Environmental organizations want to protect as much as possible; mining companies consider that most glaciers are expendable; scientists are concerned about objectively present the social benefits of preserving the glaciers. The state mediates, in safeguard of the common interest. It participates at various levels (national, provincial, local), in its three branches (executive, legislative, judicial) and in the various sectors (water, agriculture, energy, research, etc.), rarely with consistency between these various factions. Political leaders embody the will of the voters, but also exercise their own agendas. Public opinion has the power to remind politicians the need to fulfill its pre-election promises. Social movements are activated when the formal institutions fail to channel turbulent processes. This is the arena of glaciers protection initiatives: a complex and dynamic scenario that involves policy makers, scientists among other actors, their alliances and their hidden agendas.

5. Enhancing Science-Policy Links amidst social power games

The cases discussed suggest that links science-policy more complex than it might be supposed. First, it is not just a relationship between two actors: scientists and policymakers. It is naive to think that policies are decided just on the basis of the inputs provided by science. Especially when what is at stake is a common good, there are a number of stakeholders with legitimate interests. There are groups with specific economic interests (mining and tourism entrepreneurs) and advocates of private sector activity in general. There are also environmental groups, more or less close to progressive political groups. The state itself is an animal with multiple heads. It unfolds into various factions that sometimes contradict each other, as when the executive branch of the Argentine government vetoed a law passed by Congress or the Chilean president rejected the congressmen law project. Moreover, each actor has an agenda, and sometimes a hidden agenda as well. There are alliances and also situations which suggest that there may also be collusion. Scientists are one more voice among many others and, unlike politicians, they do not have an explicit social mandate to conduct social and political processes. Scientists can contribute to decision-making with information, analysis, scenarios and other evidence that will lead to more informed decisions; but the choice is not the scientific, and the communities of interest have the right to make the final choices as the sovereignty resides in the whole body of stakeholders. When evidence fails to influence decision, scientists feel it as a failure. But scientific inputs are not just neglected but considered alongside other 'evidence' to inform the decision. Dismissal is a particular way of uptake too. Research can offer alternative courses of action and assess their effects,. In fact, if a single scientific organization becomes too influential, it could turn into a technocracy with undue influence over public issues. (Mendizabal, 2013)

In this complex scenario, delivering a solid report to a policy maker is just a fraction of what is needed to build an influential science-policy interface. Research uptake is not always 'up'. Not all ideas flow 'upwards' to 'policymakers'. It could very well be 'sidetake' when science outcomes go to other researchers, to manuals, textbooks and think tanks (Mendizabal, 2013). It is a long term science-policy investment when it is used to build capacity in future generations of decision makers. It is 'downtake' when reaches final users, or when used to inform the public opinion.

Each society has mechanisms for the social construction of decisions, environmental and others. In all countries of the Americas the modern state provides rules and procedures at various levels that activate for this purpose. The scientific sector has a place in this process, especially in the case of policies and legislation that require technical and scientific definitions, as the ones dealing with conservation of nature. But when institutions are weak, or there are marked asymmetries between actors, too dissimilar positions and conflicts grow, processes become turbulent. This is where the reasons provided by science run major risks of getting blurred amidst the game of social powers, making research-uptake more difficult. The chances that scientific arguments are considered depend on the social and political context. Moreover, countries with major components of indigenous people or population living by traditional cultures combine modern decision making mechanisms with customary laws and informal procedures at the level of small communities, which often take precedence over scientific knowledge. Hence, the possibility of scientist to influence decision making also depends on the cultural context. So, there is also the context to be considered; and not only the political and cultural contexts, but also the style of development (i.e., rules of the global economy or values of the Mother Earth?), the economic structures and interests (i.e., how important is mining in the country/region revenues) (Crewe and Young, 2002). The incidence of the context relieves scientists from a part of the responsibility for the uptake of science, but investigators should be alert to seize the opportunities that arise, requiring part of their attention to be placed off the scientific field. There is also scientific context affecting the

motivations of researchers to pursue outreach. Some scientific systems and donors give value to the social impacts of research, while others favor performance indicators within the academic world. Worldviews are also part of the context relevant to science-policy links. Shifts in worldviews in favor of the conservation of nature are an opportunity for science to achieve greater influence in conservation decisions, as it could be the case in Chile nowadays. The initiatives of global institutions may seem abstract, but they have a tangible influence in creating contexts of willingness to change towards sustainability, in which scientific arguments take on greater weight. These changes are slow, though.

Finally, the contribution of science to policy formulation and decision-making goes beyond providing evidence. Sometimes scientific knowledge is needed to define a course of action. But often the general policy direction or decisions is matter of common knowledge (perhaps based on scientific knowledge generated in the past), and scientific evidence is necessary to implement specific measures, as in the case of the law of glaciers in Argentina. It is not just about making policy recommendations, but also about setting the agenda, helping explain a problem, spreading ideas, educating leaders, creating and maintaining spaces of debate and deliberation, developing critical thinking capacities, 'auditing' public and public institutions, etc. (Mendizabal, 2013). In countries where political elites are discredited, scientists also contribute with their social prestige in support of environmental causes. Science is associated with objectivity and method, and scientists may be asked to participate in multi-stakeholder decision making processes for providing some order or rationality to a heated discussion in a mediation action or even for legitimating the process by being there. For their part, scientists must be aware of the social capital they hold, and manage it ethically.

6. Renewed roles for policy makers, scientists and founding agencies

Such a broader view of the science-policy interface taking place in the social arena requires new roles and approaches for scientists and politicians (Mendizabal, 2013; Crewe and Young, 2002; references):

Politicians, policy makers and decision makers may fear that working with scientists limit their decisions and their ability to respond to other (non-scientific) interests. But political and scientific objectives may concur, depending on how the situation has been framed. It is a matter of opportunity, but also of policy-makers being capable framing the problem and setting the public agenda in a way that the various stakeholders find a space for joint construction, at least regarding the basics of the issues being discussed. Policy makers could enhance their transformation capacity and foster their technical capacities by calling upon science, especially when the technical capabilities of the bureaucracy not sufficient to address technical issues. Policy makers should also ask for scientific work to be carried out. Research is more likely to be useful if it is commissioned by the policy-makers themselves; it is then easier to get good feedback loops between research, policy, implementation and monitoring. Politicians could also get more out of working together with scientists if they consider that participation by all stakeholders (including researchers and the communities of interest) is crucial for sustainable policy-making (consensus, engagement, commitment) and that science gives legitimacy to political actions. Unfortunately, it can also happen that politicians take advantage of this situation to promote "scientific work" tailored to their interests.

Scientists should make an effort to produce understandable and usable science that is problem/solution oriented. For this, they may need to push-forward their scientific findings to

connect with socially relevant issues, so that their contribution would be more directly applied. The more complex the problems being addressed (such as global change issues), the more necessary it becomes to embrace interdisciplinarity to tackle them, posing a challenge for researchers as well as for funding agencies. There may even be necessary to practice transdisciplinary science, build mixed teams, and to connect traditional research with participatory methodologies. Making a decision or pushing a policy does not necessarily require full scientific information but sometimes just orientation; but it is needed quickly. Decision making can't wait for scientific timelines and researchers should be flexible to adjust to this timing, responding in the best possible way with existing knowledge, albeit incomplete or imperfect. Providing usable scientific knowledge is not the only possible contribution to policy making. Researchers can provide data sets collected, tools, approaches, methods, etc. and also make contributions as part of a multi-stakeholder process. For research uptake (or side-take, or down-take) to be successful there must be a match between what scientists can provide and what the policy demands, so not everything depends on the supply side. Time and efforts should be devoted to understand the context and get to know the actors. Who are the policy-makers? Researchers should be aware of the different actors in the policy community, their position within it and their relative influence, and let them know about the research team and the scientific work being carried out. Is there policy-maker demand? Is it a demand for knowledge, or is there another contribution needed? What are the sources/strengths of resistance? What are the opportunities and timing for input into formal processes? It is necessary also to understand the agenda setting process and get a sense of the opinion formation and decision-making timings. It is not that all scientists should develop skills to understand and interact, but different members of a research team may have different roles according to their capabilities. At some critical point of the decision-making process, there could be a need for scientists willing to play a more active role engaging directly in decision making processes. In complex political and social contexts, scientists should also be aware that the possibility of contributing to policy formulation and decision-making is opportunistic and that it may require bringing into play particular resources such as networking skills, personal relations, and bonds of trust.

For donors and scientific funding agencies this broad vision of science-policy links presented above is easier to propose than to implement. When promoting this kind of science, agencies are challenged to balance all these demands that are made to science without losing the innovative power of leading-edge science. Pressures on researchers should be handled carefully, as they are at the frontiers of the scientific field. There is resistance from researchers to get out of their comfort zone, but it is also true that interdiscipline and science-policy links are paths less traveled. Researchers learn by doing.

It is not only researchers that are subjected to new requirements. Donors and funding agencies should identify the best ways to promote interdisciplinarity and orientation towards solutions, develop new evaluation and monitoring competencies. Research uptake takes many forms, and outcomes can take time to show, making it difficult to assess.

Some limitations are related to the fact that the science-policy ties develop in the interplay of actors, and funding agencies operate only on the side of the scientific offer. Pushing science-policy too hard from the scientific side carries risks and may lead to grey zones or undesirable outcomes. For instance, in socially and politically sensitive matters, research can be better or worse received by policy-makers depending on the results found (e.g., social impact of mining in small Andean communities). Research carried out to close to powerful actors runs the risk of not being independent. Science is not always right and there could be up-take of "bad science". These

situations must be considered when asking investigators to pursue research-uptake, especially in the social sciences. Research-uptake cannot be achieved at any cost; the critical approach should be preserved and so are spaces of dissent.

There are not recipes to overcome barriers to interdisciplinary or to to systematize science-policy links. Learning is made case by case, program to program.

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