Environmental Impact Assessment in Chile, its application in the case of glaciers

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Introduction

Changes in the environmental law in Chile regarding the protection of glaciers are being analyzed. Besides the explicit incorporation of glaciers, a relevant fact is the inclusion of the obligation to establish the relationship between the physical environment and ecosystems in order to take into account the possible effects on ecosystems as a result of alterations of the physical environment. This requires to have better knowledge about the ecosystem relationships in the area of influence.

The role of glaciers as a water regulating element must have an adequate and reasonable characterization including interaction with other components within the area of influence in order to identify and quantify ecosystem relationships. Glacier contribution in the upper Mapocho river watershed is estimated through a simplified approximation and contribution change due to a permanent decrease of glacier area is preliminary quantified.

Changes in environmental regulation and glaciers

Amendments to the regulation of the environmental assessment system[1] include different elements that have a direct impact on glaciers, such as:

a) Significant alteration of natural bodies of water or watercourses, *including* glaciers, must be submitted to the Environmental Impact Assessment System (SEIA); glaciers officially identified are included in the Public Glacier Inventory[2].

b) By defining the concept "significant adverse effect on renewable natural resources" as the activity that affects the permanence of the natural resource (availability, utilization and future rational utilization), either the regenerative or renewal capacity is altered or the conditions that allow the presence and development of species and ecosystems are altered.

c) Explicit incorporation of glaciers in the definition of location and environmental value of the area. It establishes that a territory has environmental value when there is no human intervention, and also provides important environmental services to the population, or, ecosystems or natural formations are unique, rare or representative.

d) The definition of landscape value is incorporated while establishing that an area has value when it is visually perceptible and has natural attributes that assign a quality that make it unique and representative.

Likewise, touristic value definition is incorporated which establishes that this value emerges when there is a previous landscape value and a flow of visitors or tourists is generated.

e) Further specification in the development of the baseline for the case of glaciers, while it is established that such must take into account the geographical location, surface area, thickness, surface topography, reflectivity, detrital coverage, geometric variations in time estimation, (area and length), discharge and water contribution calculation.

f) Inclusion of existing relationships between the physical environment and ecosystems in the area. Considering both terrestrial and aquatic ecosystems

According to the aforementioned, the changes in environmental regulations incorporate elements of importance for the protection of glaciers. In fact, any activity that is presumed to have a significant effect on glaciers must submit an EIA. Glaciers for which this rule applies are those incorporated in the public inventory of glaciers

A more detailed definition of the adverse effect concept which establishes a broad scope focused on the protection of relevant environmental factors. For glaciers, occurrence is verified through changes in surface or volume.

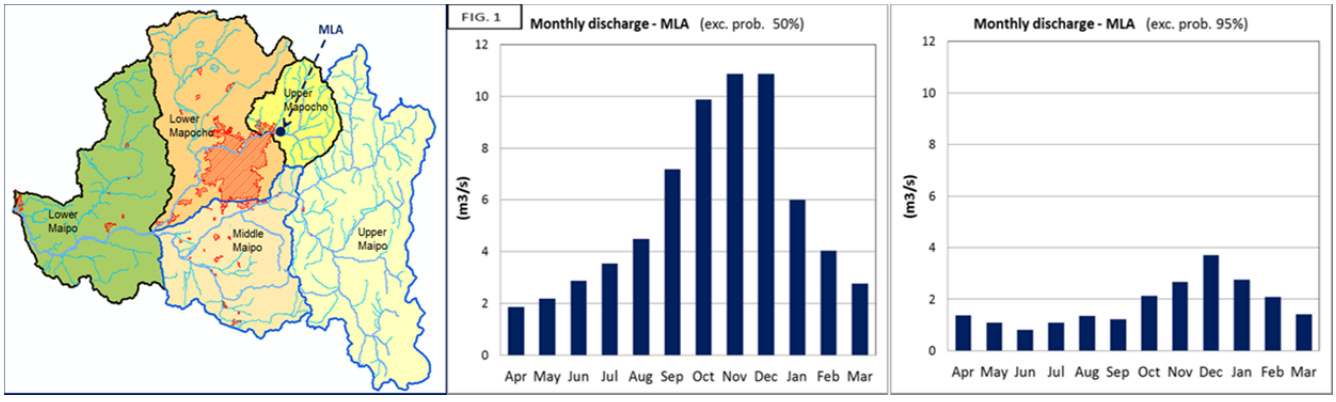
A fact of great relevance is the inclusion of the obligation to establish the relationship between the physical environment and ecosystems, whereby the possible effects that take place at the ecosystems as a result of the alterations in the physical environment are considered. This implies the need to know the ecosystem services in the area of influence in order to identify and quantify the related impacts.

On the other hand, there is more detail in the treatment of landscape and tourism, specifically in the concept of the value assigned. In the case of glaciers, this concept makes sense for non-covered glaciers since they are visible to an observer.

Approach on water contribution of glaciers: Mapocho river upper watershed

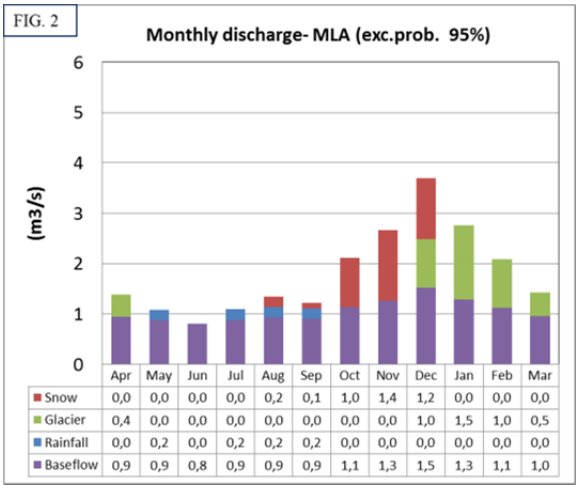
The glacier within the hydrological cycle acts as a regulating element, i.e., allows the accumulation of precipitation and generating runoff during ablation. The annual water balance determines the deficit, surplus or equilibrium status, reflecting changes in volume and area; i.e., short-term variations. For the long term, given an average hydrologic condition (i.e., average or dry year), runoff produced may be associated, in a first approximation, to glacier surface. The specific flow in this case is a good indicator.

In the case of upper Mapocho watershed, represented by Los Almendros station (MLA), monthly hydrograph for 50% and 95% exceedance probability is shown in Fig 1.



The relative contribution of glaciers in the monthly hydrograph is estimated considering the existence of a marked seasonality in terms of contribution: rainfall (May- Sep), snow (Aug- Dec), glacier melt (Dec- Apr) and base flow defined by minimum flow and in accordance with hydrograph values. Estimated contribution is shown in fig 2.

FIG. 2



The inventory of glaciers (DGA)[3] indicates that the total glacier area upstream MLA station is 20.25 km2 (15.27 km2 covered glacier and 4,98 km2 uncovered glacier), taking the average ablation rates referred by Marangunic et al.[4] and Expansion EIA-Andina[5] (4.5 l/s/km2 covered glacier and 60 l/s/km2 uncovered), the average glacier contribution is 368 l/s, which is consistent with the mean value established by hydrograph separation (358 l/s), thus, glacier contribution derived from the hydrograph is maintained. For the purposes of this paper and given the characteristics of Andean region, glacier covered refers to the so-called rock glaciers.

The change in glacier contribution by the effect of reduction of the glacier surface is estimated (Table 1) considering the aforementioned approximations and simplifications.

Table 1

Change in glacier contribution (m3/s) according area reduction scenario

a) Covered glaciers

% Areal reduc.	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
0%	0,435	0	0	0	0	0	0	0	0,960	1,470	0,960	0,465
10%	0,427	0	0	0	0	0	0	0	0,942	1,443	0,942	0,456
15%	0,423	0	0	0	0	0	0	0	0,933	1,429	0,933	0,452
25%	0,415	0	0	0	0	0	0	0	0,915	1,401	0,915	0,443

b) Uncovered glaciers

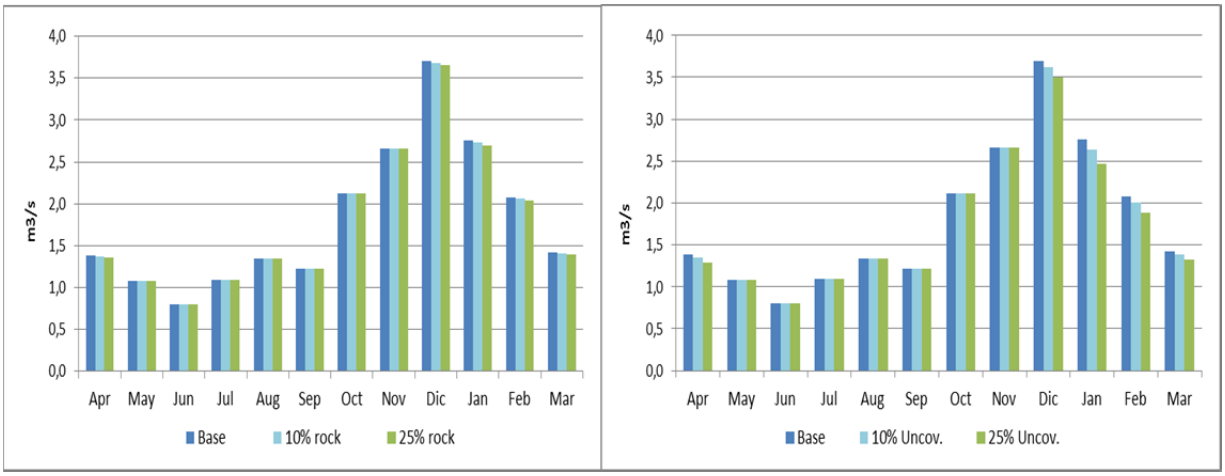
% Areal reduc.	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
0%	0,435	0	0	0	0	0	0	0	0,960	1,470	0,960	0,465
10%	0,400	0	0	0	0	0	0	0	0,882	1,350	0,882	0,427
15%	0,382	0	0	0	0	0	0	0	0,843	1,291	0,843	0,408
25%	0,347	0	0	0	0	0	0	0	0,765	1,171	0,765	0,370

Figure 3 shows the impact on total monthly runoff (MLA station) due to a 10% and 25% area reduction for uncovered and covered glacier:

- Reducing the covered glacier surface has less effect on the monthly download station MLA.
- 10% reduction of covered glacier surface (1.5 km2) produces a 0.4% decrease of the annual average flow and maximum monthly reduction is 1.0%

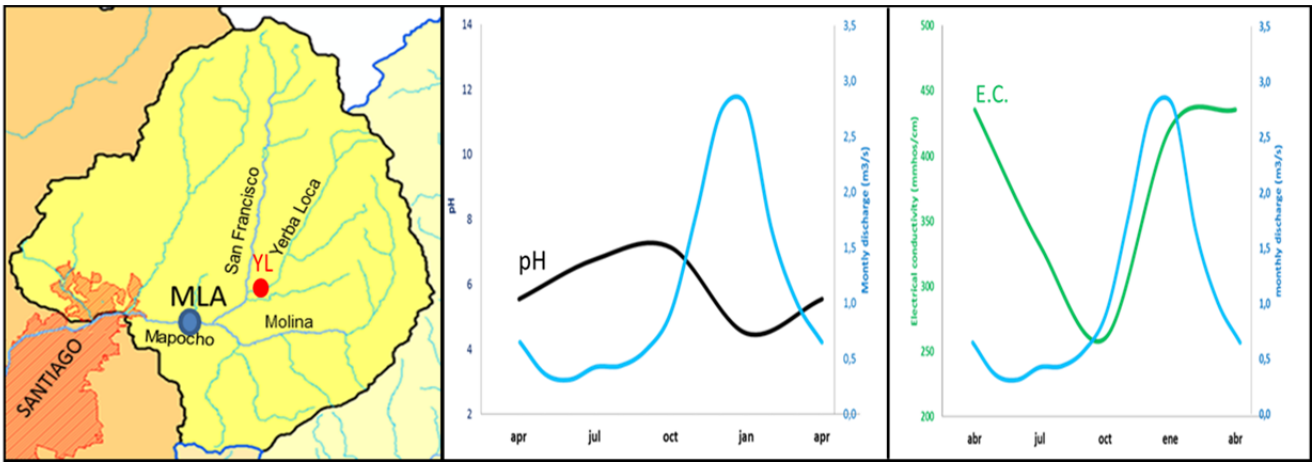
- 25% reduction of covered glacier surface (3.8 km2) produces a 0.9% decrease of the annual average flow and maximum monthly reduction is 2.5%
- 10% reduction of uncovered glacier surface (0.5 km2) produces a 1.6% decrease of the annual average flow and maximum monthly reduction is 4.6%
- 25% reduction of uncovered glacier surface (1.25 km2) produces a 4% decrease of the annual average flow and maximum monthly reduction is 10.8%

FIG. 3. Total runoff (m3/s) for 10 and 25% surface reduction



Regarding water quality for Yerba Loca Creek (YL), a Mapocho River tributary without anthropogenic intervention and significant glacial influence; registered data[6] shows that water quality is influenced by glacial melt. In fact, the pH decreases significantly during melting season while EC increases during the same period; which in turn suggests a leaching process that increases water acidity (Fig. 4)

FIG. 4. pH and EC v/s monthly discharge. Yerba Loca Creek



According to the analysis of current regulation; there should be a broad focus on the contribution of glaciers instead of an isolated characterization alone, whereby changes in hydrological patterns as well as glacier influence on water quality should be studied in detail. There should be special consideration of water quality in areas where

geology plays an important role due to the presence of mineralized formations related to Andean intrusive and volcanism. This information provides the basis for defining functional links with ecosystem for the purpose of identifying and evaluating impacts

Conclusions

The amendment of environmental regulation incorporates important elements aimed at protecting environmental factors. It allows protection for glaciers without necessarily impeding the development of activities or projects, however, ensuring environmental sustainability.

The role of glaciers as a water regulation element must have adequate and reasonable characterization (quantity and quality). This shall be consistent with the environmental law that specifies the minimum information to be provided and includes an obligation to identify and quantify ecosystem relationships.

The total glacier contribution in upper Mapocho river watershed can reach the order of 20 % of the total annual runoff (95% exceedance probability); the relative contribution tends to decrease for more favorable hydrological conditions.

A preliminary estimate of the change in runoff as a result of reducing glacier surface by 10 % can affect between 0.4 and 1.6 % of annual volume for covered and uncovered glacier respectively, taking into account that the maximum monthly discharge reaches a 1 % decrease (rock) and 4 % (uncovered).

Greater reductions (i.e. 25% or more) are more significant and out of scope of this approach and can probably be related to the climate change scenario rather than anthropogenic intervention.

The preliminary assessment for the Mapocho river watershed is focused on establishing an initial estimation on the contribution of glaciers on runoff and possible changes due to its variation; allowing to have an order of magnitude of its relative importance depending on the location of the analysis site, in addition to providing information that allows a link with other components (ecosystem, groundwater, water quality) in order to focus and prioritize research and monitoring.

References

[1] Biblioteca del Congreso Nacional. Reglamento del Sistema de Evaluación Ambiental. Decreto N°40 del 30-oct-2012. Ministerio del Medio Ambiente
[2] Dirección General de Aguas. Decreto Supremo MOP Nº 365 de 30-05-2008. Modifica Decreto Supremo MOP Nº 1.220 de 30-12-1997 sobre Reglamento del Catastro Público de Aguas
[3] Dirección General de Aguas. Centro de Información de recursos hídricos. Inventario de Glaciares
[4] Marangunic, C.; Cassasa, G., Marangunic, A. Glaciares, Medio Ambiente y proyectos de desarrollo. Comisión de Medio Ambiente y Bienes Nacionales. Senado. Chile. 2013
[5] Servicio Evaluación Ambiental. Estudio Impacto Ambiental. Proyecto Expansión Andina 244. Cap.2
[6] Dirección General de Aguas. Estadística de calidad de aguas. Estero Yerba Loca antes San Francisco