

# Challenges and opportunities for the sustainability of mountain municipalities in Chile

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## Abstract

Although the Andes play an important role in the development of Chile, the state of knowledge about them is scarce and partial. This demonstrates the need to deepen our knowledge about them from the perspective of sustainability. This research advances in this line, identifying “mountain municipalities”, according to natural and anthropogenic characteristics. Then, a set of thirty indicators of sustainability was defined to characterise the social, environmental and economic situation of these municipalities. The results obtained allow us to point out that Chilean mountain municipalities have dissimilar levels of sustainability, which presents challenges that must be addressed locally, considering the characteristics of each territory.

**Keywords:** Chile, Andes, global change, challenges, sustainability

## 1 Introduction

Mountain areas play a very important role in our planet’s economic and environmental process. Highlands are particularly sensitive and therefore current global changes – economic, climatic, cultural – constitute a serious challenge to their sustainability (Messerli & Ives 1997; Messerli 2010). Even though the world has noticeably advanced towards the scientific understanding of these regions, in underdeveloped countries like Chile with a mountain range of over 4,000 kilometers, this knowledge is still incipient and partial. It is therefore vital to raise awareness of the state, the processes and dynamics of mountain areas, because only in this way will it be possible to properly contribute to achieve the desired sustainability.

Mountains cover more than 20% of the surface of our planet and vary in shape, size, height, flora and climate regimes. This makes them quite heterogeneous areas and holders of various profitable economics resources. In this way, highlands are biodiversity hot spots, have a lot of potentially marketable natural resources, are centres of cultural diversity, and provide strategic environmental services (Chaverri 2002; Viviroli et al. 2011).

Despite these favorable characteristics, mountain regions are marginal and isolated areas subjected to processes that challenge their sustainable development, and which due to the exacerbation and acceleration of current global changes – economic, climatic, cultural – are highly vulnerable (Moss 2008; Price 2008; Borsdorf & Jandl 2009).

Chilean mountain areas account for over 80% of the country and are a key natural factor in shaping the country’s territory. The Cordillera is presented as the most

distinguishing characteristic of the relief of the country and therefore influences the distribution patterns of human settlements. Also, from an economic perspective its importance is unquestionable for the country, being the main source of revenue given the mineral wealth it possesses. Indeed it is projected that in 2011 the share of mining in the country's gross domestic product will be around 6%, equivalent to more than 53 billion dollars (COCHILCO 2011).

The main objective of this research is to deepen the knowledge of Chilean Andes from the perspective of sustainability. In a scenario of rapid global and climatic changes, which will have clear implications in the Andean environment and therefore in strategic resources such as water and other environmental services, it is hence necessary to increase our knowledge for understanding the state, the dynamics and the processes that take place in mountain areas. In this line, in the Andes of Chile it is possible to postulate the existence of different stages of development, with diverse levels of sustainability in these territories, thus this research focuses on understanding these processes and so provide new data from a holistic perspective.

## 2 Mountain areas as object of study in Chile

In the case of Chile, the Andes play a major role in the development of the country. From the geomorphological point of view, the Andes represent the most important morphogenetic unit in the configuration of the country, given that it is spread over 4,500 km; geopolitically, it is the largest existing natural border; from a cultural perspective, it is home to many native communities, such as the *Aimara*, the *Atacameños* and the *Mapuches*, and it is closely linked to the country's cultural heritage. Last but not least and from a more economic perspective, metals such as copper, gold and silver are present here (Sagredo 2006; Nuñez 2009).

Despite the importance of the Chilean Andes, initiatives, policies and scientific research of either private or governmental nature, are still insufficient and of limited time and coverage scope. The highest degree of acknowledgement achieved for Chilean Andes in recent decades has been derived only from the tension occurring in these regions, as they are sources of vast economic wealth, for example through mining activities, which are controlled by transnational and multinational companies which threatened the sustainability of these resources (Romero et al. 2009).

At present, there is a diverse and complex set of legal regulations, public institutions and public-private partnerships, which to a greater or to a lesser extent have influence in mountains. However, these regulations address only one aspect relative to these spaces, whereas many are only indicative and lack complementarity among them. Therefore, mountain areas are not a legally recognized space itself, and planning becomes a difficult issue to be carried out (Marchant 2010).

Scientific studies about mountains in Chile are characterized by being addressed according to the theoretical background of each discipline and are restricted to a geographical area only. Thus, for example, there exists research devoted to analyzing the geodynamic conditions of mountain ecosystems (Castro et al. 2009), geological processes, tectonic displacement and mineralization, archeology, anthropology and

ethnography of highland communities, and the characteristics and diversity of Andean flora.

Authors such as Romero (2002), Romero et al. (2009) and Marchant (2011) have done some work on mountain areas, and stressed that the globalisation of the economy, represented by multinationals and their million dollar investments to extract natural resources, foster unresolved debates in the Chilean society as to water rights, native communities, protection of the current diversity, weak environmental and territorial reorganisation policies, inefficiencies and clarity of the competences and attributes of government organisms. To these conflicts arising from investments of capital to exploit resources, some other issues are added arising from new environmental and cultural appreciation of mountain areas, and which have encouraged permanent and sudden movements of population to more privileged locations, known as amenity migration. This phenomenon has been recently analysed in the centre and south of the country, detecting emerging issues related to the loss of agricultural land, segregation and marginalization, and conflicts of interest among old and new residents (Hidalgo et al. 2009).

In summary, although in Chile there has been progress in basic research on mountains, particularly in sciences like biology and glaciology, it is necessary to move in a new direction, towards a multidisciplinary approach, i. e. integrating the characteristics and specificities of these regions and analyzing the specific relationships that occur in complex geographical areas like these. In this context, the main aim of this research is to identify phenomena, conflicts, similarities and imbalances that threaten and/or affect the sustainability in Chilean mountain areas.

### 3 Mountain areas in Chile: towards a definition

First of all, in order to adequately identify so called “mountain municipalities” it was necessary to consider the varying height of the Andes in all 4,000 kilometres of length. For this matter, Weischet’s (1970) zoning model was used as a starting point. This model considers homogeneous characteristics of orographic, climatic, economic and population factors in Chile, and distinguishes the following regions: Norte Grande (Big North), Zona Central (Central Area, conformed by Norte Chico or Small North, Núcleo Central or Central Core and Sur Chico or Small South) and Sur Grande (Big South). According to this classification, a “mountain municipality” is defined in terms of these characteristics (relief, height, slope, geomorphologic processes, vegetation) and anthropic features (profitable use of the land: shape, quantity and temporariness).

From a physical perspective, Weischet’s height variability model of geographic regions was the main tool used. In order to properly define the lowest area of a mountain in each one of these regions, a digital elevation model based on ASTER data (Advanced Spaceborne Thermal Emission and Reflection Radiometer) was programmed at ArcScene. The sophisticated level of precision of these images permitted to identify current relief areas, and each geographic region was given an initial boundary mark that indicated the beginning of the mountain relief (Norte Grande

2,000 m, Norte Chico 1,600 m, Núcleo Central 800 m, Sur Chico 600 m); in the case of the Zona Austral (Austral Zone), its entire extension corresponds to this type of relief.

As for the anthropic factor, adequate use of the territory was the main characteristic taken into account, i. e. permanent human settlements. The criterion applied for this was the amount of people living in settlements at the very start of the relief of a mountain area, as described in the previous paragraph, for which statistics of the last National Population and Home Census in Chile from 2002 were used. Subsequently, to determine the “mountain municipalities”, the political and administrative division of the country was overlapped. To be methodologically adequate, it is necessary to define what a municipality is, given that only in this way data can be extracted, as it represents a legally defined territory for the Local Administration and conforms the basic structure of the State (INE 2002).

In this way, “mountain municipalities” were defined as those of which at least 20% of the whole population of a community lived above the limit established as the start of a mountain relief. It was thus possible to identify 59 “mountain municipalities” (Table 1).

#### 4 Towards a model of sustainability of mountain municipalities in Chile

To identify the main phenomena that threaten and/or affect the sustainability of mountain municipalities in Chile, a set of 30 indicators was defined based on the model of the three classical pillars that make up this concept: environmental, social and economic features. This model posits as a starting point that a sustainable development can only be achieved if the objectives for each one of these features are implemented simultaneously and with the same degree of importance, so that not

Table 1: Communities classified as “mountain communities” in Chile.

<b>Norte Grande (Big North)</b>	<b>Norte Chico (Small North)</b>	<b>Zona Centro (Central Area)</b>	<b>Sur Chico (Small South)</b>	<b>Zona Austral (Austral Zone)</b>	
Gral. Lagos	Diego	Petorca	Curacautín Palena	Aysén	Río Verde
Putre	de Almagro	Putendo	Vilcún	Cisnes	San Gregorio
Camarones	Tierra Amarilla	San Esteban	Cunco	Lago Verde	Porvenir
Camiña	Alto	Los Andes	Villarrica	Coihaique	Primavera
Colchane	del Carmen	Sn José de Maipo	Pucón	Río Ibáñez	Timaukel
Huara	Vicuña	Lo Barnechea	Lonquimay	Chile Chico	Puerto Na-
Pica	Paihuano	Pirque	Melipeuco	Cochrane	tales
Ollagüe	Río Hurtado	Machalí	Curarrehue	O’ Higgins	Torres del
Calama	Monte Patria	San Fabián	Panguipulli	Tortel	Paine
San Pedro de		Antuco	Cochamó	Cabo de Hornos	
Atacama		Alto BioBio	Chaitén	Laguna Blanca	
			Futaleufú	Punta Arenas	

only present conditions improve but also preserved for future generations (Tappeiner et al. 2008).

Among the set of indicators defined, two types are distinguished according to the function they have. Schönthaler et al. (2006) distinguish between identification or status quo indicators (useful to determine the current status of a given situation) such as demographic and social indicators. On the other hand, evaluation indicators permit to track the progress or step back of a given characteristic of a previously established objective. Likewise, these indicators permit to determine if the way in which a certain activity is carried out is sustainable or not. This is the case of economic and environmental indicators.

To have a more clear perspective of the huge amount of data that each one of these indicators show independently, a *factor analysis* was carried out with the help of the SPSS programme using the method of *principal components*, which helps to reduce the number of highly interrelated variables to a significantly lesser extent, without subtracting or losing relevant related information. From the set previously defined, only highly correlated indicators ( $> 0.7$ ) were used in the factor analysis in order to ensure the validity of the analysis and these were then corroborated through Bartlett's test of sphericity (significance level: 0.0000). Likewise, a Kaiser-Meyer-Olkin measure of sampling adequacy test was carried out, with a positive result (0.617), which demonstrates the adequacy of such a test and its statistic reliability.

The result obtained account for a total of 10 factors or phenomena that explain 82.16% of the accumulated variance. Table 2 summarises the factors identified.

The latter table shows various phenomena, which explain the varying current sustainability of mountain municipalities in Chile. According to the variance of each factor, it is then possible to explain the degree of importance that a given phenomenon has in order to explain the research problem.

Variance percentages of each factor explain in varying degree the current state of sustainability in each mountain municipality in Chile. Following to this, the four most relevant factors or phenomena for our analysis are explained (all of them above 10%, which in gross represent 47.1% of the total variance).

Table 2: Resulting factors of the principal components analysis. Source: authors.

Name of the factor	Percentage of variance explained
Factor 1: Population's dynamics and structure	13.4
Factor 2: Tertiariation on municipality level	12.5
Factor 3: Accesibility to basic services	11.9
Factor 4: Accesibility to State-provided services	10.1
Factor 5: Primary activities	9.1
Factor 6: Social vulnerability	6.2
Factor 7: Information technologies	5.9
Factor 8: Biodiversity protection by the State	5.0
Factor 9: Soil degradation	3.9
Factor 10: Biodiversity protection by the private sector	3.6

#### 4.1 Factor 1: population's dynamics and structure

For Factor 1, high factor values were obtained in total dependency ratio (0.924), sex ratio (0.860) and net migration balance (0.674). These figures clearly show that in mountain municipalities there exists a significant amount of dependent individuals, which taking into account Chile's low birth rate (16/1000) this may lead to conclude that the population is getting older. This situation clearly puts pressure on the reduced active population, which directly influences the socioeconomic conditions of inhabitants. On the other hand, male presence can be clearly observed in mountain communities, this of course, in direct relation to the type of economic activities present in the area, namely agricultural and mining (corresponding to Factor 5), and also to migration tendencies, mostly of female characteristics.

Through standard deviations Figure 1 shows the situation of each mountain community with respect to the mean of the data. Lighter colours represent communities where these tendencies manifest a lower intensity, whereas darker colours show more strength in the processes described. Mountain communities located in the most remote areas of the country show levels of male presence, dependency and migration above the average. According to this, representative southernmost communities are Laguna Blanca, Torres del Paine, Timaukel and Rio Verde; in turn, representative northernmost communities are Putre, Pica, San Pedro de Atacama and Ollagüe.

#### 4.2 Factor 2: tertiarisation on municipality level

This Factor showed high factor values on indicators of population density (0.852), total municipal revenue (0.848) and percentage of population employed in services (0.675). An important part of municipal revenues are obtained through taxes paid by its citizens, as such, these will have a direct relation with variables such as population size, and thus its density, and with the predominant type of economic activity. Map 2 shows that at country level, mountain communities are places where, unlike other mountain ranges like the Alps, the degree of outsourcing is still not well developed. In this way, mountain communities are characterized by low population density and economic activities oriented towards the exploitation of natural resources with little value added. It is interesting to note that only 6 of the 59 municipalities in this study are above the average of tertiarisation: in Norte Grande, Calama; in Núcleo Central, Los Andes, Lo Barnechea and Pírcue; and in Sur Chico, Villarrica and Pucón.

#### 4.3 Factor 3: accesibility to basic services

In Factor 3, indicators with high factor values are households with acceptable sanitation rate (0.802), percentage of households connected to the mains (0.755) and number of indigenous population (-0.893); this last negative value indicates a negative correlation of this indicator over the others. The importance of this factor for sustainability is a key feature, every time it is strongly correlated with the satisfaction of basic needs that affect the quality of life of the population. At country level,

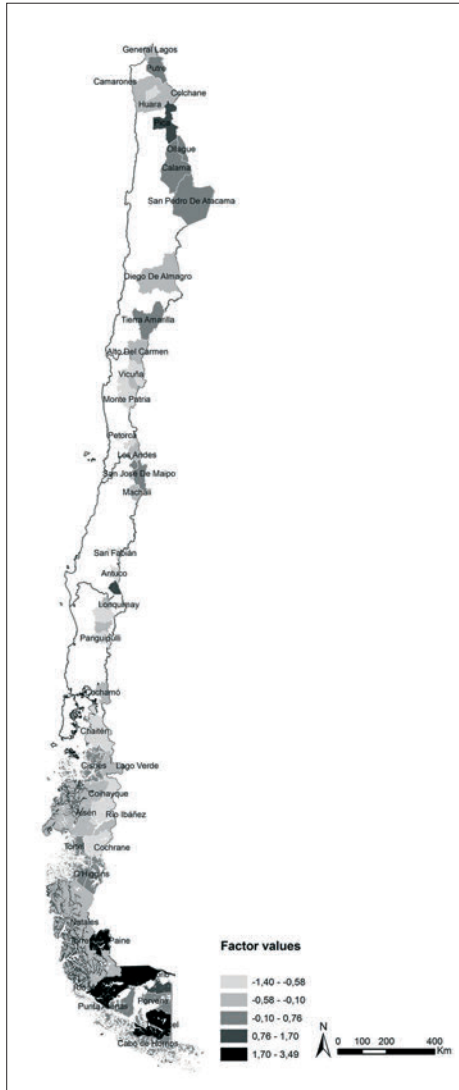


Figure 1: Factor 1: population's dynamics and structure.

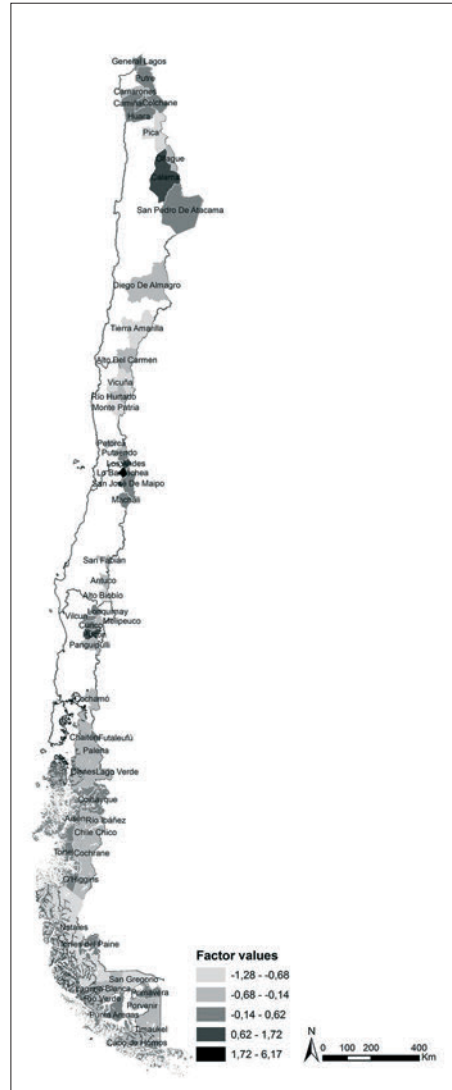


Figure 2: Factor 2: tertiarisation on municipality level.

northernmost communities are below average and face greater challenges in this matter. The opposite occurs with communities in the central area of the country, whose population has wider access to basic services.



#### 4.4 Factor 4: accesibility to state-provided services

Indicators with high factor values are: accessibility to the Capital of the region (0.837), access to higher education (0.822) and distance to the nearest hospital (0.481). These indicators reflect the degree of ease or difficulty that the inhabitants of mountain communities have to access to the benefits the State provides only at regional level, and also the difficulties they must overcome to access higher education standards. These situations also have a strong impact on quality of life, as for example in the case of access to higher education, when there is little or no offer at all and there exists a strong need for long commutes. This situation has the effect of powerful barriers and/or influences migratory movements to places where individuals find such services, thus fostering depopulation of these areas. In this factor extreme zones are those with the worst levels of access to the services described.

## 5 Conclusions

Nowadays, mountain areas, and particularly those in underdeveloped countries such as is the case of Chile, are characterised by their high degree of vulnerability to the effects of global change, which presupposes multiple and assorted challenges to be addressed from a multidisciplinary perspective given the complexity of these phenomena. As in the case of Chilean mountain areas with such disparities along the development process and consequently becoming marginalised spaces, it is fundamental to deepen our knowledge about the factors that trigger such disparities, in order to properly address them, preferably from a local perspective, which as suggested by Agenda 21 is the most adequate way to exercise this long desired sustainable development. For this matter, it is necessary that development-related strategies consider the particularities of each geographic area in Chile, i. e. that answers to the problematic be focused and deal with the specific needs that they face; only in this way will it be possible to reduce current gaps and ensure a more balance development.

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