Chapter 16
Ecosystem Services and Human Well-Being: A Comparison of Two Patagonian Social-Ecological Systems

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Abstract The literature shows several possible relationships between ecosystem degradation, ecosystem services, and human well-being. In this chapter, we compare two Patagonian social-ecological systems (the Aysén watershed and Chiloé Island) regarding the use of ecosystem services by rural people and the relationships with ecosystem degradation. Results showed that people living in isolated, less modified systems have higher use of ecosystem services and material well-being. However, they have a lower quality of life. We discuss these issues and propose a conceptual model.

Keywords Degradation · Ecosystem services · Human well-being · The environmentalists' expectation

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1 Introduction

The Millennium Ecosystem Assessment (MEA 2005) states that ecosystem services (ES) are essential for human well-being (HWB). Although the literature shows an average of 130 articles per year published during the last 15 years,[1] the relationships between ES and HWB are still far from being solved (Costanza et al. 2017; Cruz-García et al. 2017). When the MEA proposed a relationship between ES and HWB, it generated a new complexity into well-being assessments, requiring rethinking the efficiency and effectiveness of existing HWB indices such as the United Nations Index for Human Development (Delgado and Marín 2017). Current academic theories on HWB center on (a) subjective or psychological arguments, (b) economic ideas, and (c) sociological reasons or the normative ideal (Aguado et al. 2012). However, HWB indicators do not consider the benefits that people get from nature, often due to the lack of regional databases (Delgado and Marín 2017).

Sen (2009) defines HWB as the extent to which people can live the kind of life they value and develop their potentials under opportunities. So, many instrumental types of freedom determine the people's capacity to generate the kind of life they value. Today HWB implies personal and environmental security, access to material goods, good health, and social relationships related to decision-making freedom.

From this perspective, it is vital to re-evaluate the public policies related to the ecosystems' sustainability, since they define the opportunities for the access and distribution of the benefits ecosystems provide to the people. They also determine the people's capacity for ecosystems' management and, consequently, their well-being. Favorable public policies' perceptions by rural people (or ecosystems' people) would increase their opportunity to maximize their well-being through sustainable ecosystems (Delgado et al. In press).

Cruz-García et al. (2017) and Delgado and Marín (2016), working on ES and HWB in rural areas, show the benefits (economic, psychological, sociological, and cultural) of living in social-ecological systems (SES) with low anthropization levels. The authors propose that people feel happy living in such ecosystems in developing countries even when lacking essential services such as potable water and sewage systems. Nevertheless, the lack of health systems and the low presence of governmental institutions affect their well-being. Bachmann-Vargas and van Kopppen (2020) mention that in remote regions, such as Patagonia, low anthropization levels and high nature conservation values have a high cost for human beings given their distance to urban areas, generating unequal access to opportunities. Nevertheless, people consider that living in these systems is beneficial in terms of ES provision (Sangha 2019; Delgado et al. 2013; Zorondo-Rodríguez et al. 2019). For example, Delgado et al. (2013) show that free access to firewood, fungi, fishes, and macroalgae, among others, improves people's material well-being, an issue also discussed by other authors (Forest Trends, The Katoomba Group, and UNEP 2008).

[1] https://webofknowledge.com

ES provision changes due to anthropogenic causes, affecting HWB (Montes and Salas 2007). From this perspective, HWB acquires a multidimensional meaning, beyond the economy, to include health, security, social interactions, and recreation (MEA 2005). Quétier et al. (2007) state that local ES are defined by the social context, determining if an ecosystem component or function will bring concrete benefits to human life. However, the effective use of services is also conditioned by the relationships between social actors and their appropriation schemes. So, as Schmitz (2010) proposes for ecosystems, the links between anthropization, ES, and HWB in social-ecological systems seem contextual. What are their relationships in Patagonia? In this chapter, we explored this question comparing two social-ecological systems of Chilean Patagonia, with different degrees of anthropization: the Aysén watershed (Aysén Region of the General Carlos Ibañez del Campo) and Chiloé Island (Los Lagos Region).

2 Methods

2.1 Study Areas

2.1.1 The Aysén Watershed

The Aysén watershed is an extensive (surface area = 11,456 km^2) exhoreic catchment system located between 45°S and 46°S in the head of the Aysén fjord in the Chilean Patagonia (Fig. 16.1A). We have studied it from several social-ecological perspectives, including social participation (Bachmann et al. 2007), governance (Delgado et al. 2007), socioeconomic impacts (Yarrow et al. 2008), landscape structure (Torres-Gómez et al. 2009), public perception on socioeconomic development (Ianni et al. 2009), and ES and HWB (Delgado et al. 2013; Delgado and Marín 2016). Although nearly 60% of its forests were burned at the beginning of the twentieth century to produce grazing land for cattle (Torres-Gómez et al. 2009), the watershed is a low anthropization ecosystem given its low human population density (Delgado et al. 2013). Economic development in the basin comprises seven sectors (Yarrow et al. 2008), mining, aquaculture, forestry, industries, agriculture, tourism, and livestock, with aquaculture and mining as the main activities. Provisioning ES (i.e., water and firewood) used by the rural population represents an average economic contribution of 148 USD per month (Delgado et al. 2013).

2.1.2 Chiloé Island

Isla Grande de Chiloé (or Chiloé Island) is an insular space located in the northern part of the Chilean Patagonia (Fig. 16.1B). With a surface area of 8394 km^2 is among the ten largest islands on the continent. The current island's culture (Chilota culture) is a syncretism between local Mapuche-Huilliche peoples and Spaniards

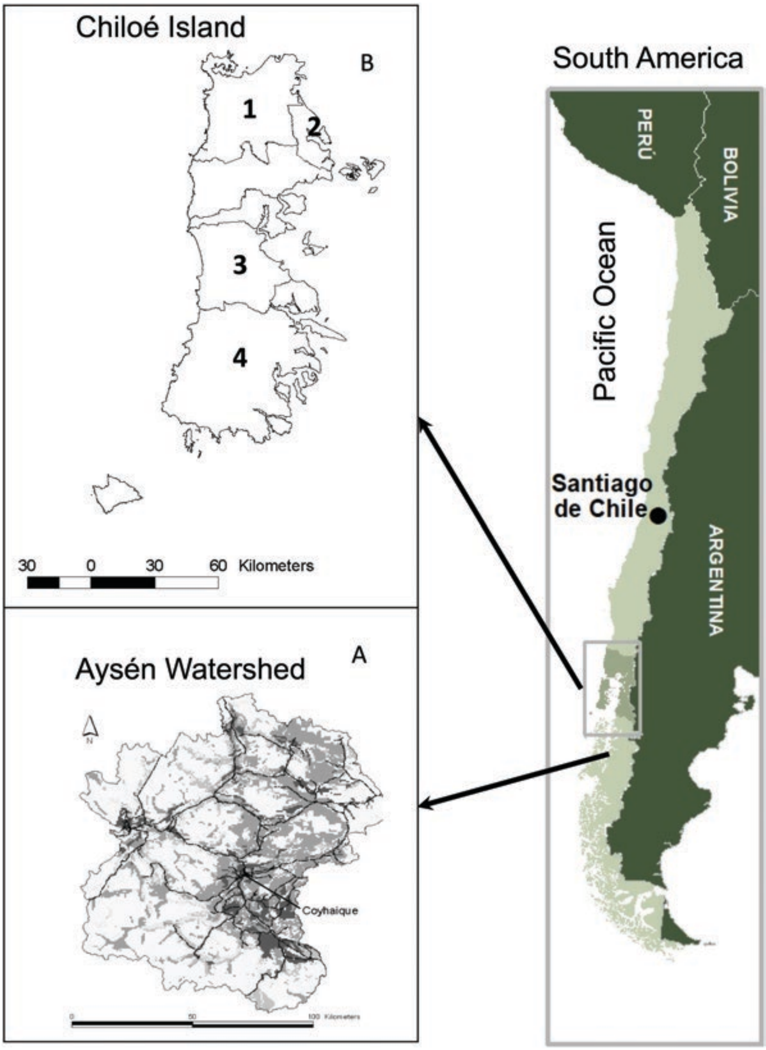

Fig. 16.1 Study areas of Chilean Patagonia. (A) Aysén watershed and (B) Chiloé Island. Numbers in the Chiloé Island correspond to surveyed communes. (1) Ancud and, (2) Quemchi, (3) Chonchi, and (4) Quellón

that arrived during the sixteenth century. Delgado et al. (2019) describe their social-economic and social-ecological conflicts. The island's main economic activities are salmon and mussel farming, potatoes agriculture, and cultural tourism (Pérez-Orellana et al. 2020). During the year 2017, the Chilean National Agency for Research and Development (ANID, former CONICYT) funded a 4-year research project[2] oriented to study its rural social-ecological relationships. In this chapter, we use part of its results.

2.2 Databases

Delgado et al. (2013) and Delgado and Marín (2016) describe all the social-ecological data for the Aysén watershed. In Aysén and also in Chiloé, the primary research tool was a social-ecological household survey. We developed the Aysén watershed survey in October 2009 (Delgado et al. 2013) and almost 9 years later (January–February 2019) on Chiloé Island. Although the surveys' structure was different (e.g., number of questions), the elements used to calculate the ES and well-being indices were the same.

Delgado et al. (2013) describe the survey structure for the Aysén watershed. The survey universe corresponded to the number of households in the Aysén watershed (5400). Thus, the sample size (83 households) generated 95% confidence and an 11% error. Chiloé's survey included four communes (Fig. 16.1B) with a total sample size of 228 households that, considering the survey universe (12,563 households), provided results with 95% confidence and 7% error. In both cases, we coded and analyzed the data using the IBM Software Statistical Package for the Social Sciences (SPSS Version 26). In the next section, we describe the information used to calculate ES and HWB indices. The full structure of the Chiloé survey is available from the first author of this chapter upon request.

Rural family size (3 ± 1.5) and the percentage of families owning the property where they live (85%) are similar in both areas (Aysén and Chiloé). However, while 100% of Aysén rural households use firewood as their primary house energy source, only 21.9% of Chiloé households use it exclusively, while 76.5% use a mixture of firewood and gas. Another difference between areas relates to the temporality of the households' head jobs. In the case of Aysén, 77% have permanent jobs, while for Chiloé, it decreases to 48.4%. Finally, although agriculture and cattle raising are the two most important activities in both areas, in Aysén, it represents 56% of the households, while in Chiloé Island, it is less than half (23.7%) of Aysén.

2.3 Indices

The question posed in this chapter required calculating three types of indices: (1) an anthropization index, (2) ES indices, and (3) HWB indices. According to Delgado and Marín (2020), ecosystem degradation is a concept that many people use, but few define. Here we define it as the changes in the ecosystem's structure and

[2] Proyecto Fondecyt Regular No. 1170532 awarded to Luisa E. Delgado

functioning due to human activities or anthropization. We used a modified version of Sanderson et al.'s (2002) "Human Influence Index" (HII) as a proxy to evaluate ecosystems' anthropization conditions (Delgado and Marín 2020):

$$\text{HII}_{\text{mod}} = \text{Pop.density} + \text{Urban}(\%) * \text{Sc}_2 + \text{agr} - \text{for}(\%) * \text{Sc}_3 \quad (1)$$

where Pop. density = influence scores of the human population per unit area (1/km^2) extracted from WCS-CIES (2005), using population data from the 2017 Chilean population census (INE 2017); Urban (%) = percentage of urban areas, extracted from CONAF/UACH (2014); Sc_2 = influence score for urban areas extracted from WCS-CIES (2005): agr-for (%) = percentage covered by agricultural or forestry sectors, obtained from CONAF/UACH (2014); and Sc_3 = average influence score for agricultural-forestry areas (6), modified from WCS-CIES (2005).

We also calculated the percentage of land use covered with native forests as an independent variable. We obtained the data from governmental databases (National Forest Corporation; CONAF[3]).

In the ES's case, we used provisioning, regulation, and maintenance services indices, using critical elements for Patagonia's rural people (Delgado et al. 2013). We calculated the provisioning services index *(PSI)* using one biotic provisioning service (wild plants as energy sources; wood) and one abiotic service (surface water or groundwater for drinking; water) according to the formula:

$$(PSI) = Wood + Water \quad (2)$$

where *Wood* = fraction of households (between 0 and 1) obtaining native wood from their properties and *Water* = fraction of households (between 0 and 1) getting water from sources other than the private (paid) service. In both cases, 0 = none of the interviewees obtain native wood from their properties, and 1 = 100% obtained it. Thus, if all rural households obtain wood from their properties and use water without paying a private service, *(PSI)* has a maximum value of 2. We chose these two variables since they represent the most basic provisioning service in rural areas of southern Chile (Delgado and Marín 2016).

In the case of the regulation and maintenance index *(RSI),* we used four elements: cattle raising (other maintenance services by living processes according to CICES V5.1[4]); subsistence agriculture without using chemical fertilizers (biotic regulation of soil quality) and the services generated from ecosystems to maintain the chemical conditions of freshwaters using the formula:

$$(RSI) = Cattle + (Agriculture * Fertility) + Sewage \quad (3)$$

where *Cattle* = fraction of households raising cattle in their property, *Agriculture* = fraction of households developing subsistence (non-commercial)

[3] http://www.conaf.cl

[4] http://www.cices.eu

agriculture, *Fertility* = fraction of households not adding fertilizers, and *Sewage* = fraction of housing not using the public (paid) sewage system. All variables had a 0 to 1 rank. If value is 0, none use the service, and 1 means that all interviewees use them. If all rural households use these four services (e.g., regulation of biological conditions providing food for cattle, without using fertilizers, regulation of water, sewage, conditions[4]), *(RSI)* = 3.

Thus, *(PSI)* and *(RSI)* reflect the extent of the current use of ES by the rural populations of both areas, based on the services researchers found are the most important in Patagonia. So, the composition of (*PSI)* and *(RSI)* is contextual; their usage in other areas should include a preliminary analysis of whether these elements are also the most basic for the local peoples.

We calculated two HWB indices material conditions index *(MCI)* and quality of life index *(QLI)* using a modified version of the equations discussed by Delgado and Marín (2016):

$$\left(MCI\right) = Housing + income + Jobs \tag{4}$$

where *Housing* = fraction of property owners, *Income* = fraction of households over the poverty line based on the definitions of the Chilean Ministry for Social Development and Family,[5] and *Jobs* = fraction of household's heads with permanent jobs (either with an employer or independent). All variables had a 0 to 1 rank, where 0 means that no household has the analyzed attribute and 1 that all households have them.

$$\left(QLI\right) = Social\,connections + Education + Health\,status \tag{5}$$

where *Social connections* = fraction of households participating in at least one social organization, *Education* = fraction of households whose head had more than the 8 years of primary education, and *Health status* = fraction of households having a health program (either private or public). The maximum theoretical value for both indices is 3.

3 Results and Discussion

The degree of anthropization was three times higher for Chiloé Island than for the Aysén watershed (Table 16.1). Human population density explains over 70% of the difference. Still, native forest land cover is more extensive in Chiloé Island than in the Aysén watershed. The lower percentage of Aysén native forest seems to be related to the colonization process during the nineteenth and twentieth centuries that burned nearly 60% of the forests, transforming them into pastureland (Torres-Gómez et al. 2009). Even so, less than 1% of both systems' total area corresponds

[5] http:// www.desarrollosocialyfamilia.gob.cl

to forestry, agriculture, and urban land. Thus, Patagonia has a smaller forestry development than other southern Chilean terrestrial ecosystems, located outside Patagonia, such as the Río Cruces watershed in Valdivia, with a 38.5% forestry land (Delgado and Marín 2016).

Results showed higher ES indices associated with a lower degree of anthropization (Table 16.2). Thus, a larger percentage of households use the analyzed services in the Aysén watershed than in Chiloé Island. The sum of both indices (**ES**, Table 16.2) was nearly 25% lower than its maximum theoretical value (5) for Aysén and 50% lower for Chiloé. Hence, even in this area with low anthropization conditions such as Patagonia, rural households depend on other sources for basic provisioning (e.g., wood) and regulation and maintenance (e.g., soil fertility) services. How much do rural people save using services directly from the ecosystem? Table 16.2 shows an example of wood, the principal heating source in Patagonian households. A cubic meter of wood in Chile cost 48 USD in 2018 (INFOR 2018). Aysén and Chiloé surveys showed that families use 5 m^3 per month in the former and 2.1 m^3 in the latter (Table 16.2). Thus, if we use INFOR (2018) price, families using the wood ES save between 101 and 240 USD per month, contributing to their economic well-being.

Table 16.1 Value and components of the modified Human Influence Index (HII_{mod}) for the Aysén watershed (Aysén) and Chiloé Island (Chiloé)

Components	Aysén	Chiloé
Population density per km^2	0.80	11.70
Forestry land (%)	0.53	0.85
Agriculture land (%)	0.10	0.01
Urban land (%)	0.11	0.32
$\mathbf{HII_{mod}}$ (dimensionless)	5.88	18.39
Native forest (%)	46	61

Table 16.2 Ecosystem services indices and their components for Aysén watershed (Aysén) and Chiloé Island (Chiloé)

Indices and components	Aysén	Chiloé	Percent change
(PSI)	*1.58 ± 0.13*	*1.32 ± 0.14*	*−16*
Wood	0.77 ± 0.04	0.39 ± 0.13	−49
Water	0.81 ± 0.10	0.99 ± 0.02	+16
(RSI)	*2.16 ± 0.13*	*1.20 ± 0.06*	*−44*
Cattle	0.57 ± 0.06	0.16 ± 0.08	−72
Agriculture	0.69 ± 0.05	0.32 ± 0.09	−54
Fertility	0.83 ± 0.04	0.36 ± 0.36	−57
Sewage	1.00 ± 0.08	0.94 ± 0.08	−6
ES	**3.74**	**2.52**	**−33**
Monthly wood use (m^3)	5.00 ± 2.00	2.10 ± 1.40	
Savings (USD)	240	101	

PSI provisioning services index, *RSI* regulation and maintenance services index. **ES** = *(PSI)* + *(RSI)*. Savings = monthly money savings, in US dollars, due to the use of wood ES

Although both ES indices had the same trend (i.e., higher values in the system with lower anthropization), regulation and maintenance services showed the most substantial difference. The component with the most significant decrease (−72%) in the more anthropized system (Chiloé) was cattle raising. Indeed, the percentage of households raising cattle in Chiloé (16%) was closer to that of ecosystems outside Patagonia with higher anthropization levels (Delgado and Marín 2016). Although with a smaller percent change (−57%), a similar difference relates to not using fertilizers for subsistence agriculture. In this case, 83% of Aysén households do not use them and 36% in Chiloé.

On the other hand, it is notorious that rural people from both areas "trust" the ecosystem to clean their sewage. Indeed, results show that almost 100% of the households do not use public or private sewage services, evacuating their liquid and solid residues into the soil through cesspits. The surveys did not provide information to know whether this is a conscient trust or the easiest, less expensive thing to do. However, since more than 80% of households use rural water, untreated by private companies (Table 16.2), they trust that its quality is suitable for human consumption.

HWB, considering the sum of both indices (*(MCI)* and *(QLI)*), was higher at Aysén watershed than at Chiloé Island (Table 16.3). However, Chiloé Island showed higher social connections and health status than Aysén. So, quality of life tends to be better in more anthropized than in less anthropized systems. The *(QLI)* value for Chiloé (2.00; Table 16.3) was almost the same (1.99) as that calculated for the Río Cruces' watershed by Delgado and Marín (2016). So, remoteness and isolation seem to affect life quality (see also Bachmann-Vargas and van Kopppen 2020).

Quality of life can be assessed in terms of "objective measurements" (i.e., the elements included in the *(QLI)*), but it can also include "subjective elements" such as life satisfaction (Delgado and Marín 2016; Costanza et al. 2017). In the Chiloé survey, we included a question to assess that element of rural quality of life: Do you have negative comments on the meaning of rural life? We then estimated life satisfaction as the fraction (between 0 and 1) of households without negative comments.

Table 16.3 Human well-being indices and their components for Aysén watershed (Aysén) and Chiloé Island (Chiloé)

Indices and components	Aysén	Chiloé	Percent change
MCI	*2.36 ± 0.08*	*1.71 ± 0.27*	*−28*
Housing	0.86 ± 0.05	0.86 ± 0.04	0
Income	0.72 ± 0.05	0.36 ± 0.11	−50
Jobs	0.77 ± 0.07	0.49 ± 0.15	−36
QLI	*1.63 ± 0.07*	*2.00 ± 0.20*	*+23*
Social connect.	0.58 ± 0.08	0.77 ± 0.06	+33
Education	0.48 ± 0.08	0.43 ± 0.09	−10
Health status	0.58 ± 0.05	0.79 ± 0.11	+36
WELL-BEING	**3.99**	**3.71**	**−7**

MCI material conditions index, *QLI* quality of life index. **WELL-BEING** = *(MCI)* + *(QLI)*

Since we did not measure this HWB component in Aysén, we can only compare it with previous results obtained in other rural areas 250 km north of Patagonia (Río Cruces, Valdivia) by Delgado and Marín (2016). Results from Chiloé (0.69 ± 0.05) and Río Cruces (0.75 ± 0.09) did not differ significantly, suggesting that nearly 72% of the people living in these rural areas are satisfied with their way of life. Also, we would like to emphasize that the most frequent negative comment about rural life, in both areas, was "isolation in case of emergencies." Thus, living in areas with low anthropization levels, such as Patagonia, seems to benefit people in terms of ES and material conditions, but with high costs in terms of their quality of life (e.g., social connections, health systems, fast solution of emergencies). We discuss these issues in the following paragraphs.

Pristine ecosystems are almost nonexistent. Moreover, the few remaining are better described as having a low anthropization level (Delgado and Marín 2020), mostly found in areas far from large urban cities. Current studies show that even remote areas, such as the Aysén watershed in Patagonia (Torres-Gómez et al. 2009), are no longer pristine (e.g., Kruse 2016). Still, our results show that its anthropization degree is lower than that of Chiloé Island (Table 16.1). They further show that this decrease in anthropization increases ES use by rural people and their HWB (Tables 16.1 and 16.2). So, they agree with "the environmentalists' perspective" (Raudsepp-Hearne et al. 2010), but not for all well-being components. Two components of the quality of life index (*QLI*; Table 16.3) were smaller in the less degraded system, which relates to the lack of infrastructure and connectivity for Aysén (Bachmann-Vargas and van Kopppen 2020). Still, Aysén isolation may appear positive under the current health conditions (i.e., COVID-19 pandemic).[6] But one of Aysén's commercial ventures is nature-based tourism (Aliste et al. 2018). For example, a Google search using the phrase "Aysén tourism"[7] produced 339 thousand pages. One consequence was that the first COVID-19 case in the Aysén Region on March 13, 2020,[8] was a British tourist arriving on a cruise. Still, Aysén is, so far, the Chilean region with the lower contagion rate.[9] However, local people fear that in case of emergencies, they are isolated. So, the benefits of isolation seem to be only partial and, at times, problematic for rural people. Furthermore, studies of Chiloé Island show that rural people perceive a low governmental presence (Delgado et al. submitted) and a lack of services such as sewage systems, trusting the ecosystem for the quality of the water they consume.

The appropriation and use of ES in rural areas may have different forms, modifying their relationships with HWB. This multiplicity of forms requires transdisciplinary studies, especially if the goal is to solve real problems such as degradation and poverty (Balvanera et al. 2020). ES in Patagonia contribute to economic and material HWB (Table 16.2). Nevertheless, there is an increase in social-ecological

[6] https://www.emol.com/especiales/2020/internacional/coronavirus/casos-chile.asp

[7] Conducted on August 4, 2020

[8] http://www.eldivisadero.cl/noticia-56048

[9] https://www.emol.com/especiales/2020/internacional/coronavirus/casos-chile.asp

conflicts, mostly due to low social participation, lack of empowerment (Pérez-Orellana et al. 2019), and the strong relationship between economic and cultural activities and ES (Bachmann-Vargas and van Kopppen 2020) and also a lack of feedback mechanisms between local collective management groups and the government (Delgado et al. In press).

Hobbs et al. (2006) and Hobbs et al. (2009) proposed two concepts incorporating the effects of human beings on earth ecosystems: "novel ecosystems" and "historical ecosystems." The first type corresponds to ecosystems that have been modified by human actions. The second type corresponds to those that "retain the biota and ecosystem properties that were prevalent in the past" (Hobbs et al. 2009: page 600). However, since finding historical ecosystems is unlikely, even in isolated areas such as Patagonia, we propose to replace the terms by "novel social-ecological systems" and "historical social-ecological systems."

Novel social-ecological systems (novel SES) have been modified in their structure and processes by human actions. They are the most common type on earth today. Historical social-ecological systems (historical SES) are those with low anthropization levels, mainly in remote, isolated areas. Both systems generate services to human beings, but relationships are contextual (Fig. 16.2). Historical SES produce more regulation and maintenance services than their novel counterparts, but provisioning services may go in different directions (Raudsepp-Hearne et al. 2010). For well-being, humans living in novel SES have lower material conditions but a higher quality of life than those living in historical SES. However, the decrease in quality of life will depend on the degree of isolation, the active or passive role of

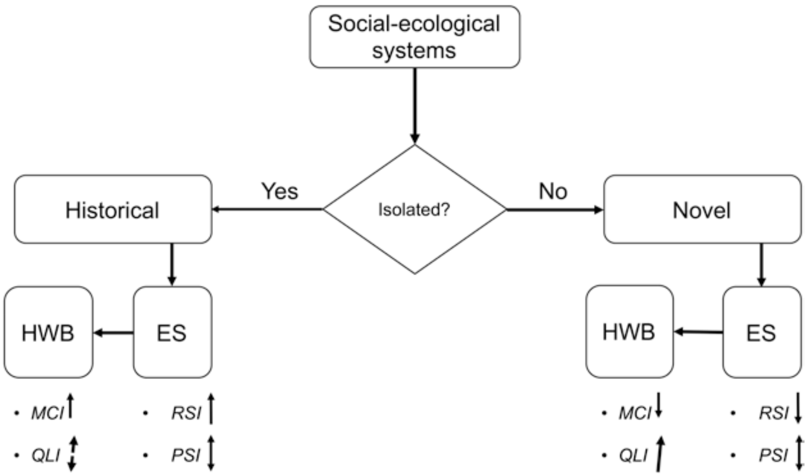

Fig. 16.2 Conceptual model on the relationships between the anthropization of historical and novel social-ecological systems, ecosystem services (ES), and human well-being (HWB). RSI maintenance and regulation services index, PSI provisioning services index, MCI material conditions well-being index, QLI quality of life well-being index. Arrows next to the indices show the expected trends for each type of service and well-being component. ↓ = decrease, ↑ = increase, ↕ = both trends. See Indices in section 2 for further details

the regional/local government, and their development pattern (Aliste et al. 2018). In summary, isolated areas such as Patagonia, with high ecological value and equally high nature' contributions to the material conditions of HWB, do not necessarily correspond to areas with high quality of life for the people living in its rural environments.

Ecosystem services are synergic to the development of other conditions that, together, satisfy essential human needs and the components of well-being. The MEA (2005) framework proposes four constituents: (1) security, (2) health, (3) basic material goods, and (4) good social relationships. Living in areas with low anthropization levels, such as Aysén in the Chilean Patagonia, contributes directly to the people's health (e.g., adequate oxygen levels, direct nature recreation, etc.). However, it also means living in an "isolation paradox" (Shihipar 2020), where remoteness may go against security and health in emergency conditions. So, remote areas require integrated ecosystem management approaches that should include ecosystems sustainability and human well-being (objective and subjective) as goals.

4 Recommendations for Policy Makers

Currently, the Chilean government has community development programs (PLADECO; Valdivieso 2020) in the studied areas. However, they do not include ecosystem services and their contribution to local households' economy, despite available information (Delgado et al. 2013; Nahuelhual et al. 2015; De la Barrera et al. 2015; Delgado and Marín 2016). Therefore, current territorial development plans have a vision of no relationships between economic development, human well-being, and ecosystem structures and functions. Bachmann-Vargas and van Kopppen (2020) propose that these partial territorial views result from the centralism of public investments in Chile and the geographic distribution of human capital. Thus, the management of territories with low anthropization requires local participation (social and governmental actors) and co-learning, given the contextual relationships between anthropization, ecosystem services, and human well-being (Fig. 16.2), to include the different social-ecological perspectives.

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