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A mapping approach to assess intangible cultural ecosystem services: The case of agriculture heritage in Southern Chile

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ABSTRACT

Modeling and mapping of cultural ecosystem services (CES) represents a significant gap in ecosystem service research. A GIS-based methodological framework was developed and applied to map agricultural heritage (AH), understood as a non-divisible combination of three cultural services (dimensions, D): the heritage value associated to a *culturally significant species* (i.e. Chiloé native potato) (D1); the traditional *systems of knowledge* of AH keepers (D2); and the social relations among them (D3). The final aim of the study was to provide indicators of the "final" service (AH_i, measured in a 0–100 point scale) and its benefits (AH_B, measured in US$/ha), capable to display areas where high value farmland was located. In essence, AH_i comprised a set of biocultural variables validated and weighted by expert opinion. The experts gave the maximum importance to 5 variables: number of native potato varieties cultivated (D1), use of own seed (D1), form in which cultivation knowledge was acquired by the keeper (D2), exchange of own seed (D3), and number of other potato keepers known (D3). In turn, AH_B reflected society's willingness to pay for the nonmaterial benefits of AH conservation. Since these benefits "propagate" across space extending from local to unknown and distant beneficiaries, and the aim was to identify the most valuable areas for their capacity to satisfy a potential demand, AH_B was spatialized following the approach of "ascribing" the potential benefits to their "point of provision". Thus the highest values of AH_i coincided with the highest values of AH_B (US\$10.64–8.64 ha^{-1}) a comprised 5608 ha of the landscape, and similarly the lowest values of AH_i matched the lowest values of AH_B (US\$1.69–0.18 ha^{-1}) comprising 13,070 ha of the landscape.

1. Introduction

The Millennium Ecosystem Assessment (MEA) defined CES as "the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and esthetic experience, including knowledge systems, social relations, and esthetic values" (MEA, 2005: p. 40). Expressed alternately to differentiate explicitly among services, benefits, and values, CES have also been defined as "ecosystems' contribution to the nonmaterial benefits (e.g. experiences, capabilities) that people derive from human–ecological relations" (Chan et al., 2012).

Although one broadly agreed upon characteristic of CES is their intangibility, they nonetheless create robust ties between humans and their natural environment and represent one of the strongest incentives for people to engage in natural capital conservation (Angulo-Valdes and Hatcher, 2009; Schaich et al., 2010; Daniel et al., 2012; Milcu et al., 2013). Cultural ecosystem services are important in a wide range of situations and industrialized societies frequently value them ahead of other services (Quétier et al., 2010; Tielbörger et al., 2010; Palomo and Montes, 2011).

However, despite this recognized importance, the incorporation of CES into decision-making remains far behind that associated with more tangible services (Daniel et al., 2012; Milcu et al., 2013). This is largely due to the many difficulties associated with measuring and mapping CES (Ambrose-Oji and Pagella, 2012). In fact, CES generally defy quantitative characterization and modeling (MEA, 2005; Daniel et al., 2012), recreation and esthetics being few exceptions to this (Chan et al., 2006; Raymond et al., 2009; Sherrouse et al., 2011; van Riper et al., 2012), since that contrary to other services which can be quantified independently from the presence of humans (i.e. water supply and regulation) – as they mostly depend on natural attributes – CES are closely linked to personal and local value systems (Pejchar and Mooney, 2009).

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Cultural ecosystem services are frequently dependent on intermediate ecosystem services (Fisher et al., 2009; Johnston and Russell, 2011), and cultural benefits arise from final CES combined with other forms of capital (Chan et al., 2011). Yet, the spatial representation of these different components presents many challenges. As a result, most studies have focused on mapping benefits rather than the CES itself. These benefits are obtained using economic valuation methods (Costanza et al., 1997; Angulo-Valdes and Hatcher, 2009; Martín-López et al., 2009; Zhang et al., 2010) and are usually ascribed to specific zones (e.g. protected areas in the case of recreation), excluding from the maps those areas of potential benefits for which indicators cannot be obtained (Anderson et al., 2009; Eigenbrod et al., 2010).

Further attempts have been made to quantify and map CES on the basis of proxies that describe societal interest for these services in specific landscape types (Maes et al., 2011; Daniel et al., 2012). Thus, for cultural values and inspirational services, maps have been based on specific classes of objects (i.e. land use, natural monuments) (Maes et al., 2011; Plieninger et al., 2013; van Berkel and Verburg, 2014). But the object classes usually executed in GIS may be insufficient to describe all connections between ecosystems and social systems that define CES (Daniel et al., 2012). In many studies the methods incorporate informants who are given a preliminary list of services and then asked to associate these with areas of the landscape. An important issue that emerges from these studies is the potential effect of "super-mappers" (Ambrose-Oji and Pagella, 2012) since "when no limits are placed on the number of ecosystem service markers that can be placed on maps, some participants tend to place many more markers than others" (Ambrose-Oji and Pagella, 2012). This has noticeable implications in terms of the representativeness of the maps produced using these techniques (Ambrose-Oji and Pagella, 2012). Examples of this approach can be found in Raymond et al. (2009), Brown and Weber (2012) and Fagerholm et al. (2012).

In this context, the goal of this study was to develop a methodological framework capable of spatially representing both the final service and the benefits from intangible CES, which was applied to mapping agricultural heritage (AH). The final aim was to provide spatial indicators, at municipality scale, capable of displaying areas where high AH value farmland is located, which can support several purposes from raising awareness of the presence and importance of AH, to the design of conservation instruments for specific farmers.

Agricultural heritage was defined here as "a specific type of inheritance composed of the farmers' way of life, production and agricultural activities" (Casanelles, 1994). Other authors have identified AH with the "cultural heritage of rural lifestyles" (Swinton et al., 2007). These definitions suggest that AH can be considered a non-divisible combination of three cultural services: the heritage value associated to a *culturally significant species* (i.e. Chiloé native potato); the traditional *systems of knowledge* of the heritage keepers; and the *social relations* established by them. Hence, mapping the final service and the benefits requires the spatial representation of the biocultural components of heritage, represented by the natural features (e.g. soil and climate) that allow the cultivation of the species as well as farmers' systems of knowledge and the values attached to AH by users. Other biophysical attributes of the ecosystem were not considered here because of their relative uniformity for this specific type of heritage along the study area.

2. Study case

The study area was the municipality of Ancud (73°15′ and 74°15′ W and 41°50′ and 42°15′), which is located in the northern portion of Chiloé Island (Fig. 1) in the Chiloé Archipelago in southern Chile. It is also part of the Valdivian Temperate Rainforest Ecoregion (35° S–48° S) (Di Castri and Hajek, 1976).

The municipality covers a territory of 172,400 ha, of which less than 1% is classified as urban. Of this total area 11,776 ha are protected by Chiloé National Park. The remainder of the rural territory is comprised of 2770 farms (INE, 2007), with an area that ranges between 0.03 ha and 4658 ha (CIREN-CORFO 1999). A large proportion of these farms (94%) correspond to peasant agricultural systems (Carmona et al., 2010).

Due to the restrictive agro-ecological conditions, Ancud can be considered marginal in terms of agricultural production, although agriculture continues to be a relevant source of rural income. These natural conditions have led to farming systems and rural livelihoods mostly oriented around self-sufficiency (Barret et al., 2002).

Within the agricultural activity, native potato (*Solanum tuberosum*) cultivation is a vital part of the food security and sovereignty of the inhabitants (CET, 2011). In fact Chiloé Island is considered one of the Vavílov centers of origin of potato, and traditionally the indigenous communities and farmers of Chiloé cultivated about 800–1000 native varieties of potatoes before the onset of agricultural modernization. The conservation of this species in small farms is closely related to the oral transmission of traditional knowledge, and the existence of a network of social relationships among the generations of peasant families (CET, 2011; FAO, 2012).

All these features have granted Chiloé the designation as a GIAHS (Global Importance Agricultural Heritage Systems) pilot site. GIAHS are defined as "remarkable land use systems and landscapes, which are rich in globally significant biological diversity evolving from the co-adaptation of a community with their environment and their needs and aspirations for sustainable development" (FAO, 2003). GIAHS are selected based on their importance for the provision of local food security, high levels of agro-biodiversity and associated biological diversity, store of indigenous knowledge and ingenuity of management systems. The principal objectives of the GIAHS program in Chiloé Island are to encourage its recognition as a source of culture, tradition, and genetic biodiversity; to stimulate sustainable development, and to alert society about the importance of protection and conservation of biodiversity (FAO, 2012).

However, in the last decades, the influx of new economic activities (forestry and fish-farming), urban expansion, migration of young people and the increasing use of commercial potato varieties have threatened the conservation of this patrimonial agriculture, and have produced deep changes in the socio-economic structure of the Island (Salières et al., 2005; CET, 2011; FAO, 2012). Recent studies show the abandonment of agricultural land, previously dedicated to crops and pastures (Díaz et al., 2011; Carmona and Nahuelhual, 2012). Whether landscape and agricultural policy interventions are undertaken to prevent the abandonment of traditional agriculture will depend on the choices and priorities of policy makers and on which development strategy is judged as preferable, i.e. exogenous modernization versus endogenous development based on the natural and cultural heritage. At present there is a clear misalignment among these strategies which menaces the in situ conservation of AH in Chiloé.

3. Methods and data

This study is part of a larger research project aimed at assessing the magnitude and spatial distribution of economic benefits of ecosystem services provided by rural landscapes in southern Chile, and therefore relied on information previously gathered by the research team. The mapping framework comprised two major stages which were the spatial representation of AH as a "final" ecosystem service (steps 1–5) and the spatial representation of the economic benefits that people derived from AH (step 6), each of

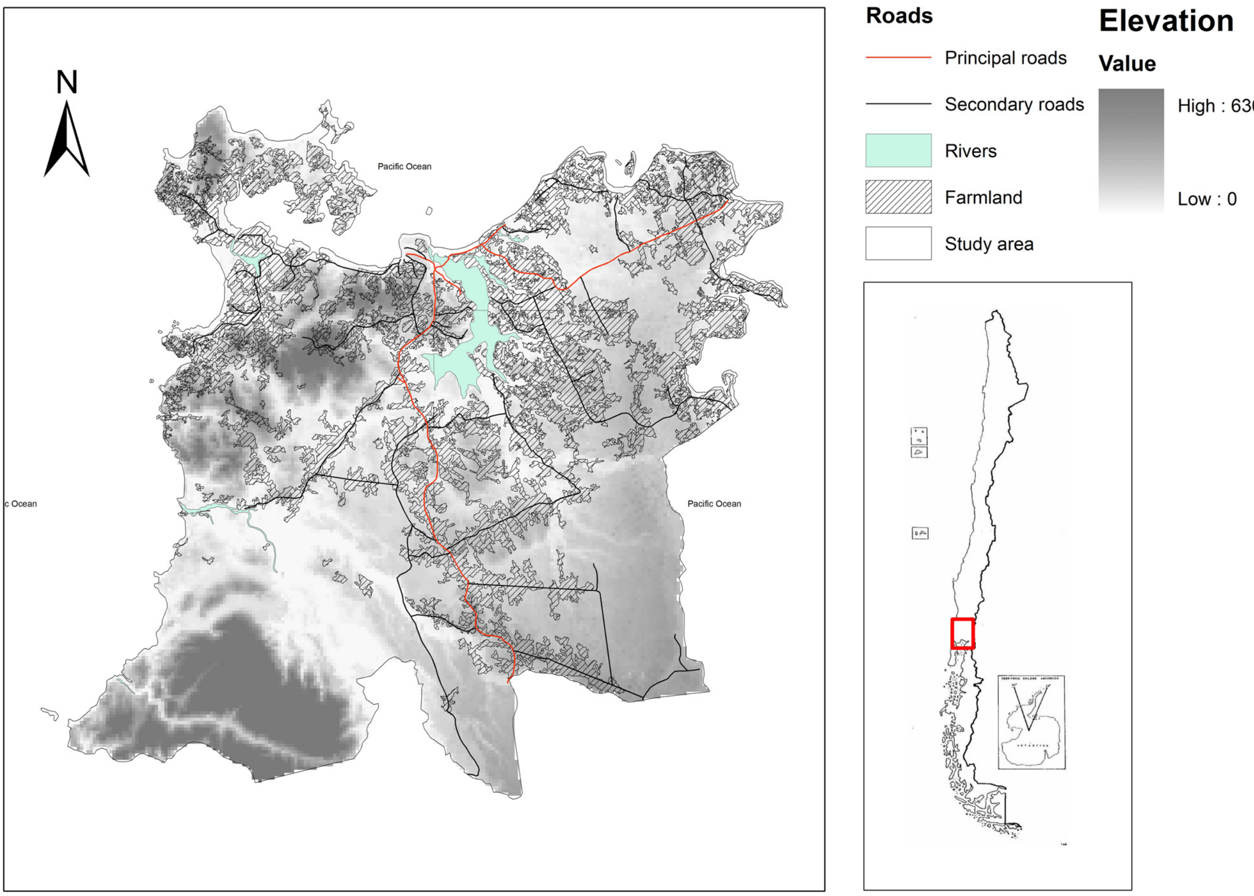

Fig. 1. Study area in Ancud municipality, Chiloé Island, Southern Chile.

them characterized by specific steps that are described in detail in Sections 3.1–3.6. Final ecosystem services are defined here as in Boyd and Banzhaf (2007): "the components of nature, directly enjoyed, consumed, or used to yield human wellbeing". The term "final" in the case of AH emphasizes not only the last biophysical natural entity used by individuals to acquire a benefit (Nahlik et al., 2012), but also some cultural elements of the socioecological system that provides the service (e.g. keepers' culture and practices).

As expressed in the introductory section, AH was considered a non-divisible combination of three cultural services (henceforth dimensions) as defined by the MEA (2005):

(i) Heritage value associated to Chiloé native potato as a *culturally significant species* (Dimension 1, D1). Crop genetic resources are the result of collective action over many generations of crops and farming people (e.g. shared knowledge, seed exchange, and the accumulation of valuable traits in crop populations) (Brush, 2007).

(ii) *Systems of knowledge* (Dimension 2, D2). Cultural knowledge is defined here as "any set of ideas, prevailing in a given culture or subculture, which provides a way of organizing information about the world or about any aspect of it" (Richter, 1972). As such, "cultural knowledge is distributed and transmitted within communities and must be learnable and broadly shared" (Keesing, 1979). Conscious crop selection and maintenance implies knowledge systems about the crop and its environment, which are subsets of the more general traditional knowledge and indigenous knowledge (Ellen and Harris, 2000).

(iii) *Social relations* (or *social networks*) established in the agricultural society of Chiloé Island (Dimension 3, D3). Traditional agricultural landscapes, such as that of Ancud, are often the product of complex farming systems that have developed in response to the unique physical conditions as well as cultural and social influences (Phillips and Stolton, 2008).

Given the complexity of these three dimensions, a major challenge for mapping AH was the selection of spatial proxies capable to represent its biocultural properties. In the proposed framework, the basis for the representation of these properties was the presence, spatial distribution, and attributes of farmers that grew native potato and recognized themselves as keepers.

3.1. Identification and characterization of native potato keepers (Step 1)

A keeper was defined as a small to medium farmer, who primarily grew native potato for traditional rather than commercial reasons. The initial identification of keepers was supported by key informants from different local institutions (e.g. Centro de Educación y Tecnología, CET-Chonchi; Programa de Desarrollo Local, PRODESAL-Achao; Municipality of Castro), and representatives of farmer's organizations (i.e. Organic Producers Association) (Mercado, 2013).

After this preliminary identification, a snowball approach was used to reach as many keepers as possible. Snowball sampling is a non-probability-based sampling technique that is used to identify potential subjects in studies where they are hard to locate. This type of sampling technique works like chain referral, where initially sampled individuals lead to other members of the hidden population, which in turn could lead to further members (Frank and Snijders, 1994).

Using this technique, 15 native potato keepers were reached within the municipality of Ancud. It is estimated that there are nearly 4000 farmers in the entire Chiloé Archipelago that cultivate some native potato varieties in very small amounts. Most of them are located in the municipalities of Castro, Dalcahue, Achao, Chonchi, Huillinco, and Quellón and particularly in the smaller islands (around 40) (Pers. comm). Ancud instead is more dedicated to livestock which would explain the low number of keepers encountered.

An in-person interview was applied to these 15 keepers in February of 2012 which gathered data on the following aspects: (i) Socio-demographic information; (ii) Native potato growing practices; (iii) Systems of maintenance of potato cultivation; (iv) Institutional support (technology and credit); and (v) Social networks (Mercado, 2013). All the questions contained in the interview were translated into variables that were related to one or more AH dimensions. For example, dimension 1 related to variables such as the quantity and type of native potato grown by the keeper, whereas dimension 2 related to variables such as the way in which the keeper learned to cultivate native potato and dimension 3 was linked to variables regarding keepers' networks and seed exchange.

The digitized interview points were loaded into a geodatabase as a point feature class, while data from each of the other survey sections were loaded into separate database tables. Each survey point and data recorded included a unique identifier (survey ID) so all data from a single survey could be related.

3.2. Expert validation of variables that determine AH dimensions (Step 2)

To validate the initial grouping of variables selected to represent AH, a focus group was held with experts who worked on the fields of agricultural economics, rural development, rural sociology and natural resources. Their selection was based on their knowledge and their academic contribution to rural development in southern Chile. It is important to recognize, that expert's selection can always be improved in almost any study of this kind and that the resulting maps can be indeed sensitive to this selection. In order to account for that sensitivity, a procedure was devised to estimate the expert's consensus level. During the focus group, a semi-structured questionnaire was applied which asked the experts about the relevance of the initially selected variables in each dimension. The importance of the variable was categorized as low, medium and high. For those variables on which experts did not reach consensus, the mode value was used to account for the degree of importance of the variable. A high consensus value was given if more than half of the experts were represented by the mode; a medium consensus value was given when the mode comprised half of the experts; and a low consensus value occurred when the mode represented less than half of them.

3.3. Weighting of variables that determine AH dimensions using Analytical Hierarchy Process (AHP) (Step 3)

After the focus group was held, and once consensus was achieved with regard to the variables that determined each dimension of AH, a questionnaire was applied to them by email which had two purposes: (i) to show the changes made in the variable's grouping based on the results of the consultation, and (ii) to assign a weight to the variables within each AH dimension.

One of the most widely used methods in spatial multi-criteria decision analysis is the Analytical Hierarchy Process (AHP) (Kordi and Brandt, 2012). Various approaches exist to improve the organization of AHP, such as the weighted coefficients method or the Saaty matrix, which was the approximation used in this study. Yet the method was adapted to handle expert rankings and translate them into pairwise comparisons using the average of the rankings weighted by the frequency of the answer. The pairwise comparison matrix relied on an underlying scale with odd values from 1 to 9, aimed at estimating the relative importance of one variable as compared to another within each dimension, and led to the construction of a comparison matrix of the ranks for each hierarchical level (Saaty, 1990). A wide variety of techniques exist for computing the alternative weights. In this case, a specific package of IDRISSI taiga (Clark Labs, Clark University, 2009) was used. To ensure the consistency of the weights given by the experts, a consistency ratio (Cr) was calculated. This ratio can be expressed as follows:

$$Cr = \frac{Ci}{Ri} \qquad (1)$$

where Ci is a consistency index equal to:

$$Ci = \frac{\lambda_{\max} - n}{n - 1} \qquad (2)$$

and where λ represents the eigenvalue of a pairwise comparison matrix, n is the matrix order, and Ri is a random index whose value depends on the matrix order in the following manner:

Order	1	2	3	4	5	6	7	8	9	10	11
Ri	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

Ri indicates the probability that the matrix ratings be randomly generated. As a general rule, matrices with consistency ratio greater than 0.10 should be re-evaluated.

The main outcome of this step was a "function" of each AH dimension where each of the three functions was the result of a weighted combination of the validated variables, expressed in a 0–100 point scale.

3.4. Spatial representation of the AH dimensions (Step 4)

Mapping AH, as mapping culture, poses the significant challenge of representing human–environment interactions which in turn implies the need to integrate data from different scales and time periods into a broader understanding of how people adapt to and modify their environments, and how they regulate and manage resources. To spatially represent each dimension of AH, the assumption was made that higher values of each dimension's function would be found in areas of highest density of keepers. While a simplification of the complex nature of AH, this assumption can be sustained on the theory of social networks (for a revision of the theory, the reader is referred to Barnes, 1954; Granovetter, 1973; Freeman et al., 1992; Meyer, 1994; Wasserman and Faust, 1994). This theory has been used to explain a wide range of real-world phenomena, such as social status and social influence. It assumes that resources, such as information and knowledge, are exchanged in the spatial-dependent relationships among individuals (Moolenaar, 2012).

Based on this general assumption, a Kernel Density (Spatial Analyst) was conducted. The Kernel function is based on the quadratic Kernel function described by Silverman (1986). Kernel density estimation calculates the density of point features around each output raster cell where only a circular neighborhood is possible. In the estimation, a smoothly curved surface is fitted over each point. The surface value is highest at the location of the point and diminishes with increasing distance from it, reaching the value of zero at the search radius distance from the point. The volume under the surface equals the population field value for the point (that depends on the variable or dimension assessed). The density at each output raster cell is calculated by adding the values of all the Kernel surfaces where they overlay the raster cell center. The reason for choosing Kernel density instead of other interpolation techniques, was that most variables comprised if the AH functions did not fit a linear regression on distance, whereas Kernel application does not require the assumption that a particular variable behaves according to distance, yet it gives the largest values to those areas of highest concentration of a given feature.

A 100 × 100 m spatial resolution was chosen to make the flow map comparable to the benefit map which was expressed in US$/ha. Given the spatial extent of the study area (e.g. the maximum distance between extremes of the municipality is approximately 60 km), a search radius parameter of 5000 m was used following Alessa et al. (2008). This value was chosen given the size of the study area, and because it represented the average distance among keepers, to which all the information to be interpolated was attached. After the interpolation, the result for each interpolated variable was normalized such as the resulting values ranged between 0 and 100. Normalization involved multiplying all the values by 100 and dividing by the maximum value obtained by each variable and dimension.

3.5. Creation of the AH flow indicator (Step 5)

The final AH indicator was the combination of each normalized dimension and had the form $AH_i = D_1 + D_2 + D_3$. From this indicator measured in a 0–100 point scale, a map was produced that showed the areas with potential for AH conservation. As AH was circumscribed to farmland, shrubland and forest cover areas were excluded from the representation of the indicator based on land cover information obtained from the National Vegetation Survey (CONAF et al., 1999).

3.6. Spatial assessment of AH benefits (Step 6)

The benefits actually delivered depend not only on the ecosystem's capacity to provide services, but also on the demand for these services, which is, in turn, driven by population size, cultural preferences, and the perceived value of the service (Villamagna et al., 2013). One of the main problems in estimating such benefits is deciding on the relevant population: whose benefits should be counted? This is important since aggregate benefits depend on both individual benefit and the number of beneficiaries. Aggregate non-use values are even more difficult to calculate, since such values may in principle be held by anyone (Hanley et al., 2003).

The estimation of non-use benefits of AH relied on data previously gathered through a Contingent Valuation (CV) survey applied in person in January of 2012 in the cities of Castro and Ancud in the Los Lagos administrative region (where Chiloé Island is located), the city of Valdivia which is the capital of the Los Ríos administrative region (379 km distance from Chiloé) and Santiago Metropolitan region which is the country's capital (1198 km distance from Chiloé). The cities were selected to represent different groups of potential beneficiaries of AH according to distance from the point of provision (Chiloé). Following Portney (1994), the CV survey consisted of three sections. The first section explained to the respondent the relevancy of Chiloé native potato as a cultivated genetic resource, its traditional form of cultivation, and the threats to its in situ conservation. The second section contained the presentation of the hypothetical market for AH, the payment vehicle (i.e. donation to a conservation Foundation) and the willingness to pay (WTP) question. Finally, the third section included questions concerning demographic characteristics of respondents, such as gender, age, monthly income, education level, and occupation. Whereas the hypothesis was that WTP decreased with distance, the results showed that were not significant differences in mean WTP across sub-samples. In consequence, the value used in this study was the average WTP for the entire sample (627 people) which was equal to US$50.54/person/year (Barrena, 2012).

Multiplying this individual value by the working population of the three regions (N = 2,370,538 people) (INE, 2012) and adjusting for hypothetical bias (NOAA, 1994; Harrison and Rutström, 2005; Bedate et al., 2009) a final aggregate benefit of US$39,935,664 was obtained, which can be interpreted as the non-use economic value people place on the AH conservation in Chiloé. This value was adjusted to represent the value of AH conservation only in Ancud, using as criteria the proportion of keepers that conserve native potato only in this municipality respect to the total, which produced a benefit of US$149,758.

Along with the question of whose benefits should be counted, another relevant issue to resolve was where to ascribe these benefits. Since these benefits are held by local as well as distant users (as is the case for non-use values) the approach was followed to spatialized AH_B by "stacking" the potential benefits at their "point of provision", following the distribution of AH_i. If all farmland had had the same AH value, the benefit map would have been obtained dividing the total benefits (US$149,758) by the number of farmland hectares. But since AH_i varied across hectares of farmland, the benefits that would have otherwise been allocated homogeneously, had to be adjusted by the AH_i value of that hectare. The equation that represents this adjustment is the following:

$$AH_B = \frac{149,758}{\text{Farmland (ha)}} * AH_i * \frac{149,758}{\sum_{i=1}^{n} AH_i * 149,758} \quad (3)$$

In this way, those hectares with a higher AH_i value will have a proportionally larger benefit. Other important reason for mapping benefits on areas of provision was the interest on the identification of the most valuable areas for their capacity to satisfy a potential demand, which has direct implications on policy design.

4. Results

4.1. Characteristics and spatial distribution of AH keepers

The age of the keepers (80% was female) ranged between 26 and 55 years, with an average of 39 years. The majority of them (73%) had completed high school, while the remaining 27% held only primary education (13%) or had a professional degree (13%). The average number of family members was four and an average of two members worked at the farm. Only 13% of the interviewees declared to hire off-farm labor. The average farm size was 4.4 ha ranging from 1 ha to 70 ha and most land was dedicated to pastures for livestock. The majority of keepers (93%) declared to cultivate some percentage of native potato for self-consumption, whereas 73% of them indicated to sell some amount. Near 80% of them grew four or more varieties of native potato, with a maximum of 13 varieties in a single farm. Regarding crop maintenance, 94% declared to keep and storage native potato seeds, whereas only 6% affirmed to buy and exchange seeds. Over 90% obtained his/her knowledge on native potato cultivation from relatives and other members of their community whereas none of them obtained this knowledge from established technical assistance programs, which suggest the importance of the oral transmission of cultural practices. Regarding government support, 80% of them did not received help from any public institution (e.g. technical assistance or credit). Finally, 60% of them declared to cultivate commercial varieties of potato along with the native varieties.

Keepers were concentrated on the northern edge of the municipality, on locations with low density of roads and near the coast and concentration of subsistence farms which represent 57% (1565) of total farm holdings in the study area (Carmona et al., 2010).

4.2. Variables that determined AH dimensions

The results of the first expert consultation showed a general acceptance of the variables selected to evaluate each of the three dimensions (Table 1).

Particularly for dimension 1, the degree of consensus varied from high to medium; the highest consensus was reached for the variables *number of potato varieties* (D1a) and the ratio *quantity of native potato for self-consumption/quantity harvested* (D1e). On the contrary, the lowest level of agreement was registered for the variable *cultivated area of native potato* (D1c). Since this variable showed a level of acceptance equivalent to indifference and a low level of consensus, it was eliminated from the group of variables selected for this dimension.

Dimension 2 registered less consensus, ranging from medium to low levels. Two exceptions were the variables *cultivation practices were learned by working at the farm* (D2b) and *main reason to grow native potato is tradition across generations* (D2c), which presented levels of acceptance equivalent to agree and strongly agree. As a result of the low level of acceptance and consensus, variables D2d, D2e, D2g, D2h, D2i and D2j were eliminated.

Dimension 3 showed the highest level of acceptance, but given a low level of consensus, variables D3d and D3e had to be excluded.

4.3. Functions of AH dimensions

The following functions were obtained for each dimension as a result of the expert consultation:

$$D1 = 0.25 * D_{1a} + 0.08 * D_{1b} + 0.04 * D_{1d} + 0.12 * D_{1e} + 0.24 * D_{1f} + 0.27 * D_{1g}$$

$$D2 = 0.19 * D_{2a} + 0.55 * D_{2b} + 0.19 * D_{2c} + 0.07 * D_{2f}$$

$$D3 = 0.39 * D_{3a} + 0.29 * D_{3b} + 0.22 * D_{3c} + 0.10 * D_{3f}$$

Dimension 1 reached a highest value of 98 (in a 0–100 point scale), a minimum of 3.9 and a mean of 37.3 (SD 28.5). The consistency ratio for the function was 0.09, which is considered acceptable for an independent distribution. The most relevant variable determining this dimension, with a weight of 0.27, was *storage and use of own native potato seed* (D1g) followed by the *number of native potato varieties cultivated by the farmer* (D1a), with a weight of 0.25.

Dimension 2 reached a maximum value of 88, a minimum of 1.1, and a mean value of 27.1 (SD 26.7). The consistency ratio was equal to 0.0 which implies coherence (not a random outcome). The most relevant variable within the function of this dimension was *cultivation practices were learned by working at the farm* (D2b) with a weight of 0.55. On the contrary, the variable *soil fertilization is made with farm-made products* (D2f) had a marginal contribution.

Dimension 3 reached a maximum value of 65.6, a minimum of 2.1 and a mean value of 24.7 (SD 20.1) and a consistency ratio of 0.06. The weights were homogeneously distributed among at least three variables which were *exchange of native potato seed* (D3a) *number of farmers that integrate your network* (D3b) and *participation of* "*minga*" (D3c) with weights of 0.39, 0.29 and 0.22, respectively. The spatial distribution of each dimension and the final AH indicator is shown in Fig. 2.

Whereas dimension 1 reached its highest values in the northwest and east coast of the municipality, the highest values of dimension 2 concentrated only in the north west coast. In turn dimension 3 had a similar distribution to dimension 1.

4.4. AH flow indicator (AH_i)

The final indicator, in which the three functions of AH dimensions merged, reached a maximum value of 81.3, a minimum of 1.3, and a mean of 29.6 (SD 24.4). Although the three dimensions had the same weight in determining AH_i, dimension 1 was more important in defining those areas of highest values of the indicator, as they reached mean values higher than other dimensions (Fig. 2).

It is important to note that both, the function of each dimension and the composite function of AH_i are theoretical functions. These functions reach their maximum value (100), only if a given hectare has the proper combination of attributes indicated by the theoretical function which for the case of Ancud did not occur, such that values of 100 were not reached (Table 1).

The areas with highest values of AH_i, were located on the north west coast (Punta Guabún) with values that ranged between 72 and 81. These areas are characterized by the presence of subsistence farming systems that combine agriculture and small-scale fishing and aquaculture, a livelihood that is characteristic of Chiloé Island. As expected, the lowest values of the indicator coincided with proximity to the city of Ancud and other urban developments (Fig. 2).

4.5. AH benefit indicator (AH_B)

The indicator of benefits reached a maximum value of US$10.64 ha^{-1} and a minimum of US$0.18 ha^{-1}, with an average of US$3.8 ha^{-1} and a standard deviation of US$3.2 (Table 2). Most farmland reached values of AH_i between 46 and 66, which corresponded to economic values between US$6.6 ha^{-1} and US$8.6 ha^{-1}. Also most farmland area (13,070 ha) held the lowest values of both indicators.

Since the benefits were assumed to follow the spatial distribution of the flows, both indicators were correlated in space as shown in Fig. 3.

5. Discussion and conclusions

This paper set out to develop a framework to identify and map highly intangible CES, which was illustrated with the case of agricultural heritage (AH) in Ancud municipality, Chiloé Island, southern Chile. As this study was primarily an exploration of a mapping approach, the process was as important as the product. In the following sections the framework is discussed around three questions: what is being mapped, how is being mapped and what for. The extent to which a mapping framework can answer these questions coherently is a measure of its internal consistency and also the basis for credibility, salience and legitimacy of maps (Hauck et al., 2013).

In line with other authors, the framework acknowledges that CES do not represent purely ecological phenomena, but rather are the outcome of complex and dynamic relationships between ecosystems and humans in landscapes over long time spans (Fagerholm et al., 2012). As a result, they are difficult to quantify in biophysical assessments, and their economic evaluation is generally subject to controversy. Moreover, their normative nature and the heterogeneity of their valuation by various stakeholders provide additional challenges (Rambonilaza and Dachary-Bernard, 2007; van Berkel and Verburg, 2014).

5.1. What is being mapped? The conceptual challenge

Underlying the framework is the assumption that decisions based on ecosystem service maps require a clear distinction

Table 1
Variables selected to represent each dimension of agricultural heritage and level of agreement and consensus given by the expert panel (excluded variables are highlighted with an asterisk).

Variable code	Variable description	High disagreement	Disagreement	Indifference	Agreement	High agreement	Consensus
Dimension 1							
D1a	Number of native potato varieties cultivated by the farmer					x	High
D1b	Type of native potato varieties cultivated by the farmer				x		Medium
D1c	Cultivated area of native potato*			x			Medium
D1d	Exchange of native potato seed				x		Medium
D1e	Quantity of native potato for self-consumption/quantity harvested				x		High
D1f	Quantity of native potato cultivated/quantity of commercial potato cultivated				x		Medium
D1g	Storage and use of own native potato seed				x		Medium
Dimension 2							
D2a	Cultivation practices used come from inheritance					x	Medium
D2b	Cultivation practices were learned by working at the farm					x	High
D2c	Main reason to grow native potato is tradition across generations				x		High
D2d	Main reason to grow native potato is self-consumption*		x				Low
D2e	Soil preparation is made manually*			x			Medium
D2f	Soil fertilization is made with farm-made products (organic fertilizers, algae)				x		Medium
D2g	Soil fertilization is mixed (own made organic fertilizers and chemical commercial fertilizers)*		x				Medium
D2h	The farmer uses crop rotation techniques*		x				Medium
D2i	Plagues control is by natural techniques (without use of chemical products)*	x					Low
D2j	The farmer uses previous management practices to avoid plagues*	x					Low
Dimension 3							
D3a	Exchange of native potato seed					x	Medium
D3b	Number of know farmers that integrate your network of seed exchange					x	High
D3c	The farmer participates of "minga"[a]					x	High
D3d	The farmer hires labor for specific farm activities*					x	Low
D3e	The farmer uses hired labor all year round*				x		Low
D3f	The farmer uses a mix of family and hired labor					x	Medium

[a] Minga is a traditional costume in Chiloé where families help each other by sharing and exchanging family labor for different farm activities.

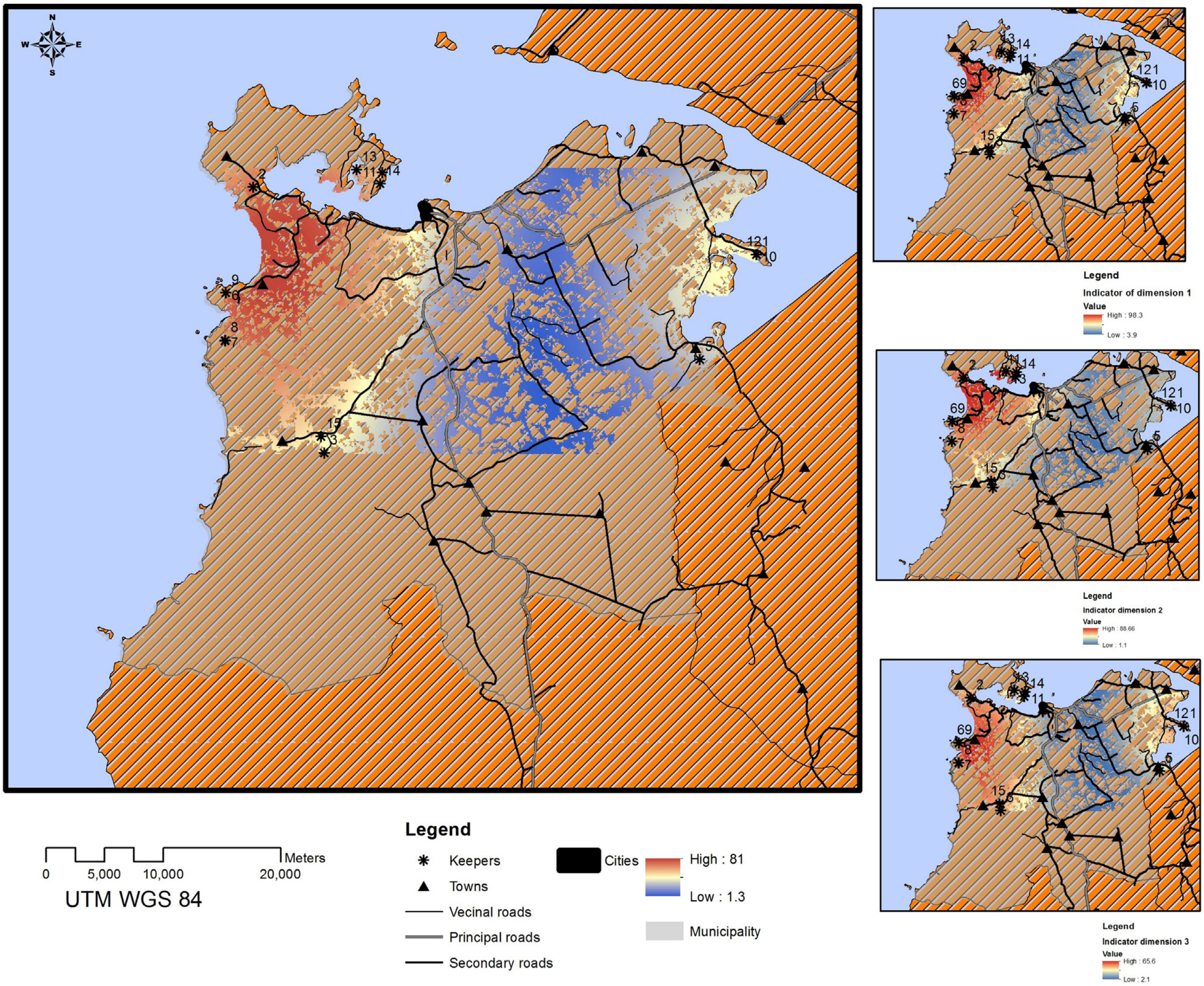

Fig. 2. Spatial distribution of each AH dimensions and AH_i in the study area (only farmland).

Table 2
Indicators of the final service (AH_i) and benefits (AH_B) and its equivalent hectares in the landscape (farmland).

AH_i	Ha	AH_B (US$/ha)
81–66	5608	10.64–8.64
65–46	3168	8.63–6.02
45–28	7556	6.01–3.66
27–13	9217	3.65–1.70
13–1	13,070	1.69–0.18

between ecological phenomena (functions), their direct and indirect contribution to human welfare (services), and the welfare gains they generate (benefits) (Haines-Young and Potschin, 2010). In this study, two indicators were produced that aimed at representing the final service (AH_i) and its benefits (AH_B). In essence, AH_i reflects the potential capacity of the socioecological system to provide the ecosystem service (Villamagna et al., 2013) and is composed of a set of attributes that represented the biophysical and socio-cultural domain of AH. Fundamentally, five variables defined the indicator and therefore the magnitude and spatial distribution of AH: the number of potato varieties cultivated by the keeper; use of own seed; way in which cultivation knowledge was acquired; exchange of own seed; and number of other keepers known. For the specific socioecological context of Ancud, these variables represent the links between ecosystem features and social features associated with cultural identities and social practices.

In turn AH_B reflected society's benefits for agricultural heritage conservation, measured by willingness to pay obtained through a contingent valuation study. "Society" here corresponds to people from three different regions of the country, who represent both local and distant beneficiaries. Economic valuation of CES has been highly contested in ecosystem service literature (Daniel et al., 2012) and in fact several authors state that while non-market economic valuation techniques can be successfully applied to cultural heritage objects, valuation of some features, such as identity or sense of place, remain largely elusive (Navrud and Ready, 2002; Butler and Oluoch-Kosura, 2006). In this study AH_B stands for individual and market mediated preferences and as such it accounts only for a group of values and benefit categories (Chan et al., 2011). As such it should be complemented by indicators obtained using other approaches such as expertly facilitated deliberation, which can elicit and refine relevant cultural heritage values and the ecosystem features with which they are associated (Gregory and Wellman, 2001; Gregory and Trousdale, 2009), thus helping to articulate management tradeoffs and effectively capturing these values for policy making (TEEB, 2010).

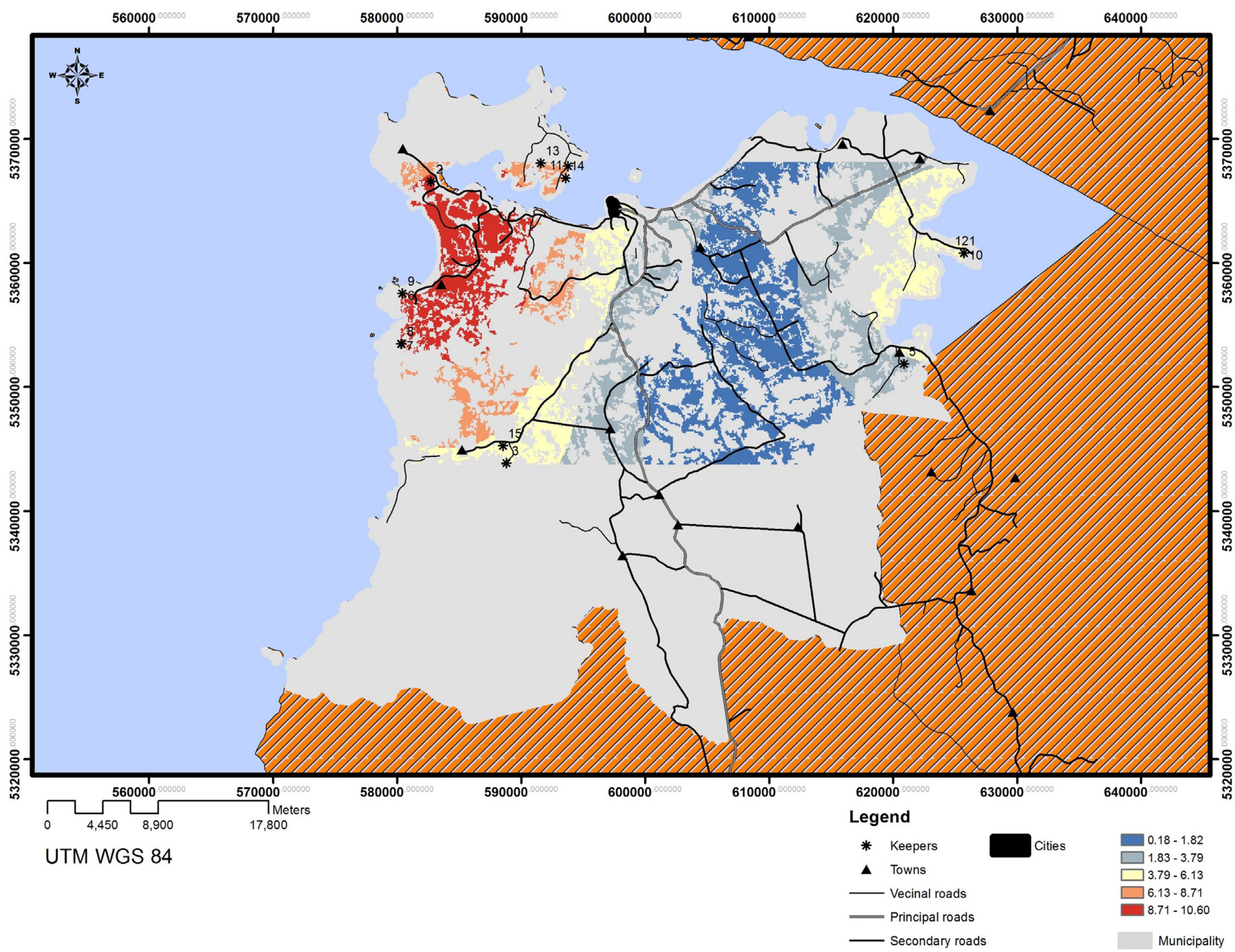

Fig. 3. Spatial distribution of economic benefits of AH in the study area (only farmland).

5.2. *How is being mapped? The methodological challenge*

Most studies mapping CES have successfully represented the biophysical and physical components of heritage, using for example spatial objects such as tree lines and hedgerows, stone quarries, and recreation sites present in cultural landscapes (van Berkel and Verburg, 2014) or sites serving as meeting points and sites relevant to local history and culture to represent social relations and cultural heritage, respectively (Plieninger et al., 2013). However, mapping these types of spatial landscape features excludes those areas for which such objects do not exist. Another characteristic of these approaches is that resulting maps are "beneficiary-driven", meaning that they relate more to the observer than to ecosystem or socio-ecosystem conditions (Kumar and Kumar, 2008; Hansen-Möller, 2009). In the case analyzed here, the presence, location and attributes of native potato keepers were central to the mapping protocol since if there are no keepers there is no ecosystem service to benefit from. Given the challenge of mapping heritage, the construction of AH_i and AH_B relied on some simplifying assumptions which are discussed below.

(a) *Expert consultation can give a robust approximation of agricultural heritage magnitude and distribution.*

Expert consultation was a key step to identify and weigh the variables that defined AH. As other mapping studies relying on expert consultation, the procedure presented here is sensitive to expert selection. Several works have stated the need for comparative studies that assess the similarities and differences between the maps generated by different stakeholders (e.g. the public, experts, and policy makers) for those intangible or abstract ecosystem services as well as those that involve more complex ecological processes such as regulating services (Brown et al., 2012). Clearly future research in developing mapping protocols should aim at improving the engagement of experts and stakeholders at different stages of the assessment. Efforts in this direction are in the context of Participatory Planning GIS (Brown and Weber, 2012) and participatory mapping of ecosystem services (Sherrouse et al., 2011; Plieninger et al., 2013).

(b) *It is possible to apply Kernel density methods to existing keepers, as a form of representing areas where there is culture latency.*

Kernel density method works under two key assumptions. The first relates to the representativeness of the sample of keepers. In this regard, while the snowball technique is a valuable tool, especially when no previous information exists regarding the universe of individuals, uncertainty prevails if a majority of that universe was actually reached. Hence the technique should be well sustained by complementary information provided by key informants. In the case at hand this complementary information supports that few keepers indeed exist in Ancud. In fact the GIAHS initiative has privileged other two municipalities (particularly the smaller islands) over Ancud to start implementing the program. The small number of keepers (15) however complicates mapping since AH_i is extremely sensitive to the number of points surveyed. A greater amount of information (keepers) means "less space" to be filled through interpolation.

The second assumption is that distance and neighboring effects among keepers are crucial for "cultural transmission". From the settlement and until present time, Chiloé population has been characterized by important family bonds which could help sustain the transmission of knowledge and social relations. Also network theory suggests that strong social relations are associated with "propinquity" (i.e. the tendency for actors to have more ties with geographically closeness; Kadushin, 2012).

(c) *Benefits from AH can be mapped at the point of its provision.*

Because the mapping of ecosystem services is a relatively new area, many unresolved issues remained associated with the spatial analysis of cultural values. One of these key issues is where to map the benefits from CES: e.g. at the areas where the enjoyers live vs. at the areas where benefits are provided (or produced). Clearly that question hides a false dichotomy since these approaches are not equally suitable for different mapping objectives. For example, while mapping benefits where enjoyers live may be useful for supply-demand analysis (e.g. García-Nieto et al., 2012), mapping at the provision points is a better option for the identification of the most valuable areas. In the last case, because of anisotropic flow patterns, maps of benefits may be not strictly coupled to the maps of CES provision. Closely related, is the issue of who within society is benefitting from the flow of cultural services, and where these people are located (Ambrose-Oji and Pagella, 2012). In the case at hand, the designation of Chiloé as a pilot GIAHS site implies that the benefits of AH conservation are global in nature – AH is valued by stakeholders at different spatial scales and in fact the designation implies that benefits accrue to humanity's present and future generations. Thus, the benefits of AH can be assumed to spread omnidirectionally – the service is provided in one location, but benefits surrounding areas without directional bias (Fisher et al., 2009) and potential benefits can be "ascribed" at their "point of provision", i.e. the place where AH is "produced" rather than the area over which it propagates.

The approach of ascribing the benefits at the point of provision follows a similar logic to benefit transfer and it should not be confused with mapping ecosystem service supply or demand. Some recent conceptual frameworks distinguish these constituents of ecosystem service delivery, but definitions and relations among these components differ widely across authors. For example, capacity has also been referred to as potential supply (Burkhard et al., 2012), ecosystem potential (van Oudenhoven et al., 2012), stocks of nature, and ecosystem service per se (Norgaard, 2010; Layke, 2009), yet the underlying meaning is the same. In turn, demand has been defined as the sum of all ecosystem goods and services currently consumed or used in a particular area over a given time period (Burkhard et al., 2012; Tallis et al., 2012) which differs from the economic meaning of the demand concept as it is used in this study, as the aggregation of benefits as measured by willingness to pay.

Given the difficulties of mapping CES beyond esthetics and recreation, some authors have suggested mapping methods such as having respondents delimit service providing units by markers or sticker dots, which however, involve similar or other inaccuracies (Fagerholm and Käyhkö, 2009), and "the best" or a "best" method has not been identified. Triangulation processes (Lynam et al., 2007), for example which relies on qualitative approaches such as in-depth interviews about how and why respondents appreciate a particular site for a specific service, may offer further intuitions (Tyrväinen et al., 2007).

(d) *Variation of AH flow with biophysical attributes of the ecosystems and landscapes is negligible.*

Since it was assumed that farmlands were biophysically uniform at the observation scale, no specific biophysical variables were considered in the calculation of AH_i. However, this may be not the case under wider extent or lower resolution scales, where variation in AH_i might not be necessarily independent of landscape features like land cover types (Plieninger et al., 2013).

5.3. What to map for?

Usually, studies mapping ecosystem services state a decision of some sort as the final aim of mapping, but the final map outcomes do not necessarily coincide with the needs of decision-making (Nahuelhual et al., 2013). A recent work remarks the "salience" feature of maps which deals with the relevance of the assessment to the needs of decision makers. Probably the only way to meet this requirement is by having the final purpose of the map (the "what for" question) as a guide for the scientific inquiry (Hauck et al., 2013).

In most studies (this included) mapping efforts tend to focus on the "how to map" question (i.e. the methodological challenge) and aim at gaining scientific understanding of the complex relations underlying the provision of ecosystem services. In terms of influencing or contributing to decision-making (usually stated purpose, but arguably achieved), the mapping protocol presented here is intended to serve the goals of the GIAHS program in Chiloé Island, which are to encourage Chiloé recognition as a source of culture, tradition, and genetic biodiversity; to stimulate sustainable development, and to alert society about the importance of protection and conservation of biodiversity (FAO, 2012).

Having this as the decision-making setting, the purposes of developing AH indicators are primarily two. The first is to promote consciousness of CES conservation among different stakeholders. The indicators proposed can show the location of areas of highest ecological and economic value for AH conservation. In this sense the resulting maps can be a useful communication tool in the context of the GIAHS initiative and beyond. This is particularly important in the case of AH which in contrast to what has been achieved for other heritage categories in Chiloé (e.g. religious patrimony), has been underestimated and scarcely considered despite its relevancy in maintaining food security and rural livelihoods. The second purpose is to help public decision makers visualize the spatial consequences of different scenarios. In the case at hand two relevant scenarios are migration of keepers and agricultural land abandonment. Policy makers should take into consideration that vulnerable landscapes designated by GIAHS were created by rural communities and, in order to maintain them, farmers must have the possibility of making a living without intensifying their management practices. This is only possible if farmers are made aware of their role in the provision of other ecosystem services beyond food, such as the case of AH. In this sense, the results from mapping studies might help design specific incentives or compensation initiatives, for specific farmers.

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Appendix A. Results from the regression of each variable selected for each dimension having distance as independent variable.

Variable code	Variable description	R^2	Spatial representation method
D1a	Number of native potato varieties cultivated by the farmer	−0.51	Interpolation with IDW
D1b	Type of native potato cultivated by farmer	−0.50	Interpolation with IDW
D1d	Exchange of native potato seed	0.009	Density function with Kernel estimator
D1e	Quantity of native potato for self-consumption/quantity harvested	−0.56	Interpolation with IDW
D1f	Quantity of native potato cultivated/quantity of commercial potato cultivated	−0.37	Density function with Kernel estimator
D1g	Storage and use of own native potato seed	−0.8	Interpolation with IDW

Variable code	Variable description	R^2	Spatial representation method
D2a	Cultivation practices used come from inheritance	0.21	Density function with Kernel estimator
D2b	Cultivation practices were learned by working at the farm	−0.53	Interpolation with IDW
D2c	Main reason to grow native potato is tradition across generations	−0.79	Interpolation with IDW
D2f	Soil fertilization is made with farm-made products (organic fertilizers, algae)	−0.031	Density function with Kernel estimator

Variable code	Variable description	R^2	Spatial representation method
D3a	Exchange of native potato seed	0.009	Density function with Kernel estimator
D3b	Number of know farmers that integrate your network of seed exchange	0.16	Density function with Kernel estimator
D3c	The farmer participates of "minga"[a]	−0.12	Density function with Kernel estimator
D3f	The farmers uses a mix of family and hired labor	−0.44	Density function with Kernel estimator

[a] Minga is a traditional costume in Chiloé where families help each other by sharing and exchanging family labor for different farm activities.

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