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Ecosystem services provision, tourism and climate variability in shallow lakes: The case of La Salada, Buenos Aires, Argentina

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HIGHLIGHTS

- Ecosystem services provision is crucial for tourism in La Salada shallow lake.
- Wet and drought periods have been in turn registered in the area.
- Stakeholders have a crucial role into the lake management.
- Participatory research helps to evaluate stakeholders' perception.
- Ecosystem services provision remained almost unchanged between wet and dry periods.
- Tourism in la salada seems not to depend on the precipitation scenarios.

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ABSTRACT

Water ecosystem services have been widely explored within the context of climate change studies, becoming a key piece in addressing local water challenges and designing possible strategies for diminishing climate risks. This paper explores how ecosystem services provision in La Salada shallow lake, Argentina, including maintenance of the landscape for touristic and recreational activities, have been affected by changes in climate conditions according to the local stakeholders' perception. After mapping and prioritizing ecosystem services using participatory research activities, it analyzes how this provision has evolved in response to the different precipitation scenarios already observed in the area. The results for the case of La Salada shallow lake indicate that there is not a clear relationship between precipitations and the key ecosystem services provided by the lake and their surrounding ecosystem, mainly due to the anthropogenic lake management, and that tourism does not seem to directly depend on climate conditions.

1. Introduction

Anthropogenic impact on the environment has been the core motivation for several research lines oriented to elucidate the complex network of interactions between human beings and natural resources. Within this context, the notion of ecosystem services (ES), defined as the benefits that people obtain either directly or indirectly from ecological systems (Millenium Ecosystem Assessment, 2005), constitutes a way of understanding the relationship between humans and nature (Raymond et al., 2013) or between hydrology, landscapes, ecology and society (Martin-Ortega, Ferrier, Gordon, & Khan, 2015).

In a strict sense, there is no agreement on the exact definition and classification of ES. This situation has generated a broad global debate in the academic world on its scope and limitations. Since the

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term *ecosystem services* was coined (King, 1966), a huge amount of literature dealing specifically with this issue has been published (Bagstad, Semmens, Waage, & Winthrop, 2013; Boyd & Banzhaf, 2007; Braat & de Groot, 2012; Chaikaew, Hodges, & Grunwald, 2017; Costanza et al., 1997; Costanza et al., 2014; Daily et al., 2000; De Groot, Wilson, & Boumans, 2002; De Groot, Alkemade, Braat, Hein, & Willemen, 2010; Ehrlich & Mooney, 1983; Fisher, Turner, & Morling, 2009; Helliwell, 1969; Matzdorf & Meyer, 2014; Milcu, Hanspach, Abson, & Fischer, 2013; Schröter et al., 2014; Villa et al., 2014; Wolff, Schulp, & Verburg, 2015; among a hundred others). Moreover, the popularization of the concept has generated a lack of clarity about its meaning (Martin-Ortega et al., 2015) and an entanglement of all the related terminology. For practical purposes, this paper adopts the definition of ES proposed by Fisher et al. (2009), according to which they are the aspects of an ecosystem utilized actively or passively to generate human wellbeing.

For the particular case of water ecosystems, Fisher et al. (2009) propose to differentiate between abiotic inputs such as rainfalls, intermediate services such as water regulation, final services such as constant stream flow, and benefit such as water for different uses (irrigation, hydro-power or recreation). Nevertheless, since a particular service can be simultaneously intermediate and final, Fisher et al. (2009) point out the importance of considering the stakeholder's perception at the moment of defining what kind of ES is under analysis. On the one hand, every stakeholder perceives different benefits from ecosystem processes, which can in turn generate conflicts of interests; on the other hand, some stakeholders may not eventually perceive any ES value, even in the case of the generally appreciated ones, conditioning any valuation process.

The recognition of this important role of the stakeholders' perception leads to the incorporation of another dimension to the ES assessment, which can contribute to dealing with the idiosyncratic component of ecosystems defined by Daily (2000). This new dimension is aimed at shedding light on how water influences human livelihood and wellbeing, as well as on how ecosystems are impacted by human activities (Martin-Ortega et al., 2015).

The concept of ES has also been widely discussed from an economic perspective, and it is still one of the most controversial topics in environmental and ecological economics (Bateman et al., 2013; Brander, Florax, & Vermaat, 2006; Brauman, Daily, Duarte, & Mooney, 2007; Gómez-Baghettun, De Groot, Lomas, & Montes, 2010; Liu, Costanza, Farber, & Troy, 2010; Martín-López, Gómez-Baggethun, García-Llorente, & Montes, 2014; De Groot et al., 2012). Although there is no agreement on its exact meaning, almost all related works coincide in adopting some ES classification in line with the Common International Classification of Ecosystem Services (CICES) developed by the European Environmental Agency (EEA), which groups them into Provisioning, Regulation and Maintenance and Cultural Services, granting some degree of homogeneity to the specific language.

In recent decades, it has been found that climate variability affects human activities and, therefore, the economy of different regions of the world (Hughes, 2003). Climate changes cause an increase of extreme events, such as high winds, cold and heat waves and storms, among others. Both the intensity and occurrence of droughts and floods increase, but it is still very difficult to predict their future evolution. Therefore, communities should be alert, especially as regards water resources (Havens et al., 2016). In particular, the Pampas region is subject to continuous periods of heavy rain which cause floods in the area. Each lake there responds differently to flooding according to its typical characteristics. In some lakes, the increase in water volume favors fishing activities due to an increase in the abundance of fish species. Simultaneously, the intense erosion on their banks damages the infrastructure located in the area and deteriorates the roads reaching the lake. Droughts associated with La Niña phenomenon are also important and frequent and the human activities associated with lakes change. Fishing decreases; sometimes species disappear. Pollution increases due to the reduced volume of water, causing health problems and algae blooms, both with significant implications for the entire socio-ecological system surrounding the lake. Historically, ecosystems have suffered continuous periods of flooding and drought, although the current climate variability is generating an increase in their frequency and intensity at short intervals.

Within this context, the Ecosystem Services-based Approach, which was conceived as a transdisciplinary space aimed at understanding the complex relationship between resource users, nature and policy (Martin-Ortega et al., 2015; Rova & Pranovi, 2017), can help to explain how climate change is affecting the living conditions of local populations. In the particular case of La Salada shallow lake, Buenos Aires, Argentina, the socio-ecological system has been subject to varied scenarios of precipitations over the last decade, which in turn has determined wet and drought periods. The primary object of this paper is to qualitatively determine how this climate variability has affected the provision of the more relevant ES associated with the shallow lake, according to both its provision levels and consequent influence over the quality of life of the local population.

The paper is structured as follows. After the Introduction, Section 2 presents a brief overview of the ecosystem services-based approach and the participatory research methodology. Section 3 describes the area under study as well as its climatic characterization. Section 4 presents the methodology proposed for the analysis of both the morphometric changes seen in the shallow lake and the fieldwork for assessing the ES provision. Section 5 summarizes the results of the identification and prioritization of the key ES and the discussion of the comparison between both states, which constitutes the core of the paper. Finally, some concluding remarks are outlined in Section 6.

2. Nesting participatory research into ecosystem services-based approach

An ecosystem services-based approach (ESbA) can be defined as "*a way of understanding the complex relationships between nature and humans to support decision-making, with the aim of reversing the declining status of ecosystems and ensuring the sustainable use/management/conservation of resources*" (Martin-Ortega et al., 2015, p. 8).

Both the complexity and the multiple dimensions of the concept of ecosystem services have been acting as an attracting pole to combine the work of scientists belonging to several branches of knowledge, creating a transdisciplinary space aimed at dealing with environmental issues.

According to Martín Ortega et al. (2015), four core elements are needed to implement an ESbA. First, the interest must be focused on the status of ecosystems and their contributions to human welfare. This focus displaces ecology or biology from the center of the scene and turns the ESbA into a merely anthropocentric tool. Second, the biophysical support of ecosystems in terms of service delivery must be well understood. Until now, ecosystems have only been considered in terms of population dynamics, species, energy flows and other biological or ecological cycles. In this sense, the ESbA implies some kind of re-thinking of the relationship between humans and nature. Moreover, according to Martin- Ortega et al. (2015), the interactions of the components of an ecosystem, as well as their effects on a service or a set of services, must be identified and quantified. Recognizing interdependencies becomes essential for assessing ES across temporal and spatial scales.

The third element is transdisciplinary (Balvanera et al., 2017; Brandt et al., 2013; Schröter et al., 2014). As stated above, the integration of natural and social sciences and other strands of knowledge for a comprehensive understanding of the service delivery process leads to the need to implement an ESbA. This transdisciplinary element encourages environmental scientists to integrate their research, which solves this need for combining different areas of knowledge in a broader vision of socio-ecological systems (Bosch, Ross, & Beaton, 2003; Van Kerkhoff, 2005).

Note that the concept of integration implies the need for creating new dialogue spaces not only between researchers and decision makers but also with the users of natural resources. This idea has gained ground in the framework of watershed management research (Collins, Blackmore, Morris, & Watson, 2007; Johnson, Ravnborg, Westermann, & Probst, 2002). Since it suggests the involvement of local stakeholders, ESbA is open to non-academic strands of knowledge, including their views and perceptions at relevant scales. Furthermore, the "*co-construction of knowledge with stakeholders is essential to understand the variety of ways in which ecosystems generate wellbeing, and to establish the legitimacy of decisions based on the valuation of ecosystem services*" (Martin-Ortega et al., 2015, p. 9). Moreover, designing ES research according to the needs of the stakeholders involved makes the approach more user-inspired and user-friendly (Ramirez-Gomez et al., 2015), granting more relevance to their inclusion into decision-making processes.

Within this context, the stakeholders' perception of ES becomes a key piece in this framework of analysis. Moreover, under some conditions, stakeholders' involvement in resource management might also contribute to optimizing its use. Among these conditions, both the absence of different endowments of social capital among stakeholders and the organizational power of groups of stakeholders have an important role. This is because different social capital leads to different levels of political pressure, which in turn can lead to an outcome that would not match with the social interest (Scheffer, Brock, & Westley, 2000). Furthermore, these factors can eventually be combined and they might result in a poor treatment of the environmental issues.

Finally, the fourth element listed by Martin-Ortega et al. (2015) is the incorporation of ES assessment into decision-making, which can only be possible in the case of recognizing some social or individual kind of value of ES. The relevance of this is straightforward, since ESbA loses its meaning if the result does not involve local people. Moreover, according to De Groot et al. (2010), the ESbA has a great potential to manage environmental priorities and transform environmental policy making. The authors advocate the development of robust ES measurement and standards for ecological, socio-cultural and economic values to be shared between scientists devoted to ES in order to ensure the comparability and transferability of information.

From the third and the fourth elements, it can be concluded that the incorporation of stakeholders becomes the key piece to understanding environmental issues. The Participatory Research Approach fulfills this purpose, giving local people a crucial role in discussion and policy formulation (Blackstock et al., 2015). Furthermore, top-down and technical approaches should be combined with bottom-up approaches based on participatory knowledge if management strategies are aimed at obtaining positive results (Forrester, Cook, Bracken, Cinderby, & Donaldson, 2015).

On the other hand, it must be noticed that the Participatory Research Approach presents important advantages but also several difficulties derived from its own social nature. In fact, the proposed methodologies are embedded in a significant degree of subjectivity not only in its formulation but also in the way it interprets and evaluates the results (Bryman, 2015; Creswell, 2013; Ritchie, Lewis, Nicholls, & Ormston, 2013), incurring also some kind of bias. Unfortunately, going any further on this issue remains out of the scope of this study on account of its depth.

3. La Salada shallow lake: location and description

La Salada (39°27′S, 62°42′W) is a shallow saline lake located in the south of Buenos Aires province, Argentina (Fig. 1). There are few studies in the literature that mention this lake and it is only included as an example of a site (e.g., Quirós, Rosso, Rennella, Sosnovsky, & Boveri, 2002). It is a small, shallow and polymictic lake, with a total surface area of 4 km^2 and a mean depth of 2.5 m. Its main affluent is a channel derived from the Colorado river, which is managed by the Water Authorities, in a region where agriculture is carried out with irrigation. The river has a thaw regime, with floods between October and February and droughts between April and August (Spalletti & Isla, 2003). The water level fluctuation of the lake depends on the climate, but water management of the site is important and therefore it is seasonally controlled. In this endorheic system, water loss is only due to evaporation and groundwater infiltration. La Salada is an alkaline, mesotrophic-eutrophic shallow lake, with low Chlorophyll *a* concentrations (mean value of 8.6 μg L^{-1}) (Alfonso et al., 2015). Only two fish species live in the shallow lake: a particular type of omnivorous silverside (*Odonthestes* sp.), which is common (MAA, 2012) and the ten-spotted livebearer *(Cnesterodon decenmaculatus),* also known as *tosquero.* The climate of the region is cold temperate and mostly dry, although characterized by wet and dry cycles which depend on the annual rate of rainfall. Annual atmospheric temperature values range between 14 and 20 °C, with pronounced summers and winters, and moderate springs and autumns. According to the precipitation, the region was characterized as semiarid (Aliaga, Ferrelli, Alberdi-Algarañaz, Bohn, & Piccolo, 2016); the heaviest precipitations normally occur in spring and summer (average annual rainfall of 518 mm) (Scian, 2000). The dominant winds in the region are from the NW and wind speed stronger than 40 km h^{-1} for several hours is usual (Alfonso et al., 2015).

Regarding human activity, La Salada constitutes an important location for tourism activities related to water sports and recreational fishing, among other leisure activities. The shallow lake holds a seasonally varying flow of visitors, most of them neighbors of the surrounding rural and urban areas. In response to this tourism affluence, commercial activities and related provision services are experiencing an increasing degree of development that began a couple of decades ago. This has resulted in a rapid and not-completely well-planned urbanization process, which in turn reinforces the incipient development process of the shallow lake and the surrounding areas.

Although tourism is the core economic activity developed around La Salada shallow lake, other activities are performed as well. In the rural areas, land use has evolved from wild and native vegetation into livestock farming, and from livestock farming to agricultural activities. The type of crops has also changed according to both the climatic conditions and changes in demand, leading to different uses of soils, agrochemicals and fertilizers. Although the adjacent areas are devoted to agriculture and livestock production, they do not extract water from the lake for irrigation. As stated above, the water flow is managed by a water consortium. The Development Corporation of the Colorado River Valley (CORFO, for its name in Spanish) manages the concessions, permits and waterworks related to the rights of use of water and agricultural lands and has also the mission of preventing and combating erosion and degradation in order to preserve soil

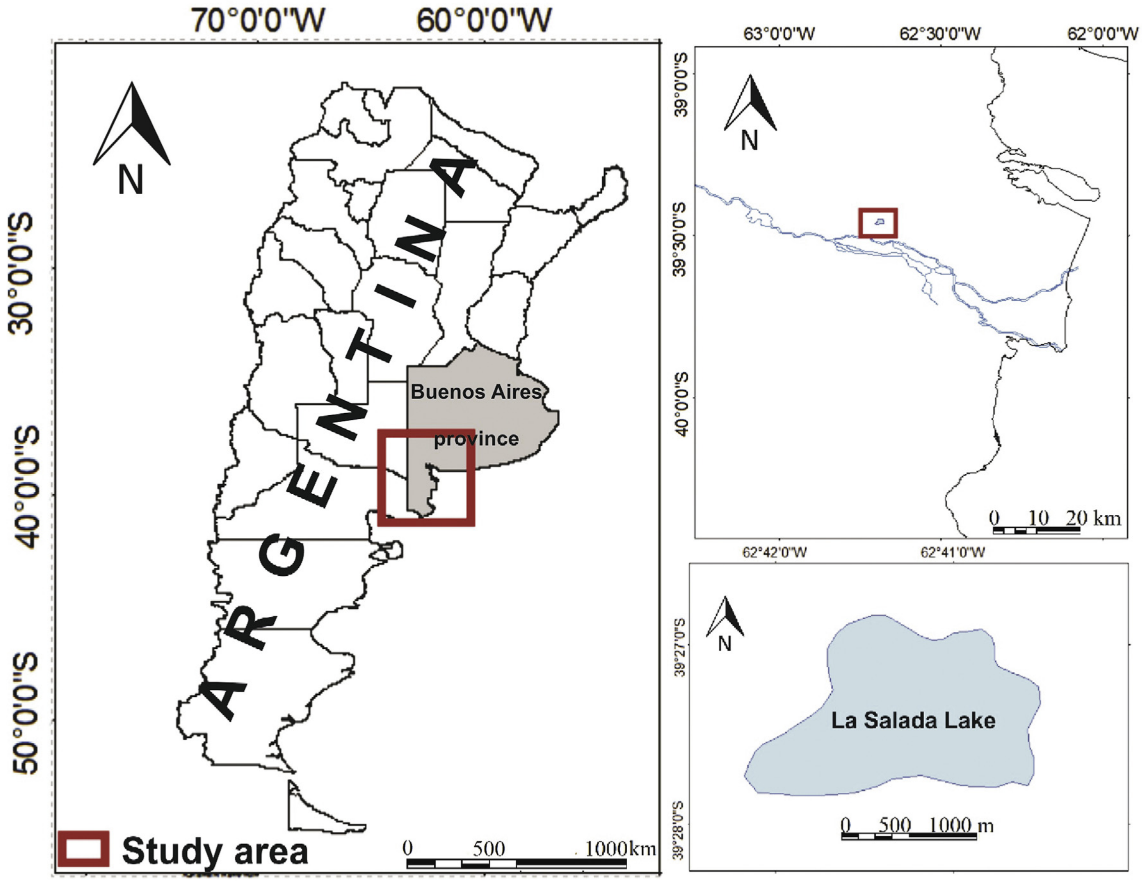

Fig. 1. Location of La Salada shallow lake.
Source: modified from Alfonso et al. (2015)

fertility. In the absence of a community-based management tradition, CORFO administers and enforces the irrigation regime in the area. Normally, the irrigation system gates are open each year from August 1st to May 1st.

Regarding the climate, La Salada shallow lake is located in a region where wet and dry cycles are usual. As stated above, the Water Authorities decide when and how much water enters the lake. Consequently, water level fluctuations in the lake are frequent, due to either climatic or anthropogenic causes. Once the key ecosystem services in the area are identified, some participatory techniques determine qualitatively whether ecosystem services provision changes or remains constant in each of the cases.

4. Methodology

4.1. SPI analysis

To assess the effect of climate variability, historical precipitation and temperature values from 1966 to 2015 were obtained from a nearby meteorological station within 10 km from La Salada (Instituto Nacional de Tecnología Agropecuaria INTA- Hilario Ascasubi, http://rian.inta.gov.ar/). To quantify precipitation anomalies the Standardized Precipitation Index (SPI) was calculated (Du, Fang, Xu, & Shi, 2013; McKee, Doesken, & Kleist, 1993), which classifies the intensity of dry and wet conditions (Table 1) (Du et al., 2013; McKee et al., 1993; Tao, Borth, Fraedrich, Su, & Zhu, 2014).

Table 1
The Standardized Precipitation Index (SPI) classification.

Category	SPI
Extreme wet	SPI ≥2.0
Severe wet	1.5 ≤ SPI <2.0
Moderate wet	1.0 ≤ SPI <1.5
Normal	−1.0 < SPI ≤1.0
Moderate dry	−1.5 < SPI ≤ −1.0
Severe dry	−2.0 < SPI ≤ −1.5
Extreme dry	SPI ≤ −2.0

4.2. Digital processing analysis of LANDSAT images - morphometric changes

In the Pampas, the pluviometric variations generate the most intense impacts on water bodies. The alternating droughts and floods produce a significant change on their morphology due to inundation or significant evaporation, therefore the ecosystem services that they offer are also modified (Palmer et al., 2008). The occurrence of El Niño or La Niña events is important in generating extreme precipitation anomalies (Aliaga, Ferrelli, Bohn, & Piccolo, 2016; Bohn, Delgado, Piccolo, & Perillo, 2016).

In order to calculate the variation of different morphometric parameters between drought and wet periods recorded in La Salada, two satellite images, one from LANDSAT 5 TM and another one from LANDSAT 8 OLI (scene 227-087), were downloaded from the

USGS website (http://glovis.usgs.gov/). They present a temporal resolution of 16 days and a spatial resolution of 30 m. Both images were selected by considering the clear sky conditions. The one from LANDSAT 5 dates from February 18, 2009, and it is representative of a severe drought that occurred in 2008. The one from the LANDSAT 8 date is from January 2, 2015, and corresponds to a very wet period observed during 2014. Digital processing analysis was applied to both images in order to estimate the morphometric parameters described by Hutchinson (1957): A. Area, P. Perimeter, Z. Maximum Depth, V. Volume of water, L. Maximum length, W. Mean width, Wmax. Maximum width, L/W. relation between L and W, WD. waterfront development.

A geographical correction was first applied considering a control point technique by selecting points equidistantly apart from each other. After that, a radiometric calibration of the visible and near infrared bands (Bands 1, 2, 3 and 4 from LANDSAT 5 TM and 1, 2, 3, 4 and 5 from LANDSAT 8 OLI TIRS) was performed. This correction was applied to satellite images for converting digital numbers to radiance values ($L_{\lambda sat}$) through:

$$L_{\lambda sat} = G_{\lambda} ND_{\lambda} + B_{\lambda} \quad [1]$$

where λ is the band number and G_{λ} (Gain) and B_{λ} (Biase) are the transforming coefficients of digital numbers to radiance values.

In addition, the solar spectrum corrections were applied to correct the dispersion of the atmospheric effects in the infrared and visible bands. Thus, the reflectivity was estimated considering a uniform Lambertain surface and free cloud conditions using equation (2) (Schroeder, Cohen, Song, Canty, & Yang, 2006):

$$\rho_{\lambda S} = \frac{[\pi(L\_\lambda sat - L\_\lambda p\ )]}{(T_{\lambda v}(E_{\lambda 0} d^{-2} cos\theta_z T_{\lambda z} + E_{down}))} \quad [2]$$

where $L_{\lambda p}$ (W m^{-2} sr^{-1} μm^{-1}) is the radiance recorded as a result of the interaction between the electromagnetic radiation and the atmospheric components, $T_{\lambda v}$ is the atmospheric transmisivity from the surface to the sensor, $T_{\lambda z}$ is the atmospheric transmisivity in the solar illumination direction, and E_{down} is the diffuse irradiance downwelling from the sky (W m^{-2} μm^{-1}).

Once the images had been geographically, atmospherically and radiometrically corrected, an Interactive Self-Organizing Data Analysis Technique Algorithm (ISODATA) (Swain, 1973) method was applied considering the methodology described in Aliaga, Ferrelli, Bohn, et al., 2016. This allowed the differentiation of the area of the lake due to the water (both clear and turbid) presents lower radiation values in the near infrared. On the other hand, RGB combinations using the ENVI 4.3 Software were performed on both images in order to understand the modifications in the landscape during drought and wet periods.

4.3. Ecosystem services provision in wet and dry periods

This paper integrated several techniques of the Participatory Research Approach to compare the ES provision between two precipitation scenarios. This combination allowed the capture of perceptions of different groups of actors involved in the ES provision around the lake, making the data collection process more efficient.

The identification and prioritization of ES in La Salada shallow lake constituted the first stage of the research process, which is composed of two sub-sections.

In the first one, the relevant ES for the particular case of La Salada shallow lake were identified and listed by an Expert Panel. Following Maynard, James, and Davidson (2010), this panel brought together technical experts, biologists, geologists, environmental economists and other scientists familiar with the shallow lake ecosystem and its characteristics. The Expert Panel met together twice to develop definitions and lists of ecosystem functions, ecosystem services and constituents of human wellbeing, to apply their expertise in identifying interactions between the ES in the shallow lake area, and to identify and eventually quantify the benefit that can be attributed to the ES provision.

In the second sub-section, the ES already identified and listed by the Expert Panel was prioritized through a participatory exercise performed in a workshop undertaken at La Salada shallow lake with a group of previously mapped local stakeholders.

This mapping was performed according to the guidelines of the Participatory Research Approach provided in Geilfus (2002) and Maya, López, & Cárdenas, 2004. For this purpose, both pertinence and representativeness criteria were used for the selection, looking for a complete sample of inhabitants of the shallow lake area. Pertinence was evaluated through the relationships between the users and the resources, their knowledge on the system and their ability to affect the shallow lake. Representativeness was defined according to how well or how accurately each individual reflected his/her own group of interests (London et al., 2012). Moreover, the list of stakeholders whose wellbeing could be related to the use of water ecosystem for the particular case of lakes provided by Scheffer et al. (2000) was also consulted in order to achieve an exhaustive mapping as possible. All economic and social activities were included, as the mapping emerged from a previous socio-economic characterization of the area under study.

Following the guidelines proposed by Geilfus (2002), once the relevant stakeholders were accurately mapped, they were invited to attend to an informal meeting during which a participatory activity aimed at prioritizing ES was performed.

The research team was in charge of presenting the list of ES and leading the working group toward the construction of an individual priority ranking. With this objective, illustrated cards, one for each selected ES, were used to reinforce the definition of each one to simplify the ranking process. Once ordered, all the individual rankings were re-ordered in an aggregate.

The last step in the proposed methodology consisted in analyzing the evolution of the ES provision between 2009 and 2015, characterized by high and low levels of precipitations respectively. To accomplish that aim, three Focus Group discussions on the ES evolution for the considered period were performed as well as some personal interviews with key informants to complement the data collection. As in Ramirez-Gomez et al. (2015), a purposive sampling approach was implemented for the Focus Group case to select participants based on two main criteria: a) participants had to be actively engaged in activities directly related to ES provision and b) they had to have been residents of La Salada shallow lake area during the whole observed period (2009–2015).

In all the cases, the size of the group was determined following the most usual practices in focus group studies (Carlsen & Glenton, 2011) and, according to standard ethical guidelines, participation in the research was entirely voluntary (ESRC, 2006).

Fig. 2 shows the process for analyzing the evolution of the ES provision for La Salada shallow lake for both wet and drought periods using the Participatory Research Approach and the above mentioned methodology for morphometric changes.

5. Results and discussion

5.1. Climatic features

Annual precipitation for the study period was very variable, 2009 presented a total annual precipitation of 252 mm, whereas 2015 presented a total precipitation value of 627 mm. During the

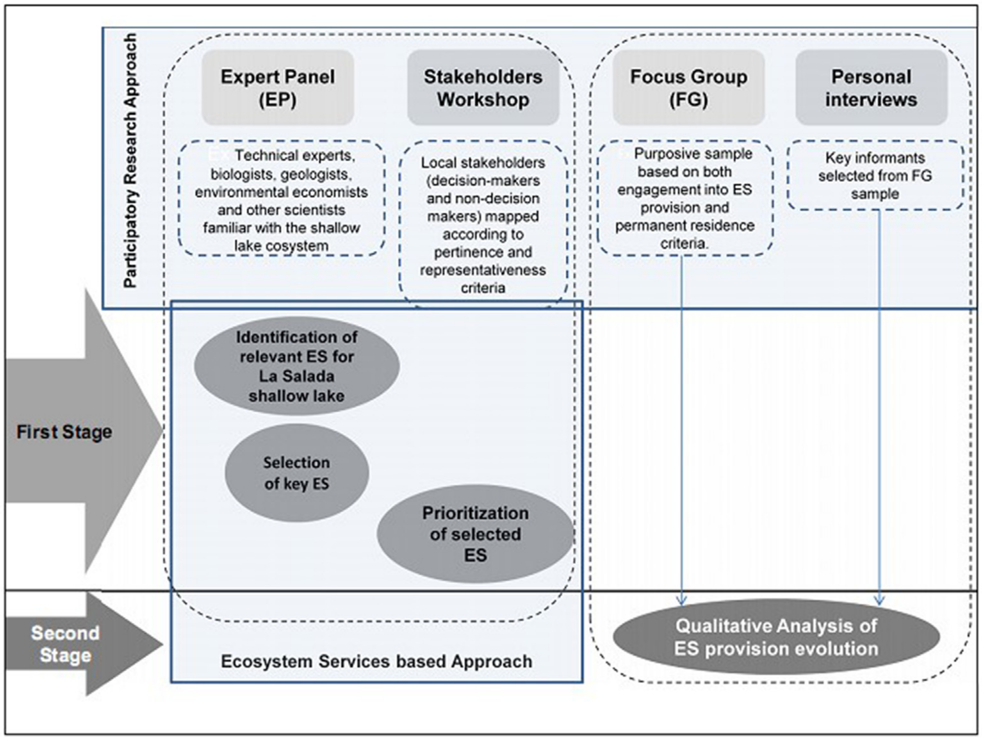

Fig. 2. Scheme showing the process for analyzing the changes in the ES provision between wet and dry periods in La Salada shallow lake.

study period, La Salada presented remarkably contrasting precipitations conditions between years, with a severe dry year during 2009, whereas 2015 resulted in a moderately wet year. According the classification of the SPI, both were contrasting years, resulting 2009 a severe dry year and 2015 a severe wet one (Fig. 3). Across the Pampas, from N to S, precipitation patterns show large variability, both geographically and inter-annually (Diovisalvi et al., 2015). From the NE to the SW of the region the mean annual precipitation ranges from 1000–400 mm (Aliaga, Ferrelli, Alberdi-Algarañaz, et al., 2016; Viglizzo & Frank, 2006). Scarpati and Capriolo (2011) found a marked interannual variation in precipitation comparing two consecutive time series, one for a dry period and another for a wet one (1947–1976 vs. 1977–2006) in the Pampa region. During the dry period, the mean annual precipitation ranged from 300 to 1200 mm y^{-1}, whereas during the wet period precipitations ranged from 400 to 1400 mm y^{-1} and the largest inter-annual differences (from this data set 200 mm y^{-1}) occur in the northern and middle areas of the region. In La Salada values between 252 and 730 mm y^{-1} were found during the study period (1966–2014). A difference of 375 mm y^{-1} was found, exceeding the recorded difference values found by Scarpati and Capriolo (2011), which emphasizes the contrast found in La Salada between both years.

5.2. Morphometric changes

Although La Salada has anthropogenic flow management, some differences were observed when two contrasting rainfall scenarios were analyzed from the satellite images. La Salada shallow lake is an ellipsoidal water body which maintained its shape during the different rainfall events, but variations in its area were observed between the dry and wet periods (0.7 km^2). The perimeter and the maximum length were longer during the wet period, showing an

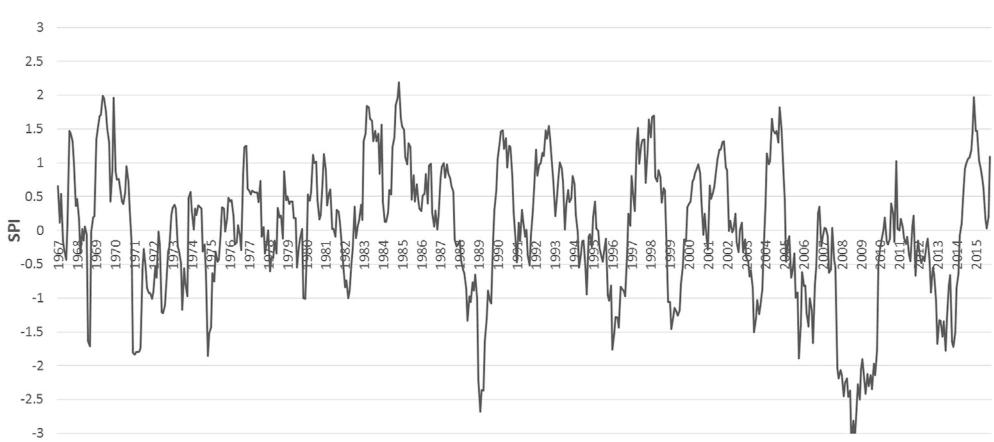

Fig. 3. SPI index from 1966 to 2014 in the study area.

Table 2
Variation of different morphometric parameters in La Salada shallow lake during a dry (2009) and a wet period (2015).

Morphometric parameters	2009	2015
Area (km^2)	3.2	3.9
Perimeter (km)	7.2	8
Maximum Length (km)	2.4	2.8
Maximum Width (km)	2	2.1
Mean Width (km)	1.3	1.4
Volume of Water (km^3)	0.0096	0.0117
LW	1.85	2
WD	0.7	0.7

increase of 0.8 and 0.4 km, respectively. Finally, the maximum and mean width only showed minor variations (0.1 km) (Table 2).

The most important landscape changes were observed to the northeast of La Salada shallow lake. In 2009, over 46.5 km^2 of the surrounding rural area presented bare soil exposed to wind erosion. Crops were only observed to the north and the east of the lake (in irrigated areas). The banks of the lake had saline soils. To the west, there was an extension of 4 km^2 of salt deposits (Fig. 4). On the other hand, during 2015 the area of bare soil decreased as consequence of the increase in rainfall and the salt deposits as well, as the saline soils observed on the banks were covered by water, resulting in the formation of small ponds located to the east and to the west of the shallow lake (Fig. 4).

5.3. Identification, prioritization and changes in the ES provision

The results of the participatory activities performed to identify and prioritize the ES in La Salada shallow lake area, together with the direction of the perceived change in its provision are presented in Table 3.

After a wide debate, the Expert Panel identified seven ES which are key to developing daily life in the shallow lake area: two provisioning services (*Fish Production* and *Water Reservoir);* one cultural (*Maintenance of Landscape for Recreational, Educative and/or Cultural Purposes*); three belonging to the regulation and maintenance group (*Protection Against Floods by Coastal or Riparian Ecosystem, Maintenance of Water Quality and Nursery Habitat for Terrestrial Animal Wildlife)* and only one supporting service *(Genepool Protection*).

Then, the selected ES were ranked according to the stakeholders' perceptions through a prioritization exercise undertaken at the workshop. The resulting ranking indicates that the most important ES for the local actors in the particular case of La Salada is *Maintenance of water quality*, followed by *Genepool Protection* and *Water Reservoir.*

Surprisingly, *Maintenance of Landscape for Recreational Purposes* is not well ranked according to the stakeholders' opinion, which constitutes an important finding since the main economic activity developed in the shallow lake is tourism, which directly depends on this ES. The idea that a higher rate of growth of tourism activities could put at risk the provision of the more relevant ES for supporting life in the area, such as *Maintenance of Water Quality* or *Nursery Habitat for Wildlife,* has also emerged as a result of the participatory techniques performed in the workshop. Furthermore, the constructed ranking also emphasized the relevance that regulation and maintenance of the ES have over cultural and provisioning services, showing that this kind of ES is recognized as crucial for supporting life and maintaining its quality for the local population.

Once identified and prioritized, the FG and some individuals were interviewed in order to qualitatively evaluate how the provision of these ES had changed (if they had) between the wet and dry periods identified above (2009 and 2015, respectively).

The results in this case do not indicate any significant changes between the two situations for *Water Reservoir* and *Fish Production*. In the first case, it remains clear that during La Niña in 2009 the groundwater diminished; it was absorbed by riparian vegetation and went back to the shallow lake. Moreover, the anthropogenic management of the water input to the lake through the connection with the irrigation system allowed its level to be maintained and, at the same time, it impeded the measurement of how much the surface area of the water had decreased due to the lower precipitations.

Regarding *Fish Production,* as stated above, only a particular silverside and the *tosquero* are found in the lake. According to the provincial Fishing Agency (MAA, 2012), the silverside population is not very well structured; there are more large individuals than juvenile or small ones. Aimed at satisfying an increasing demand of the visitors devoted to sport fishing, other exotic and sports-worthy fish species were introduced to the lake once in last decade with unsuccessful results. In La Salada the mean salinity value is 34 g. L^{-1} (Alfonso et al., 2015) and several studies suggest that the development of *Odonthestes* sp. is better at intermediate salinities (10–20 g. L^{-1}) (Kopprio et al., 2010; Tsuzuki, Ogawa, Strüssmann, Maita, & Takashima, 2001, 2000). Regarding the fish production service, no significant changes were seen between 2009 and 2015, suggesting a relatively stable fish population of silversides and tosqueros.

The evolution of the *Maintenance of Water Quality* is maybe the most relevant item in terms of quality of life, which was also confirmed with its location at the top of the ES ranking built by local stakeholders. According to the personal interviews, a rapid proliferation of algae, compared to the existing populations in 2009, was experienced during the wet season in 2015. This algae bloom resulted in several cleaning activities to keep the water

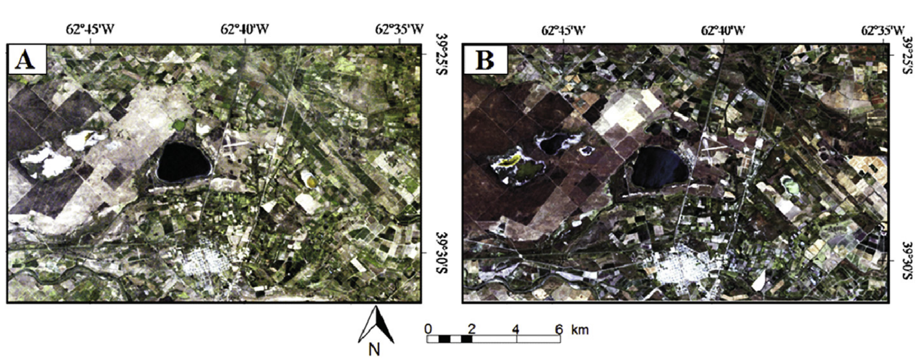

Fig. 4. La Salada shallow lake during **A.** a dry period (2009) and **B.** a wet period (2015).

Table 3
The qualitative evolution of ecosystem services provision in La Salada according to the perception of local stakeholders.

Rkg	Ecosystem service		Perceived provision change
1°	*Maintenance of Water Quality*	Regulation & Maintenance	▼
2°	*Genepool Protection*	Supporting	–
3°	*Water Reservoir*	Provisioning	=
4°	*Nursery Habitat for Terrestrial Animal Wildlife*	Regulation & Maintenance	=
5°	*Maintenance of Landscape for Recreational, Educative and/or Cultural Purposes*	Cultural	▼
6°	*Protection Against Floods by Coastal or Riparian Ecosystem*	Regulation & Maintenance	▲
7°	*Fish Production*	Provisioning	=

▼ Moderate decrease; = Unchanged; ▲ Moderate Increase; – Unanalyzable.

suitable for sport activities and other recreational purposes; this obviously implied a cost, not only monetary but also in terms of resource allocation. Furthermore, the summer season of 2012 recorded a decrease in the number of visitors probably due to the incidence of foul odors coming from algae blooming and/or some diverse natural processes that occurred in or around the shallow lake (Fig. 5). This particular situation clearly affected tourism affluence, suggesting the relevance of water quality as an explanatory variable of tourism demand. Unfortunately, neither physical nor chemical data were collected to record the difference in water quality parameters for the whole period. The availability of data of water transparency, chlorophyll content and suspended sediment, among other indicators, would clearly contribute to the evaluation of the changes in water quality due to climate variability in future works.

Genepool Protection refers to the ability of an ecosystem to maintain viable gene pools through natural selection or evolutionary processes which enhances the adaptability of species to environmental changes, and the resilience of the ecosystem (TEEB, 2010). Undoubtedly, the period considered in this study is too short to analyze evolutionary processes, which are not defined as simple changes over time but as genetic change in a population that is inherited over several generations (Mayr, 1982). In this context, the possibility of the occurrence of some change in the service of genepool protection is not neglected, but its magnitude and direction may have been imperceptible in such a brief interval. In accordance with this, the Focus Group did not identify any relevant changes in the provision of this ES during the considered period, in spite of the high relevance that stakeholders assigned to this service in the prioritization exercise. For the particular case of La Salada, this service is extremely important for touristic activities in the case of vegetation, since a large number of bird species feed, nest and shelter in native shrubs (Scoffield, 2010), and birdwatching is one of the more attractive activities in the area.

Regarding fish species, the high salinity of the water impeded the development of a higher number of species in the shallow lake, becoming a natural barrier to alien species introduction and so

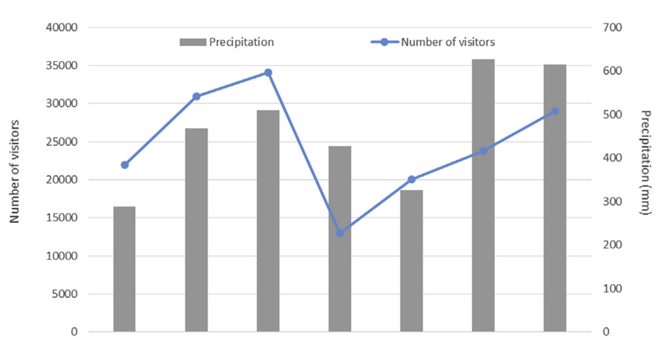

Fig. 5. Relation number of visitors – precipitation.

helping to protect native genetic resources. Within this particular context, *Genepool Protection* can be considered as an ES with very stable provision, totally independent of the precipitation conditions.

Nursery Habitat for Terrestrial Animal Wildlife takes the fourth place into the ES prioritization ranking. The nursery service is markedly relevant for the particular case of birds, because birdwatching is another touristic and educational activity carried out in the area. Black-necked swans (*Cygnus melancoryphus),* Coscoroba swans *(coscoroba coscoroba),* Silvery grebes *(Podiceps occipitalis*) and flamingoes (Phoenicopterus) have been recorded in La Salada shallow lake in recent years (Scoffield, 2010). In the case of the swans, 415 Black-necked and 143 Coscorobas were reported in 2009 (immediately after La Niña event), whereas only 43 Black-necked were observed in 2014. This change can be explained by the higher availability of freshwater in the north of the province where aquatic birds move during the wet periods, probably hiding from the excessive salinity of La Salada shallow lake. Records of flamingoes have been more frequent but were limited by missing data for the period 2006–2009. However, the existing records infer a movement of individuals according to the precipitation patterns that differs from that shown for swans. In fact, 230 individuals were reported in 2001 (during an extremely wet period), 154 in 2003, 136 in 2004, 155 in 2005, 113 in 2011, 235 in 2012 and less than 100 individuals in 2009, 2010, 2013, 2014 and 2015. These numbers indicate that the presence of flamingoes is not linearly dependent on precipitations at all, and that its migratory behavior seems to be determined by another factor. In general, however, nursery service remained unchanged between wet and dry periods. Even if some minor changes were recorded, they could probably be attributed to variations in the regional dynamics rather than to different precipitation scenarios (Scoffield, pers. com).

In spite of its low position in the prioritization process, *Maintenance of Landscape for Recreational, Educative and/or Cultural Purposes* would be the ES most affected by precipitation variability according to the stakeholders' perception. Nevertheless, that perception is not supported by the joint observation of data about precipitations and the number of visitors to La Salada (obtained from the register of entrances to the lake area) during the period under study. Fig. 5 presents both series, showing a very weak positive correlation between them. This might indicate that visits to La Salada are usually driven by factors other than the volume of water and the width of the beach. Maybe the speed and direction of winds and the temperature are stronger drivers than precipitation at the moment of deciding whether to visit the shallow lake. Another reason for which visits were not directly related to precipitations is that the higher affluence of tourists looking for water sports and fishing in wet periods counterbalances the number of tourists who do not visit the lake because of the constriction of the beach and *vice versa*. Furthermore, it is evident that the strong decline of the number of visitors in the summer of 2012 was not related to the precipitations, but instead it might be explained by the episode of foul odors recorded in the shallow lake area, mentioned above. Once again, water quality became the principal ES around which the whole activity of the lake develops, reaffirming the perception of the local stakeholders.

Ranked towards the end of the list, *Protection Against Floods by Coastal or Riparian Ecosystems* is only effectively provided in wet seasons, whereupon the analysis of the changes in provision between wet and dry periods only indicates that during the wet ones the level is positive while during La Niña the level of provision equals zero.

Table 3 summarizes the results of identification, prioritization and analysis of the qualitative changes in the provision of ES between the dry period recorded in 2009 and the wet period in 2015.

6. Conclusion

In a context of climate variability as seen by more unpredictable weather patterns and more frequent and extreme storms, the regulation of ecosystem services becomes more and more relevant in adaptation policy design and risk reduction (Munang, Thiaw, Alverson, Liu, & Han, 2013). The adoption of a generic ESbA can contribute to identifying, prioritizing and evaluating the evolution of key ecosystem services in each particular ecosystem.

The adopted definition of ESbA, proposed by Martin-Ortega et al. (2015), brings together the three main pillars for natural resource management: environmental sustainability, human well-being and decision-making. The involvement of stakeholders in climate policy design is crucial, since the success of the implementation of mitigation and adaptation strategies depends on their perception on climate variability, as well as on their ability to adapt their lifestyles to a new climate scenario.

For the particular case of La Salada shallow lake, the ESbA implemented resulted in the identification and prioritization of seven ES, although their provision has not shown any significant changes between the dry and a wet periods recorded in 2009 and 2015, respectively. The main reason behind these results seems to be the anthropogenic management of the input of water into the lake through the discretional control of the sluice gate that communicates the irrigation channel with the lake. Clearly, this water management appears to maintain the services of water reservoir almost unaffectedly and also the nursery habitat for animal wildlife and fish production –crucially limited by the salinity factor-. On the other hand, the local stakeholders considered that the maintenance of water quality is the most relevant ES provided by the lake. In line with this perception, the number of tourists arriving at the lake showed the highest decrease in the summer of 2012 due to a worsening in the water quality that generated foul odors. Since tourism is clearly the main economic activity in La Salada shallow lake, the link between economic development and water quality is straightforward. These results also show that climate variability does not directly impact on the ES provision, which has remained almost unchanged throughout two very different precipitation scenarios.

The experience of performing the Participatory Research Approach in La Salada shallow lake using the framework of the ESbA asserts that the local stakeholders must have an active involvement in the water resource management because they are the most interested party in achieving a sustainable use of water resource. Their perception about the relevance of each ecosystem service will crucially determine their position in the public agenda of local decision makers. Moreover, the role of anthropogenic water management becomes essential for preserving the ecosystem services provision within a context of adaptation to climate change.

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