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Ecosystem services research in contrasting socio-ecological contexts of Argentina: Critical assessment and future directions

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ABSTRACT

In Argentina, agricultural expansion and intensification has stimulated the utilization of the ecosystem services (ES) approach to understand the consequences of land-use and land-cover changes. However, Argentina's increasing trends of environmental degradation and social conflict due to agriculture continue unabated. We qualitatively analyzed 24 published ES studies done in either the temperate Pampean (context of consolidated agriculture) or subtropical extra-Pampean regions (context of expanding agriculture), in order to identify country-level and context-specific research needs and gaps, and propose ways to address them. We observed that ES studies in both contexts: (i) tended to focus much more on the biophysical, supply-side of the ES cascade than on the assessment of cultural ES and benefits, (ii) invested more effort in describing coarse ecological patterns/processes than in producing locally-adapted knowledge through stakeholder participation, and (iii) were poorly articulated with decision-making processes regarding sustainable ecosystem management. Despite this, some ES studies performed in the context of expanding agriculture showed incipient efforts to recognize, disaggregate and involve stakeholders, and to understand ES values. To increase the applicability of ES knowledge in decision-making, "strong" transdisciplinary approaches should be implemented so that changes in ES delivery and values feedback on management decisions for reverting environmental degradation.

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1. Introduction

Unabated environmental degradation and poverty across the globe has led to the development of novel approaches to better understand how ecosystem change is affecting human well-being. The most prominent has been the ecosystem services (ES) approach, which originated in 1970s (Holdren and Ehrlich, 1974; Westman, 1977) and during the 1990s gained popularity in environmental research and policy forums (Costanza et al., 1997; Daily et al., 2009). During the last decade, the growing body of literature on ES was characterized by greater efforts towards delivering policy tools to mitigate and adapt to environmental problems (Abson et al., 2014). Despite an increasingly solution-oriented approach, several factors impede mainstreaming ES into public and private environmental agendas (Logsdon and Chaubey, 2013). Barriers to an effective uptake of ES in decision-making processes include a lack of consensus on how to define and assess ES (Nahlik et al., 2012), a weak integration of the biophysical and socio-cultural dimensions of the ES approach (Iniesta-Arandia et al., 2014), and a poor consideration of contextual factors driving ES supply and demand at the local scale (Potschin and Haines-Young, 2012).

The Millenium Ecosystem Assessment (MEA, 2005) defined ES as the benefits people obtain from ecosystems. This definition equates ES and the benefits derived from them, without a clear distinction between the ecosystem processes underpinning ES provision and the ES *per se*, thereby limiting the applicability of the ES approach to inform management and policy decisions (Wallace, 2007). The boom of the ES concept following the MEA came along with revisions of the ES conceptual framework, in an attempt to disentangle the links from ecosystems and biodiversity to human well-being, by distinguishing among the structure and function of ecological systems relevant to a service (the supply), the service actually used or enjoyed by people (the service *per se*), and the change in people's well-being that results (the benefit) (Tallis et al., 2012). In Latin America, research on ES supply and social values of ES is quite well developed, but research on the actual delivery of ES to societies has received much less attention (Balvanera et al., 2012). Measuring supply is necessary but not sufficient to determine the level of ES provision or the resultant benefits to society, which also requires information concerning the demand for and use of ES, taking into account the spatial distribution of people, infrastructure, ecosystems and the control of institutions over access and human behavior (Tallis et al., 2012).

Given that areas of high ES capacity and flow are often spatially mismatched and that ES demand is influenced by many factors extraneous to service production, quantifying ES components separately is an important step toward enhancing the ability of ES assessments to inform environmental decision-making (Villamagna et al., 2013). Haines-Young and Potschin (2010) proposed a framework that links the biophysical and socio-cultural dimensions of the ES approach along a cascade of components and linkages. In the ES cascade, biodiversity and ecosystem processes support multiple ecosystem functions, which underpin the provision of ES and the benefits derived from them (Fig. 1). We adopt the ES cascade framework for our analysis and define ES as the ecosystem processes and attributes that contribute directly or indirectly to produce a benefit to people.

The implementation of the ES approach has been mainly advocated for developing countries (Norgaard, 2010), owing to its claimed merits in this context. First, the ES concept is proposed to act as a boundary object for sustainability science, stimulating the integration of disciplines that were traditionally segregated (Abson et al., 2014). Second, the ES approach is portrayed as being flexible enough so as to be effectively applied in diverse socio-ecological contexts, thereby allowing the production of knowledge relevant for local stakeholders (Opdam et al., 2013). Third, given its focus on the linkages between ecological, economic and social change, the ES approach can help tackling the twin challenges of poverty and environmental degradation (Daw et al., 2011). These characteristics render the ES approach suitable to produce policy-relevant knowledge in countries with economies dependent on its natural capital and diverse and unequal societies. Argentina is a clear example of this situation as it has a large and heterogeneous territory that produces food for ten times the size of its population (400 million people, FAO, 2014), although the benefits derived are unequally distributed (World Bank, 2013).

In this country, the expansion and intensification of agriculture has led to rapid and extensive environmental degradation which led, for example, to the loss of 70% of its native forest area in the 20th century (SAyDS, 2007). In the last 20 years, international demand and national policies enabled the expansion of the agricultural frontier, initially within the temperate Pampean region and then into extra-Pampean subtropical regions such as the Chaco, Yungas, Campos and Atlantic forests (Fig. 2). The area cultivated with genetically-modified soybeans rose from 5 Mha in 1994 to 20 Mha in 2013, covering 65% of the country's arable lands (FAO, 2014). In the Chaco region, soybean cultivation expanded mostly through the conversion of native forests, to the extent that this region had the highest rate of forest loss in the 21st century (Hansen et al., 2013). This scenario has stimulated the utilization of

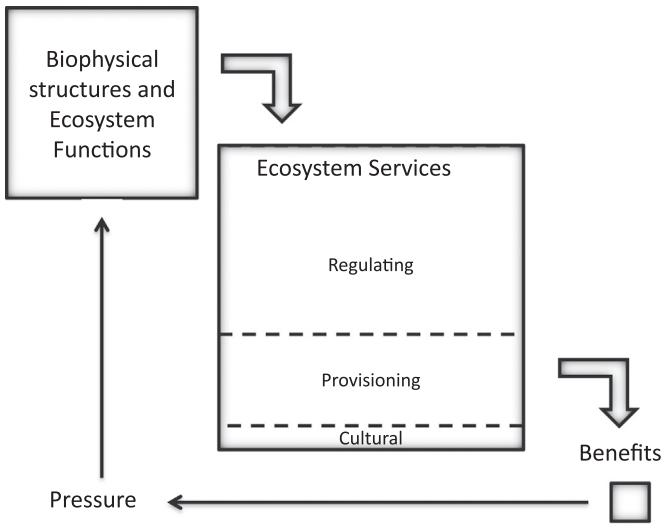

Fig. 1. Cascade conceptual framework (adapted from Haines-Young and Potschin, 2010). The box size is proportional to the number of studies that focused on that component of the cascade. The dotted lines within the ES box divide it into three sub-boxes. The size of these sub-boxes is proportional to the number of studies that evaluated each type of ES.

the ES approach in Argentina to understand the consequences of land-use and land-cover changes (Balvanera et al., 2012). However, despite significant research efforts using the ES approach, Argentina's trends of environmental degradation due to agriculture continue unabated (e.g. Vallejos et al., in press).

The described trend is in part associated to a decoupling between research and management decisions, which should be articulated in order to increase the policy-relevance of ES knowledge (Mastrangelo et al., 2014; Bennett et al., 2015). ES research has great potential to contribute to finding solutions to socio-environmental problems driven by agricultural change in Argentina, but its development is incipient. Such potential stems from the flexibility of the ES approach to produce normative and transformative knowledge adapted to the particularities of socio-ecological contexts (Díaz et al., 2011; Abson et al., 2014). As agricultural change is taking place in and contributing to configure contrasting socio-ecological contexts in Pampean and extra-Pampean regions, we expect differences in the way in which the ES approach is being applied in these contrasting contexts. We believe it is timely to identify context-specific research needs and gaps in order to propose future directions for increasing the policy-relevance of ES research.

Here we critically assess how the ES approach has been used in two large areas of Argentina with different socio-ecological contexts where agriculture has exerted profound but differential changes on the environment, the temperate Pampean and the subtropical extra-Pampean regions (Fig. 2). First, we describe the two contrasting socio-ecological contexts. Second, we qualitatively analyzed 24 published studies that use the ES approach in the Pampean or extra-Pampean region in relation to three qualitative attributes: (i) the level of integration of biophysical and socio-cultural components of the ES framework, (ii) the level of consideration of the local socio-ecological context, and (iii) the level of applicability of the knowledge generated in decision-making. Third, we discuss the general qualitative patterns observed and identify context-specific research needs and gaps, in order to propose future ES research directions in Argentina and regions undergoing similar socio-ecological changes driven by agriculture.

2. Contrasting socio-ecological contexts

2.1. Temperate Pampean region: consolidated agriculture

The Pampean region is a vast plain located in the centre-east of Argentina that extends over ~600,000 km^2 (Fig. 2). It was originally covered by temperate grasslands composed by C3 and C4 *Poaceae* species (Soriano, 1991). Arable lands in this region have been used for cropping and cattle ranching for more than a century owing to its deep fertile soils and the temperate humid climate. During the 1960s, the cropping system was characterized by low-input and mixed crop-livestock production systems (Viglizzo et al., 2001). From 1970s, the expansion of crop cultivation over cattle grazing lands and a more intensive use of agricultural inputs (machinery and agrochemicals) led to yield increases, but also to substantial landscape homogenization (Reboratti, 2006). This process of "agriculturization" accelerated with the adoption of the technological suite formed by no-till and glyphosate-resistant soybean in the 1990s (Manuel-Navarrete et al., 2009). Soybean expansion in the Pampean region was associated with profound ecological and social changes. Cattle production was either intensified in feedlots or displaced to marginal areas (Ortega and Azcuy Ameghino, 2009). Average farm size increased by 25%, and 34% of small and medium-sized farmers left the activity between 1988 and 2002 (SAGPyA, 2002). In addition to land tenure, production management was also concentrated in fewer hands, as it has been estimated that 75% of grain production is managed by leaseholders (Pengue, 2005).

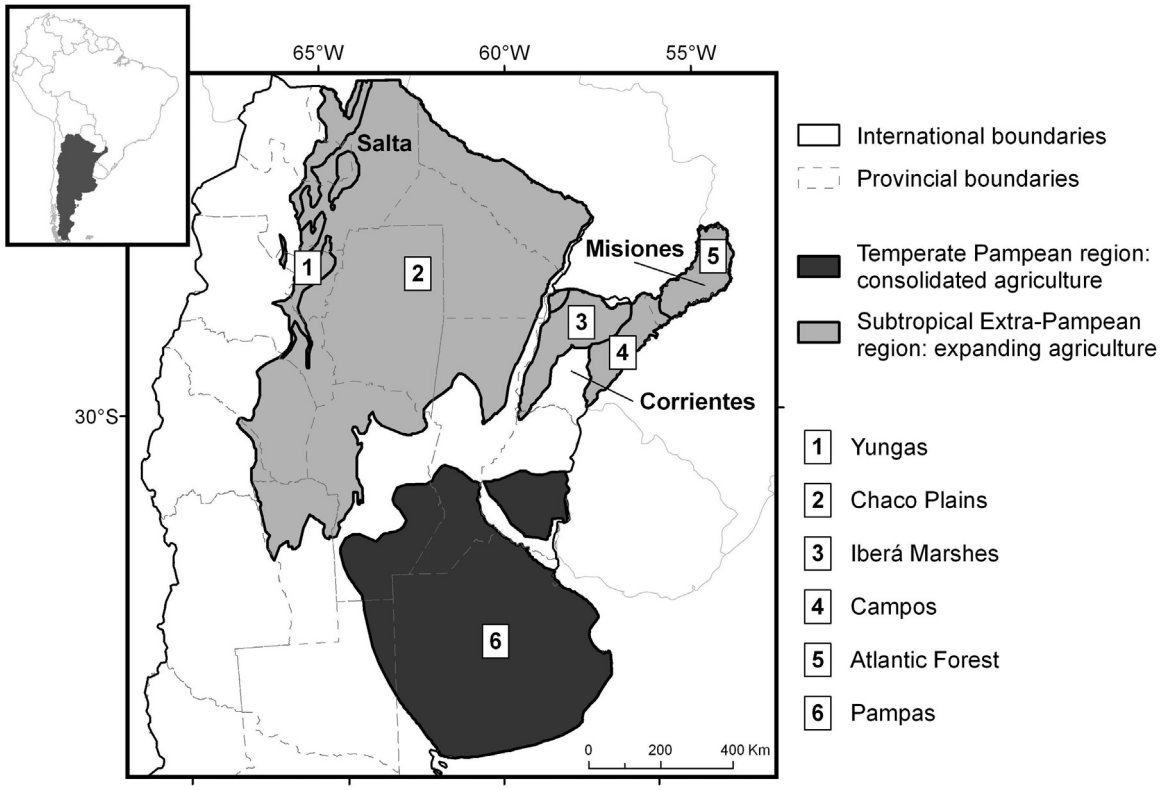

Fig. 2. Location of the socio-ecological contexts analyzed (Pampean region with consolidated agriculture and extra-Pampean region with expanding agriculture), the eco-regions included in these contexts (Pampa, Yungas, Chaco, Campos and malezales, Iberá marshes and Atlantic forest), and the name of the provinces mentioned in the text.

2.2. Extra-Pampean subtropical region: expanding agriculture

The extra-Pampean region comprises four subtropical eco-regions that extend through Northern Argentina, from the eastern slopes of the Andean range to the large rivers of the Rio de la Plata basin (Paraguay, Paraná and Uruguay rivers, Fig. 2). The extra-Pampean region goes from the Yungas (montane rainforest) in the north-west, through the vast Chaco plains (dry forests and savannas) in the centre-north, to the Campos and Malezales (savannas), Iberá marshes and Atlantic forest (lowland rainforest) in the north-east. Until 1980s, this region has been used mainly for wood and charcoal extraction, low-intensity cattle ranching and small-scale farming by indigenous people, native people with Spanish descent (criollos) and immigrant people mainly from Eastern Europe (Morello et al., 2012). During the last two decades, these bio-culturally diverse landscapes changed dramatically due to the coupled expansion of soybean and pasture cultivation (Paruelo et al., 2011). Displacement of cattle production from the Pampas stimulated pasture expansion and cattle grazing intensification over fragile ecosystems (Goldfarb and Zoomers, 2013). Demand of feedstock for livestock in China and Europe, increasing rainfall over Northern Argentina and national policies promoting land privatization and agricultural exports set the stage for the expansion of genetically-modified soybean cultivation in the extra-Pampean region (Grau et al., 2005). Capitalized farmers and ranchers acquired lands to deploy high-intensity production systems, causing the displacement of local actors and rural depopulation (Grau et al., 2008). Soybeans expanded by replacing other crops (beans, cotton) and pastures, but mostly through the conversion of native forests and savannas (Gasparri and Grau, 2009).

3. Methods

3.1. Literature search

We undertook a systematic exploration of the peer-reviewed literature using the Scopus database to search for studies on ES performed in Argentina. The search was done on January 2015, to select studies published on any year that contained the following terms in the title, abstract or keywords: (biodiversity OR "eco* function" OR "ecosystem service*") AND argentina AND agricultur*. Each of the 72 articles retrieved were evaluated and selected if the study (i) employed an ES framework (any of them), (ii) assessed ES in ecosystems/landscapes within the Pampean or extra-Pampean region, and (iii) focused on agriculture as the main driver of ES change. In addition, we searched the grey literature for peer-reviewed studies that met the criteria described above. Overall, we selected 24 studies for the analysis, of which 12 were done in the Pampean region (hereafter "consolidated agriculture") and 12 in the extra-Pampas region (hereafter "expanding agriculture") (Table A1, Supplementary data). We consider that the number of peer-reviewed studies analyzed in this paper is valid and appropriate since the studies selected under the defined criteria represent the state-of-the-art of ES research in Argentina.

3.2. Criteria and assumptions for assessing attributes of ES studies

We qualitatively analyzed the 24 selected studies in relation to the three aspects we considered relevant for determining the extent to which the study could have an influence on real-word decisions about sustainable ecosystem management: (i) the level of integration of biophysical and socio-cultural components of the ES framework, (ii) the level of consideration of the local socio-ecological context, and (iii) the level of applicability of the knowledge in decision-making. As these attributes are conceptual constructs that cannot be measured directly (latent attribute), we evaluated each of them using three observable attributes through qualitative analysis, as described in Table 1. Next, we describe the justification of the assumed link between observed and latent attributes and the criteria used to assess each observed attribute.

The level of integration of the biophysical and socio-cultural components of the ES framework was assessed by looking at three attributes. First, given that adopting a definition that distinguishes between ES and benefits facilitates the integration of biophysical and socio-cultural aspects (Fisher et al., 2009), we observed if the authors adopted the MEA definition which equals ES and social benefits or other definitions that distinguish between them (e.g. Boyd and Banzhaf, 2007; Fisher et al., 2009). Second, provided that assessing several components and links of the ES cascade provides a comprehensive understanding of how the ecosystem structure and processes affect the flow of benefits, we identified the number and identity of the cascade components (ecosystem structure/processes, ecosystem functions, ecosystem services and social benefits) assessed in the study. Third, given that assessing different types of ES allows better capturing the contribution of ecosystems to different components of human well-being (Summers et al., 2012), we identified ES types assessed in each study following the classification of Haines-Young and Potschin (2010) of provisioning, regulating and cultural ES.

The attributes observed to assess the level of consideration of the local socio-ecological context are as follows. First, considering that incorporating diverse knowledge and values into ES assessments allows better understanding the human and natural dimensions of local socio-ecological contexts (Balvanera et al., 2012), we assessed the diversity of knowledge sources and valuation methods employed in each ES studies. Second, given that disaggregation of social groups is a prerequisite for addressing the social distribution of ES (Daw et al., 2011), we identified whether the roles that stakeholders played in the issue being investigated were made explicit by the authors, and if they did, we evaluated which roles were recognized (Scheffer et al., 2000). Finally, considering that active stakeholder participation from the research design allows producing locally-adapted and socially-relevant knowledge (Seppelt et al., 2011), we assessed whether and how stakeholders participated in the research process. If they did, we identified (i) the type of stakeholder, (ii) the stage of participation, and (iii) the level of involvement following Pretty and Smith (2004).

The third latent attribute assessed in the study was related to the applicability of ES knowledge for decision-making. First, as the chance of incorporating ES knowledge into decision-making processes increases with the articulation of research and management/policy objectives (Roux et al., 2006), we identified whether the objectives of the study were articulated with a social and/or institutional demand, motivated by scientific inquiry, or a combination of both. Second, given that ES knowledge uptake by decision makers is easier if ES knowledge is available at spatial scales relevant for decision-making (Hein et al., 2006), we identified the spatial scale at which ES were assessed and whether it fits the spatial scale at which management decisions are made. Finally, considering that ES knowledge can be transformative and transcend its academic value as long as it informs some policy or management actions that are socially and institutionally feasible (Abson et al., 2014), we identified whether the study offered management and/or policy recommendations derived from the ES assessment. If they did, we evaluated whether the authors discuss the feasibility of implementing such recommendations.

Table 1
Summary of the trends emerged from the analysis of ES studies in relation to each latent and its corresponding observable attribute and the proposed actions to address the research gaps.

Latent attribute	Observable attribute	Which research trends emerged from the assessment?		Which actions are proposed to address research gaps?
		Consolidated agriculture	Expanding agriculture	
Integration of the biophysical and socio-cultural components of the ES approach	Attention to the contribution of ES to different benefits	Low	Low	Meaningful collaboration between natural and social scientists, and development of interdisciplinary frameworks for ES research. This will endow research teams with higher capacity to assess the socio-cultural/demand-side of the ES cascade.
	Assessment of several components and links along the ES cascade	Very rare	Rare	
	Assessments of different ES types, including cultural ES	Very rare	Rare	
Consideration of the local socio-ecological context	Incorporation of different sources of knowledge and valuation methods	Low	Medium	Higher investment in trans-disciplinary education of young and early-career researchers. Development of concepts and methods to work in participative, multi-stakeholder ES assessments.
	Explicit recognition and disaggregation of stakeholder groups	Very rare	Rare	
	Participation of stakeholders	Very rare and passive	Rare, but more active	
Applicability of ES knowledge in decision-making	Alignment of research objectives to social and/or institutional demands for ES knowledge	Very poor	Poor	Creation and strengthening of forums and networks at the interface between science and policy. This will allow effective communication and knowledge sharing among researchers, policy-makers and resource managers.
	Fit between spatial scales of ES assessment and decision-making	Low	Medium	
	Discussion of social and institutional feasibility of recommendations	Unusual	Unusual	

4. Results from the analysis of ES studies

4.1. Integration of biophysical and socio-cultural components of the ES framework

ES studies showed a significant dispersion in the definition of ES adopted both in the context of consolidated and expanding agriculture. Six out of the 24 ES studies did not provide an explicit definition of the ES framework adopted. This situation was found, for example, in a study that discusses the degradation of regulating ES due to bird population declines in the context of consolidated agriculture (Gavier-Pizarro et al., 2012) and in a study that discusses the consequences for ES of forest recovery in the context of expanding agriculture (Grau et al., 2008). Of the 18 studies that make their ES conceptual framework explicit, half of them adopted the MEA definition, which equates ES and benefits. In many cases, adopting the MEA definition implied a one-to-one relationship between ES and benefits and obscured the role of socio-cultural practices in producing diverse benefits from a single ES (Boyd and Banzhaf, 2007). From those 9 studies that adopted a definition that distinguish between ES and benefits, 6 of them were done in the context of expanding agriculture and only 3 in the context of consolidated agriculture (Laterra et al., 2009, 2012; Caride et al., 2012). Such conceptual dispersion has generated inconsistencies that make comparisons or generalizations among studies difficult. For example, soil protection is considered to be a service in studies adopting the MEA definition (e.g. Carreño et al., 2012), while it is treated as a function in studies adopting Fisher's et al. (2009) definition (e.g. Laterra et al., 2012).

In general, most studies focused on the links among ecosystem processes/structures, ecosystem functions and ES, with the benefits derived from ES being seldom evaluated (Fig. 1). This pattern was more pronounced in the context of consolidated agriculture, where (i) almost half of studies (5) evaluated ecosystem processes/structures and/or functions and only discussed their contribution to ES, and (ii) none study measured indicators of ES benefits. This pattern reveals the dominant role of the natural sciences in driving ES research in Argentina, particularly in the Pampas. In the context of expanding agriculture, most studies evaluated the link between two components in the ES cascade, especially that between ecosystem functions and services (e.g. Achinelli et al., 2011; Volante et al., 2012). However, there exist three studies that evaluated the social value of ES (Dagnino et al., 2011; Cáceres et al., 2015; Mastrangelo and Laterra, 2015), and one study that integrated the evaluation of three components along the ES cascade: Chacoff and Aizen (2006), Chacoff et al. (2008) assessed the contribution of an ecosystem function (pollination) to an ES (fertilization of cultivated fruit trees) and to a direct benefit to society (fruit yield).

The diversity of ES types assessed in the studies was generally low. The types of ES more frequently assessed in both contexts were provisioning and regulating services (Fig. 1). Trade-offs in the supply of several provisioning and regulating ES were assessed by Laterra et al. (2012) in the context of consolidated agriculture, while Mastrangelo and Laterra (2015) assessed trade-offs in the biophysical supply and social valuation of these ES types in the context of expanding agriculture. In general, cultural ES received the lowest research attention (Fig. 1), with the nation-wide analysis of recreation potential of Weyland and Laterra (2014) being the only study assessing a cultural ES in the context of consolidated agriculture. In contrast, three studies assessed several cultural ES in the context of expanding agriculture. Dagnino et al. (2011), Somma et al. (2011), Cáceres et al. (2015) elicited the social valuation of the esthetic and cultural value of landscapes, ecosystem and species threatened by agricultural expansion in the Dry Chaco region. Despite these advances, we found disproportionately few assessments of cultural ES relative to other ES types, similarly to the pattern reported for the regional (Balvanera et al., 2012) and global ES literature (Daniel et al., 2012; Hernandez-Morcillo et al., 2013). In sum, the state-of-the-art indicates a limited capability of ES studies for providing a descriptive understanding of the interactions between ecological and social systems linking ES supply and demand.

4.2. Consideration of the local socio-ecological context

Knowledge about ES was mostly obtained through the application of concepts and methods from natural sciences, especially those of ecology, ecohydrology and agricultural sciences. Therefore, the ecological valuation dominated ES assessments in both contexts. Nevertheless some exceptions to this general trend were found. In the context of consolidated agriculture, Viglizzo and Frank (2006), Carreño et al. (2012) incorporated conceptual and methodological elements from the economy for the monetary valuation of ES. In turn, two studies worked on the social valuation of ES, incorporating ES knowledge and values from stakeholders (farmers, ranchers, etc.) in the analysis of land-use changes in the context of expanding agriculture. Cáceres et al. (2015) applied the social aspects of an interdisciplinary framework developed by Díaz et al. (2011), in which the perspectives of ecological and social sciences are integrated from the design phase of research. On the other hand, Mastrangelo and Laterra (2015) complemented the ecological assessment of ES with concepts and methods from social psychology to understand stakeholder preferences for ES. Social valuation methods in these two studies, however, did not incorporate ES knowledge and values of indigenous groups. None ES study integrated ecological, social and monetary valuation methods in the same assessment.

Only five out of 24 ES studies made some explicit consideration of the diversity of roles played by stakeholders in ecosystem management. These five studies were done in the context of expanding agriculture, employing different methods and criteria for stakeholder classification and/or characterization. Three of them aimed at capturing the different attitudes and knowledge about ES of stakeholder types defined a *priori*. Somma et al. (2011), Cáceres et al. (2015) shared the distinction among small farmers (subsistence, peasant), large farmers (commercial, corporate), cattle ranchers and government agencies related to land-use research and land management. In turn, Dagnino et al. (2011) did not distinguish farmer types, but included stakeholders from the public administration, education and health sectors. Unlike these, Mastrangelo and Laterra (2015) offered an empirical typology of landholders based on their agricultural identities and regimes (i.e. pre-productivist, multifunctional and productivist) characterized using survey data. Paruelo et al. (2011), Volante et al. (2012) propose to classify stakeholders based on their role in ES supply and/or demand, that is, as “affectors” or “enjoyers” of ES. Overall, the socio-cultural context of ES studies in terms of the identity and interactions among stakeholders was rarely made explicit by the authors, undermining the possibility of making visible, and accounting for, differential access and dependence on ES of stakeholders.

The level of stakeholder participation differed among ES studies done in contrasting socio-ecological contexts. Stakeholder participation was very poor in the context of consolidated agriculture, with only two studies (Barral and Maceira, 2012; Rositano and Ferraro, 2014) incorporating stakeholders from academia to elicit their expert opinion. Low levels of stakeholder participation in these studies impedes getting a sense of which ecosystem management options are desired by those affected by the interventions, and thus are more likely to be accepted (Reyers et al., 2010). Conversely, one third (4) of ES studies done in the context of expanding agriculture had a more active participation of a larger

number of stakeholders. Somma et al. (2011) incorporated stakeholders in local workshops for the participative assessment and mapping of ES, which then feed into the design of a provincial land-use plan. Dagnino et al. (2011), Cáceres et al. (2015) used interviews and focus groups to assess the relative importance of multiple ES for stakeholders' well-being, and revealed contrasting ES values in socio-culturally diverse landscapes. Finally, Mastrangelo and Laterra (2015) surveyed different types of landholders to assess their preferences for two ES and identify socially desirable trade-offs between them. Despite these advances, ES studies in agricultural contexts of Argentina showed a deficit in the production of knowledge about the actual or potential social outcomes of ecosystem change, potentially eroding its social legitimacy and policy relevance.

4.3. Applicability of knowledge to decision-making

The degree to which the objectives of ES studies were articulated to some specific social and/or institutional demand for ES knowledge was very low. Most ES studies were motivated by concerns in the scientific community about the environmental impacts of landscape and ecosystem change. Articulation of research and policy objectives was not explicit in any of the ES studies done in the context of consolidated agriculture. Some of them channeled their concerns about the impacts of agricultural intensification through the assessment of ecological/economic trade-offs between food production and regulating ES (Viglizzo and Frank, 2006; Carreño et al., 2012; Laterra et al., 2012). The motivation behind the objective of two studies done in the context of expanding agriculture was related to social/institutional demands. Paruelo et al. (2011) provided conceptual elements for the assessment of accumulated impacts of deforestation requested by the National Supreme Court in response to indigenous claims. Somma et al. (2011) described the process of elaboration of a land-use zoning proposal requested by a provincial government and based on scientific criteria, including various ES assessments. Finally, there was a set of ES studies in both contexts that articulated to some degree research and planning objectives by providing a spatial identification of priority areas for the conservation of biodiversity and ES (Achinelli et al., 2011; Barral and Maceira, 2012; Izquierdo and Clark, 2012).

The spatial scale/s at which ES are assessed varied greatly among studies and contexts. In the context of consolidated agriculture, most studies evaluated ES at the scale of landscape units, catchments and counties, which can be seen as a "meso-scale" (500–5000 km^2). For example, four studies (Cisneros et al., 2011; Giaccio, 2011; Orúe et al., 2011; Laterra et al., 2012) used different eco-hydrological scales to delimit their ES assessments as they were interested in water regulation services. At this meso-scale, only Barral and Maceira (2012) used municipal boundaries to define the scale of assessment of multiple ES with the purpose of informing municipal land-use plans. In contrast, most studies done in the context of expanding agriculture assessed ES at larger scales. Some of these encompassed several provinces sharing a type of environmental threat (deforestation in provinces of the Chaco region, Volante et al., 2012), a single province with a highly threatened ecosystem type (Atlantic forests in Misiones province, Izquierdo and Clark, 2012) or portions of provinces with distinctive biophysical and socio-cultural attributes (Iberá marshes in Corrientes province, Achinelli et al., 2011; subtropical forests in Salta province, Paruelo et al., 2011). In these studies, the selected spatial scale has a good fit with the institutional scale for decision-making as provincial governments have the legal stewardship of natural resources in Argentina.

ES studies that derived recommendations for policy and/or management were more common in the context of expanding agriculture. In some cases, these studies also included an analysis of how feasible the recommendations can be, given the existing institutional context, which facilitates the uptake of ES knowledge by planners and policy-makers (e.g. Paruelo et al., 2011). However, the institutional feasibility of recommendations was not analyzed in most ES studies, independently of the context. Few ES studies done in the context of consolidated agriculture provided recommendations, and these were mostly derived from biophysical analyses of ES. Among these, Barral and Maceira (2012) proposed a land-use zoning map based on analyses of ES supply, while others provided general recommendations for the management of crop rotations (Caride et al., 2012), riparian vegetation (Giaccio, 2011) and crop field margins (D'Acunto et al., 2014). Conversely, incorporating the social dimension into ES assessments provided some hints on the desirability and feasibility of the conservation and/or transition to more multifunctional land-use systems in the context of expanding agriculture (Cáceres et al., 2015; Mastrangelo and Laterra, 2015). Overall, these patterns reveal a general lack of diallog between the scientific community and that of managers, planners, and policy-makers, which becomes apparent in the few efforts to "translate" ES knowledge into recommendations easy-to-understand by planners and policy-makers or ready-to-use by land managers. Achieving the full potential of the ES approach in agricultural contexts of Argentina requires significant changes in the way we think and do ES research. As a first step, we identify and discuss the implications of our findings for Argentina and beyond.

5. Discussion

5.1. Potential causes and consequences of findings

Argentina has pioneered ES research in Latin America (Sala and Paruelo, 1997). However, the number of studies for which the assessment of ES is their primary focus is low compared to Latin-American countries of similar size (e.g. Mexico, Balvanera et al., 2012). As it occurs in large developing countries with diverse environmental and socio-economic situations, the ES approach has been applied in highly dissimilar socio-ecological contexts in Argentina. Agricultural expansion and intensification are the main drivers of ES change in the great majority of ES studies, reflecting the widespread and intense environmental impacts of agriculture in Argentina during the last 25 years. The way of using the ES approach differed in some characteristics among studies performed in the context of expanding and consolidated agriculture. Such differences are caused by distinct motivations and approaches of researchers and/or the different demands of socio-ecological contexts, and have consequences for the overall advancement of ES research in Argentina and elsewhere.

We observed a relatively more frequent focus on ecosystem structure and functioning and its contribution to ES on studies performed in the context of consolidated agriculture. This higher emphasis on the supply-side of the ES cascade in the Pampas region may be associated with a long research tradition on grasslands ecology and crop/pasture management (e.g. Soriano, 1991). The dominance of this perspective has possibly prevented interaction of natural sciences with a rich expertize in rural social studies in the Pampas (e.g. Stratta Fernández and de los Ríos Carmenado, 2010; de Martinelli, 2011). In this context, insufficient efforts to integrate the ecological and social dimensions of the ES framework undermine the policy-relevance of ES studies. Here, treating stakeholders in aggregate form (e.g. farmers) may hide differences in access to and delivery of ES among them, and asymmetrical benefit distribution affecting the well-being of vulnerable stakeholders (e.g. smallholder farmers). This lack of "social

transparency" precludes us from gaining insights into the possible effects of further agricultural intensification on human well-being (Daw et al., 2011).

On the other hand, we observed incipient efforts to recognize, disaggregate and involve stakeholders in the research process of some ES studies performed in the context of expanding agriculture. These attempts may be partly in response to the larger diversity of cultural, social and economic conditions found in the Northern regions of the country compared to the Pampas. But interestingly some of them are also motivated by specific demands from government institutions to incorporate ES knowledge into land-use planning and environmental impact assessments (e.g. Paruelo et al., 2011; Somma et al., 2011). The bi-directional flow of information between science and policy in these cases is auspicious, although interests of powerful stakeholders usually end up having more influence on policy decisions (e.g. design of provincial land-use plans, Seghezzo et al., 2011). Without more active stakeholder participation in ES research, there is a risk of scientific information serving to legitimize policies with narrow consensus, leading to poor compliance. To bridge this implementation gap, ES research should strengthen the focus on participation, negotiation and co-learning processes with local stakeholders (Castella et al., 2014).

5.2. Argentina's situation in the Latin American and global context

Some of the findings for Argentina reinforce trends and gaps in global ES research, while others point to needs and challenges that are specific to the socio-ecological context of the country/region analyzed. The divergence and incongruence in the use of ES definition and classification systems described here is a common issue emerging from reviews of ES studies (e.g. Nahlik et al., 2012). This has been related to the focus on individual ES, rather than bundles of ES, which usually have their own definitions and indicators (van den Belt and Blake, 2014). It has also been associated with the inconsistent utilization of foreign assessment frameworks in national and sub-national ES studies (Zhang et al., 2010). Such discrepancies hamper understanding of ES studies by local stakeholders, limiting its applicability to decision-making. In response to this, it is important to develop assessment frameworks adapted to the characteristics of national or regional contexts, which offer consistent concepts and methods to assess relationships among multiple ES (e.g. Mastrangelo et al., 2014).

The poor integration of components and links along the ES cascade has been described in recent analysis of the global ES literature (Nahuelhual et al., 2015). The emphasis on the supply-side of the ES cascade – and the consequent disconnect among ES supply, delivery and values – found in Argentina has also been described for other Latin American countries (Balvanera et al., 2012), China (Zhang et al., 2010) and New Zealand (van den Belt and Blake, 2014). Another shared feature is the focus on ES of global importance (e.g. climate regulation), to the detriment of locally-relevant ES (Balvanera et al., 2012). Poor attention to the delivery of locally-relevant ES and its supply-demand mismatches has been related to the lack of multi-scale, dynamic models of ES change (van den Belt and Blake, 2014). Current efforts in Argentina to integrate the assessment of multiple ES at various spatial scales (e.g. Laterra et al., 2012) provide a solid ground to develop ES frameworks that account both for spatio-temporal dynamics of ES delivery and diversity of ES values.

The need for research into the social and institutional aspects of the application of the ES approach has also been identified in country-level analyses (e.g. van den Belt and Blake, 2014). ES values have a strong influence on the outcomes of ES-based interventions. The rise of payments for ecosystem (PES) programs in some Latin American countries has stimulated monetary valuation of ES (Balvanera et al., 2012). PES are very incipient in Argentina; only some biophysical ES values had been incorporated in an inconsistent manner into provincial land-use planning (Garcia-Collazo et al., 2013). Some efforts are being made to explicitly consider competing values and objectives in ES studies (e.g. Mastrangelo and Laterra, 2015), but tools to incorporate social ES values into decision-making processes are to be developed (Cáceres et al., 2015). Indeed, the amount of ES studies driven by social and institutional demands in Argentina lags behind that of similar Latin American countries, like Mexico and Brazil (Balvanera et al., 2012).

5.3. Suggested steps to address identified gaps and needs

Assessing ES delivery is critical to understand the (mis)matches between ES supply and demand, both spatio-temporally and across stakeholders, and to inform policy design aimed at ensuring secure access and fair distribution of ES. ES delivery is at the interface between ecological and social sub-systems, when people attribute value(s) to ecosystems and where potential services are actually mobilized to produce benefits and increase human well-being (Spangenberg et al., 2014). Therefore, assessing ES delivery involves linking ES supply and values (Fig. 3), which requires meaningful interaction between ecological and social sciences to answer how ES supply and values change over space and time, and who is affected by supply-demand mismatches (van den Belt and Blake, 2014). Interdisciplinary ES frameworks should be developed and tested to assess ES delivery. Such frameworks may benefit from existing perspectives and epistemologies to integrate the temporal, spatial and social dimensions of ES delivery. Long-term socio-ecological research (LTSER) platforms have potential to understand the temporal dynamics of socio-ecological systems (Anderson et al., 2012; Maass et al., 2010). Place-based frameworks for ES assessments allow better understanding of local priorities and values (Potschin and Haines-Young, 2012). They also enable exploring how ES bundles have changed in the past and in response to future scenarios, and thus the conditions to promote landscape multifunctionality (Mastrangelo et al., 2014). However, institutional and cognitive factors impede the development of interdisciplinary ES frameworks. Expensive, long-term and time-consuming endeavors like this can hardly find its way where specialization and short-term outcomes are rewarded. Strong disciplinary traditions prevent combining the different skills and expertize needed for the integrated analysis of places. Fortunately, an interdisciplinary ES framework has been developed (Díaz et al., 2011) and is being applied (Cáceres et al., 2015) in the context of expanding agriculture, with the potential to draw lessons and pave the way for more interdisciplinary research in Argentina and elsewhere. Further development of this framework to account for ES contribution to human well-being and its feedback on policy and management (Fig. 3) will increase its applicability to decision-making.

Understanding ES values is a necessary step to link ES impacts on human well-being and policy/management decisions aimed at maintaining the capacity of socio-ecological systems to supply and deliver ES (Fig. 3). Stakeholders' preferences for ES reflect the tangible and non-tangible benefits they obtain from ecosystems, and thus have a strong influence on stakeholders' motivations to manage ecosystems for enhancing the supply of valued ES, or support policies towards this end. ES frameworks incorporating elements from social sciences may allow producing knowledge *about* people, for instance, by eliciting stakeholders' preferences through questionnaires and/or interviews (Mastrangelo and Laterra, 2015; Cáceres et al., 2015). ES values may be better captured through participatory approaches that allow co-producing knowledge *with* people, thereby integrating different knowledge

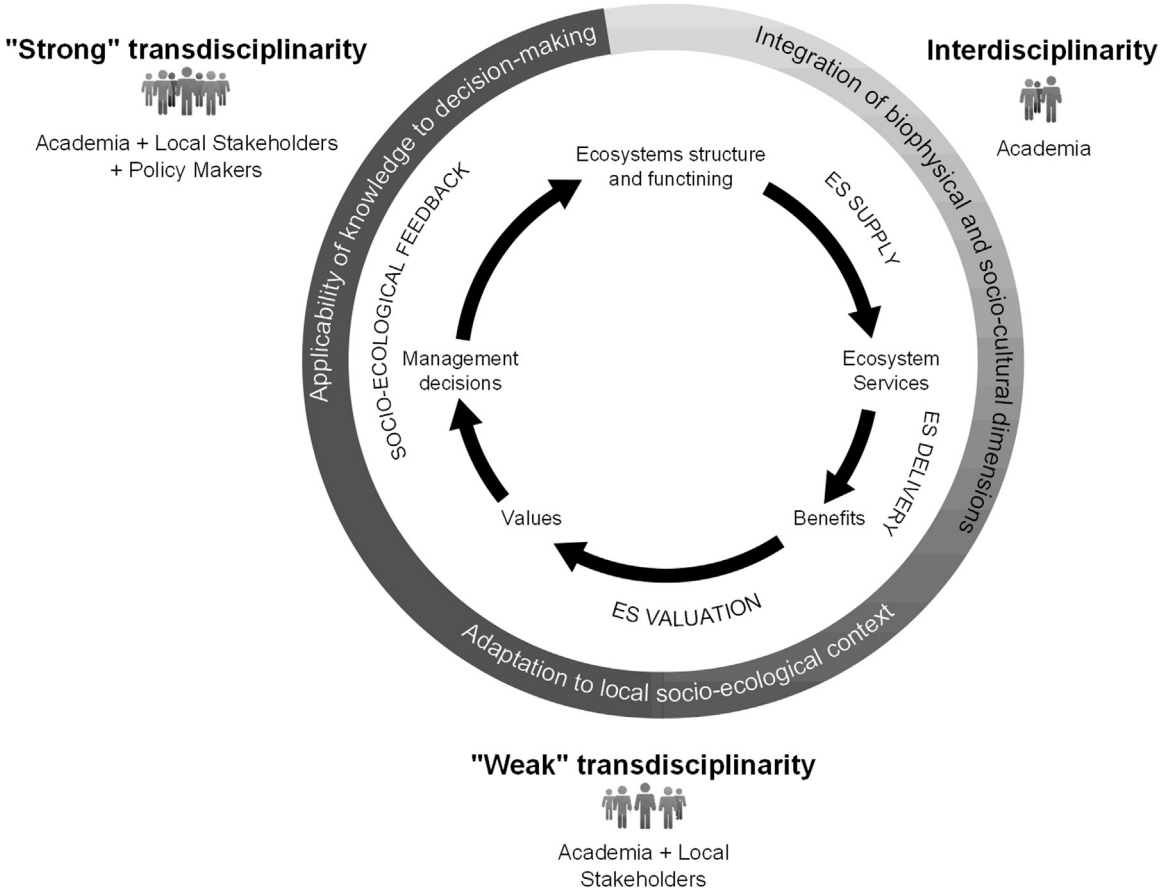

Fig. 3. Graphical representation of the process of ES assessments, showing the steps and approaches needed to facilitate the uptake of ES knowledge in ecosystem management decisions. Interdisciplinary approaches are important to integrate the biophysical and socio-cultural dimensions of ES, and to be able to move beyond ES supply and into the assessment of ES delivery and the distribution of benefits. Participation of local stakeholders through trans-disciplinary approaches becomes critical to grasp the complexities of local socio-ecological systems, and to be able to understand how its dynamics configure different values and objectives. A "strong" trans-disciplinary approach that creates a platform for effective communication among academia, local stakeholders and policy-makers is crucial to allow for locally-relevant ES knowledge to feedback on management and policy decisions. This platform will in turn set future research needs and demands. The color gradient of the outer circle represents an increasing need of trans-disciplinarity in ES assessments as we advance in the science-policy cycle.

and value systems and avoiding the pitfall of science as the only legitimate source of knowledge. Such "stronger" transdisciplinary approaches (*sensu* Max-Neef, 2005) should be developed for the sake of legitimacy, but also to address issues of equity (e.g. addressing *how do stakeholders access ES*) and contribute to poverty alleviation (e.g. addressing *how do stakeholders depend on ES*). Transdisciplinary work under the ES approach is in its infancy in Latin America, with some capacity building efforts ongoing (Uribe et al., 2015). Universities and other research and education institutions should (re)create graduate and postgraduate programs to endow new generations of scientists and practitioners with the ability to work in inter and transdisciplinary research teams. Transdisciplinary training should enable professionals to work at the interface between science and management, acting to articulate effective communication and knowledge sharing between these communities of practice (Roux et al., 2006). Such strong transdisciplinarity is needed to allow knowledge on ES supply, delivery and values to feedback on policy and management decisions, and thus follow an adaptive cycle along the ES cascade (Fig. 3).

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Appendix A. Supplementary material

Supplementary material associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.ecoser.2015.10.001..

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