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Review Article

Ecosystem services research in Latin America: The state of the art

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ABSTRACT

Ecosystem services science has developed at a fast rate in Latin America, a region characterized by a high biological and cultural diversity, strong emphasis in foreign investment, and high socioeconomic inequities. Here we conducted the following analyses at the regional and national scales: (1) how and when did the study of ecosystem services arise in each country?, (2) what is our present understanding of ecosystem service *supply*, *delivery* to societies, and social and economic *values*?, (3) what is the state of the art in integrating tradeoffs among services and in using interdisciplinary perspectives?, and (4) how has ecosystem service research been connected to policy design or management for sustainability? A large literature review (> 1000 references) showed that in Latin America ES supply and links to policy have been the most frequently assessed. Overall, emphasis has been placed on a few services, namely carbon and water. Payments for ecosystem services have received considerable attention in the region, though with strong differences across nations and with important limitations in their application. The future of the ecosystem service paradigm in Latin America will largely depend on its capacity to demonstrate effectiveness in meeting both conservation and development goals.

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Contents

1. Introduction

Ecosystem services (ES) science has developed at a very fast rate over the last decades (Nicholson et al., 2009). The recent growth of ES science can be attributed to the usefulness of ecosystem services as a concept that explicitly links ecosystems to human needs. Yet, the specific application, focus, and outcome of the ES research framework and resulting interventions cannot be interpreted without attention to the way we define such approaches, and to the historical, geographic, and political context in which it develops.

Ecosystem services benefit human societies at multiple levels (Tallis et al., in press). ES *supply* is the potential beneficial contribution of ecological functions or biophysical elements in an ecosystem to humans, irrespective of whether humans actually use or value that function or element. Potential flood regulation depends on several biophysical factors such as precipitation, topography, soil and land cover characteristics (Bathurst et al., 2011). ES *delivery* represents the actual contact of the potential supply of the service with human populations, and takes into account the spatial distribution of people and infrastructure. For example, fuel wood delivery depends not only on primary productivity, but also on people's consumption rates and location relative to a forest stand (Ghillardi et al., 2007). Finally, ES *value* reflects the way in which peoples' preferences for different services can be measured. Value can be expressed in economic terms (Costanza et al., 1998); the economic value of forests in supplying water for human consumption has been used to promote their management and conservation (Núñez et al., 2006). Values can also include non-tangible dimensions (Chan et al., 2012); the Purhepecha people in Michoacán, Mexico, value maize for its ceremonial, social and culinary values while industrial farmers prioritize yield and income from corn fields (Balvanera et al., 2009).

Any management decision may have positive or negative effects on different ES and lead to tradeoffs among them. For instance, management decisions tend to favor provisioning services such as food, water or wood at the expense of regulating services such as climate or water quality regulation (Bennett and Balvanera, 2007; Raudsepp-Hearne et al., 2010). Assessments of the drivers that underpin management decisions as population growth, or policies that foster particular ES (Liu et al., 2007; Carpenter et al., 2009), increasingly require interdisciplinary perspectives (Nicholson et al., 2009).

Ultimately, the use of the ES concept is intended to support the development of interventions, policies or management schemes that integrate the functioning of ecosystems and the benefits they provide to societies into decision making towards sustainability (Nelson et al., 2009; Simpson and Vira, 2010; McKenzie et al., 2011). A wide range of interventions may be used to sustain ES: (i) k*nowledge* interventions (i.e., scientific research) generate, synthesize and communicate new information, (ii) *institutional and governance* interventions (e.g., local rules for access to resources) address the way societies are organized to make decisions, (iii) *societal and behavioral* interventions (e.g., empowerment) relate to values and address societal and individual response patterns, (iv) *technological* interventions (e.g., best management practices) search for efficient ways to manage ecosystems and their services, and (v) *market* and *financial* interventions (e.g., markets for carbon) aim to modify decision-making through financial incentives. From all these potential interventions, Payments for Ecosystem Services (PES) schemes, the creation of a market and associated financial incentives to foster the maintenance of particular ES, have been broadly developed and adopted (Wunder, 2007; Engel et al., 2008; Jack et al., 2008).

Research on ES in Latin America (LA) has reflected the particularities of the region. LA encompasses areas with a large

Table 1
Selected indicators of biological and cultural diversity for ten political entities of Latin America.
Sources: Brazeiro et al. (2012), Groombridge et al. (1994), CIA (2011), Paine (1997), Sistema Nacional de Áreas Naturales Protegidas, United Nations Statistics Division World Statistics Pocketbook, World Bank, WWF (2010), www.unesco.org.

	Argentina	Bolivia	Brazil	Chile	Colombia	Costa Rica	Mexico	Panama	Puerto Rico	Uruguay
Biological diversity										
Total number of species	11,443	19,666	59,214	5989	54,443	13,680	28,469	11,553	2813	3653
Mammals	320	316	394	91	359	205	450	218	16	114
Birds	976	1274	1635	449	1695	850	1026	929	239	435
Reptiles	220	208	468	72	584	214	687	226	46	66
Amphibians	145	112	502	41	585	162	285	164	19	48
Freshwater Fishes	410	389	–	44	–	130	–	101	0	240
Plants	9372	17,367	56,215	5292	51,220	12,119	26,021	9915	2493	2750
Terrestrial species density (species per km^2)	0.004	0.018	0.007	0.008	0.049	0.265	0.015	0.154	0.317	0.019
Endemic species (% of total)	11.50	21.10	24.90	46.90	3.40	7.60	46.60	11.30	10.40	1.60
Number of ecoregions	19	17	49	10	34	7	46	9	5	7
Cultural diversity										
Dominant population group	White 97%	Quechua 30%	White 53.7%, Mulatto 38.5%	White and White-Amerindian 95.4%	Mestizo 58%	White 94%, Black 3% Amerindian 1%	Mestizo 60% Amerindian or predominantly Amerindian 30%	Mestizo 70% Amerindian and mixed 14%	White 76.2%	White 88%
Other dominant groups	Mestizo, Amerindian, or other 3%	Mestizo 30%	Black 6.2%, Other 0.9%, Unspecified 0.7%	Mapuche 4%	White 20%	Chinese 1%, Other 1%	White 9% Other 1%	White 10% Amerindian 6%	Black 6.9% Asian 0.3% Amerindian 0.2%	Mestizo 8%
Minorities		Aymara 25%, White 15%		Other indigenous groups 0.6%	Mulatto 14%, Black 4%, Mixed black-Amerindian 3%, Amerindian 1%				Mixed 4.4% Other 12%	Black 4%, Amerindian (practically nonexistent)
Number of native language speakers	199,005	4,380,166	292,407	2,004,521	716,028	70,753	2,150,248	267,019	–	3000
Number of native languages spoken	18	39	190	7	68	8	143	8	–	1

diversity of topographical and climatic conditions, and holds a large fraction of the world's unique biodiversity (Table 1). The indigenous cultures were deeply integrated with the westernized European colonizers, those from the Caribbean, and more recently by the frequent migration to the United States and Canada (Vargas Llosa, 2007). In the past two decades, the region has experienced fast economic growth as well as economic crises (Escalante et al., 2008; Guedes et al., 2009; UNEP, 2010). Improvements in human livelihoods associated with these socioeconomic trends have largely come at the expense of strong inequities in income, health, education and power, the migration of rural populations to the cities, and negative environmental impacts derived from unsustainable use of natural resources (UNEP, 2010; Tables 2 and 3). From colonial times to the present, economic policies in the Region have stimulated export-oriented foreign and national investment by maintaining or intensifying social inequalities (i.e., low wage labor) and exploiting cheap and abundant land, natural resources and agricultural products (Table 2). Although there has been some progress in the development and adoption of environmental policies (Nepstad et al., 2009), these efforts cannot counteract pressures from the driving forces of the Region's economic model such as urban expansion, increasing human populations, as well as energy and material intensive production patterns (Killeen, 2007; UNEP, 2010; Tables 2 and 3).

To assess the state of the art of ES research in LA we focused on ten LA political entities (9 countries and 1 state associated to the US) in which ES research has been ongoing: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Mexico, Panama, Puerto Rico, Uruguay. Our goals were to examine the historical evolution of the study of ecosystem services in LA, provide a synthesis of the state of science, and offer recommendations for moving forward. Within this framework, we asked the following questions:

(1) How and when did the study of ES arise in each country?
(2) What is our present understanding of ES *supply*, *delivery* to societies, and social and economic *values* of ES?
(3) What is the state of the art in integrating tradeoffs among services and in using interdisciplinary perspectives?
(4) How has ES research been connected to policy design or management for sustainability?

For all four questions we qualitatively assessed general trends across LA and variations across nations. We then identified the key challenges that lay ahead.

Table 2
Selected indicators of current societal conditions for ten political entities of Latin American.
Sources: IMF Panama: Statistical Annex (1998), IMF Argentina: Selected Issues and Statistical Annex (2000), IMF Panama: Selected Issues and Statistical Appendix (2000), IMF Bolivia: Statistical Annex (2001), IMF Brazil: Selected Issues and Statistical Appendix (2001), IMF Colombia: Selected Issues and Statistical Appendix (2001), IMF Mexico: Selected Issues, 2001, IMF Uruguay: Recent Economic Developments (2001), IMF Costa Rica: Selected Issues (2002), IMF Chile: Selected Issues (2003), CIA World Factbook (2011), World Bank.

Theme	Indicator	Argentina	Bolivia	Brazil	Chile	Colombia	Costa Rica	Mexico	Panama	Puerto Rico	Uruguay
Colonial history	Year independence gained	1816	1825	1822	1810	1810	1821	1810	1903 (from Colombia); 1821 (from Spain)	None (USA)	1825
Demography	Population, total	40,764,561	10,088,108	196,655,014	17,269,525	46,927,125	4,726,575	114,793,341	3,571,185	3,706,690	3,368,595
	Population density (people per sq. km of land area)	14.767	9.166	23.045	23.017	41.726	91.243	58.347	47.307	419.614	19.178
	Population in urban agglomerations of more than 1 million (% of total population)	39.093	33.455	40.799	34.777	37.700	31.357	34.881	39.196	73.701	48.705
	Rural population (% of total population)	7.651	33.601	15.665	11.058	24.980	35.814	22.175	25.389	1.227	7.547
	Mortality rate, under-5 (per 1000)	14.100	50.600	15.600	8.700	17.700	10.100	15.700	19.500	–	10.300
	Emigration rate of tertiary educated (% of total tertiary educated population)	2.781	5.784	2.047	6.015	10.383	7.089	15.468	16.681	–	9.049
Economy	GDP per capita (constant 2000 US$)	11,602	1275	4803	6754	3379	5366	6270	6654	15,822	9581
	Agriculture (% GDP)	10	10	5.5	5.1	7	6.3	3.8	4.1	1	10.1
	Industry (% GDP)	30.7	40	27.5	41.8	37.6	21.7	34.2	16.7	45	25.3
	Services (% GDP)	59.2	50	67	53.1	55.5	72	62	79.2	54	64.7
Trade	Exports (% of 2011 GDP)	19.2	37.3	10	35.4	17.6	26.9	28.4	43.2	73.6	19.4
	Major export commodities										
	Agricultural products	X			X	X	X	X	X	X	X
	Coffee			X		X	X	X			
	Soy & soy products	X	X	X							X
	Petroleum & natural gas	X	X			X					
	Metals		X	X	X	X		X	X		
	Equipment			X			X			X	
	Clothing			X		X				X	
	Other	X		X	X	X	X	X		X	
	Food exports (% of merchandise exports)	51.15	14.97	31.08	16.91	11.90	34.73	6.06	72.59	–	64.34
	Food imports (% of merchandise imports)	2.63	7.88	4.65	7.46	9.69	8.98	6.47	8.00	–	10.09
Poverty	Human development Index HDI	0.797	0.663	0.718	0.805	0.71	0.744	0.77	0.768	–	0.783
	Life expectancy at birth	75.9	66.6	73.5	79.1	73.7	79.3	77	76.1	–	77
	Mean years of schooling	9.3[b]	9.2[b]	7.2[b]	9.7[b]	7.3[b]	8.3[b]	8.5[b]	9.4[b]	–	8.5[b,c]
	Multidimensional poverty index	0.011[a]	0.089[a]	0.011[a]	–	0.022[a]	–	0.015[a]	–	–	0.006[a]
	GINI Inequity index	44.9	56.29	54.69	52.06	55.91	50.73	48.28	51.92	–	45.32
Governance	Military expenditure (% of central government expenditure)	5.2	7.7	6.0	14.7	19.8	–	3.7	4.6	–	6.6
	Transparency, accountability, and corruption in the public sector rating (1=low to 6=high)	–	3.5	–	–	–	–	–	–	–	–
	Property rights and rule-based governance rating (1=low to 6=high)	–	2.5	–	–	–	–	–	–	–	–
	Battle-related deaths (number of people)	–	–	–	–	428	–	37	920	–	–
	Refugee population by country or territory of origin	557	590	994	1170	395,577	352	6816	100	12	186
Research	Research and development expenditure (% of GDP)	0.52	0.28	1.08	0.39	0.16	0.4	0.37	0.21	0.49	0.66
	Scientific and technical journal articles	3655	45	12,306	1868	608	98	4128	73	–	246

[a] Published in 2011 using data from 2000 to 2010.
[b] Data refer to 2011 or the most recent year available.
[c] Updated by HDRO based on UNESCO (2011) data.

Table 3
Selected indicators of past and current environmental conditions for ten political entities of Latin America.
Sources: FAOSTATS, GEO Uruguay (2008), IUCN and UNEP (2009), Baeza et al. (2012), World Bank, FAO, WWF International (2012).

	Argentina	Bolivia	Brazil	Chile	Colombia	Costa Rica	Mexico	Panama	Puerto Rico	Uruguay
Agriculture										
Land in agriculture (%)	50.5	33.6	31.1	20.8	37.3	35.2	52.4	29.6	21.4	18.8
Arable land (hectares per person)	0.77	0.38	0.32	0.07	0.04	0.04	0.22	0.16	0.02	0.56
Agricultural irrigated land (% of total agricultural land)	1.05	–	–	5.63	–	1.50	5.47	–	8.47	1.17
Agricultural machinery, tractors	24,4320	6000	788,053	53,915	21,000	5432	238,830	8066	3255	36,465
Fertilizer consumption (kilograms per hectare of arable land)	25.43	6.14	125.05	452.22	499.41	826.62	54.52	46.88	–	109.60
Forests										
Forested land (%)	10.7	52.3	61.3	21.4	53.1	50.5	33.1	43.3	61.2	9.6
Planted forests (1000 ha-2010)	1394	20	7418	2384	405	241	3203	79	0	978
Land use change										
Total converted land (%)	89.2	46.9	38.3	78.2	45.4	49.4	66.6	56.1	38.8	30.4
Land converted by decade (million ha)										
1970	129	30	195	15	43	1.9	98	1.7	0.6	0.34
1980	128	34	224	17	45	2.5	99	1.9	0.5	0.34
1990	239	46	271	80	48	2.5	124	3.6	0.6	0.29
2000	242	48	300	79	49	2.7	128	4.1	0.4	0.44
2009	244	51	324	78	50	2.5	129	4.2	0.3	0.53
Water										
Annual freshwater withdrawals, agriculture (% of total freshwater withdrawal)	66.07	57.23	54.59	70.28	38.89	53.36	76.69	50.92	7.417	86.61
Annual freshwater withdrawals, industry (% of total freshwater withdrawal)	12.2	15.18	17.46	20.49	4.222	17.16	9.273	3.321	1.698	2.186
Renewable internal freshwater resources per capita (cubic meters)	6889.24	31,053.55	28,036.71	52,135.75	46,260.96	24,483.80	3650.70	42,577.76	1898.19	17,638.59
Biodiversity condition										
GEF benefits index for biodiversity (0=no biodiversity potential to 100=maximum)	17.72	12.55	100.00	15.32	51.52	9.72	68.68	10.95	4.05	1.25
Bird species, threatened	49	34	122	34	94	19	56	17	8	24
Fish species, threatened	37	0	84	20	54	50	152	41	19	36
Mammal species, threatened	38	20	81	20	52	9	100	15	3	11
Plant species (higher), threatened	35	72	98	34	215	112	191	192	51	0
Terrestrial protected areas (% of total land area)	5.47	18.51	26.28	16.55	20.90	20.92	11.13	18.70	10.08	2.60
Marine protected areas (% of total surface area)	1.10	–	16.48	3.69	15.53	12.24	16.67	4.01	1.59	0.33
Sustainability										
Policy and institutions for environmental sustainability rating (1=low to 6=high)	–	3.5	–	–	–	–	–	–	–	–
Footprint										
Total ecological footprint (global ha/person, 2008)	2.71	2.61	2.93	3.24	1.8	2.52	3.3	2.97	–	5.08
Biocapacity (Global ha/person, 2008)	7.12	18.39	9.63	3.74	3.89	1.6	1.42	2.67	–	10.03
Degradation										
Natural resources depletion (% of GNI)	4.89	12.30	3.35	12.44	7.75	0.14	5.71	0.00	–	0.65
Net forest depletion (% of GNI)	0	0	0	0	0	0.10	0	0	0	0.53
Mineral depletion (% of GNI)	0.43	2.89	1.71	12.33	0.52	0.05	0.33	0	0	0.11
Organic water pollutant (BOD) emissions (kg per day)	155,536	11,539.2	–	92,501	86,991.8	–	424,965	13,734.3	–	–

2. Methods

We address question 1 by providing a brief narrative of ES research in each country based on the experience and perspectives of the co-authors of this paper.

To address questions 2, 3, and 4, we conducted several systematic web-based searches. We first searched ISI Web of Science using the country name plus the terms "*ecosystem service OR environmental services*". In some countries like Panama, this search retrieved a large number of publications, but many of those were not directly related to ES; in others, like Bolivia or Colombia, the number of publications was extremely low.

To account for research on ES that did not use these general terms and to assess ES research in countries for which the above search retrieved very little information, we repeated the search using the key words "*water OR food OR crop OR pasture OR cattle OR fisheries OR wood OR fuelwood OR non-timber forest products OR genetic resources OR climatic regulation OR flood regulation OR water quality OR erosion regulation OR pollination OR ecotourism OR esthetic appreciation OR economic ecological valuation OR natural capital*".

To capture relevant information for each country that could not be tracked in ISI, we conducted additional searches for technical reports, student theses, government publications, conference proceedings, agency reports, non-ISI papers, websites and databases of ongoing projects, and synthesis papers or book chapters. A list of all sources used for this synthesis per country is found in Appendix 1. Although this approach cannot capture all ES initiatives in the region, particularly global initiatives or those managed or initiated by transnational corporations, it does capture links between research and implementation at the national level.

Once these searches were completed, we classified studies into one or several non-exclusive themes associated to the questions we posed: (i) supply, (ii) delivery, or (iii) value of ES, (iv) tradeoffs among services, and (v) ES and policy design or management for sustainability. We first analyzed the trends for each of the countries individually and then examined similarities and differences among them. The analyses presented here are illustrative rather than exhaustive. For each major theme, we rely on only one or a few examples to illustrate the major tendencies.

In the case of policy design or management for sustainability, we focused on: (1) the development on demand-driven research, and (2) PES programs. We focused on PES rather than on all potential policy and management interventions because PES schemes can be explicitly linked to ES and make the search feasible. Additionally, PES programs are increasingly common in the Region and, in many cases, have strongly influenced policy design and scientific research. To assess the characteristics of PES programs in the Region, we searched the web using the terms "*Payments for Ecosystem Services* OR *PES* OR *PSA*" (PSA is a synonym of PES in Spanish, *Pagos por Servicios Ambientales*). The search focused on identifying databases and synthesis documents where information on existing PES schemes was compiled by region. Results from the literature searches described above were also utilized where explicit mention was made of PES relating to the studied services.

To further understand how the characteristics of the whole Region and the differences among countries contributed to the tendencies described here, we compiled information from different global and regional sources that provide an overview of their biological and cultural diversity, economic, demographic, and governance characteristics and, and those of the impacts of land use and land conversion patterns over the last decades.

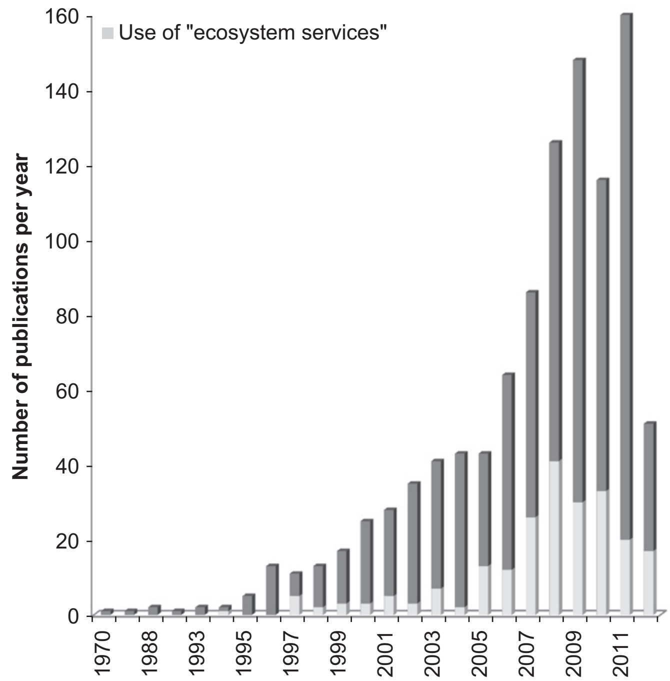

Fig. 1. Number of publications on ecosystem services in ten political entities of Latin America between from 1970 to 2011. A search in ISI-Web of science was complemented by a search of relevant websites, reports and theses. Papers that explicitly contain the words "ecosystem services" OR "environmental service" in their title are shown in gray.

3. How and when did the study of ecosystem services arise in Latin America?

The study of the linkages between ecosystems and societies in LA started in the 1980s under the conceptual frameworks of ethnoecology, cultural ecology, political ecology, or societal metabolism (Balvanera et al., 2011). Yet, the term ES was first used in a LA publication (Fig. 1) in 1997 (Fearnside, 1997), shortly after the publication of the seminal paper by Costanza et al. (1997). This use was likely motivated by the new global awareness on environmental sustainability that followed the first Rio conference in 1992 (UNEP, 2010). Initial studies focused on individual ES (e.g., Chamberlain and Galwey, 1993), or conducted economic valuation of specific ES (e.g., Gonzalez-Caban and Loomis, 1997), influenced by the nascent field of ecological economics (e.g., Costanza et al., 1997).[1] A critical transition point for most countries was the publication of the Millennium Ecosystem Assessment in 2003, which highlighted the societal dependence on ecosystems and demonstrated the existence of tradeoffs between different ES (Bovarnick et al., 2010). The latter was particularly important for regional efforts to reconcile economic development and poverty alleviation with environmental conservation (Bovarnick et al., 2010; UNEP, 2010).

Despite these general trends in the region, there are also marked differences in the study of ES among countries, which reflect the particular historical context, pressures and needs of each nation (Tables 1–3). **Argentina** was one of the early pioneers in ES research, likely motivated by the extensive conversion of fertile, natural grasslands and forests to agriculture that occurred in the 1990s and the importance of this agricultural expansion to the national economy (Sala and Paruelo, 1997; Tables 2 and 3). In **Bolivia**, early work focused on the provision of timber and non-timber forest products (NTFP), and more recently on the regulation of water quality and quantity, and on carbon sequestration. The strong focus on forest-related services was probably triggered by the large number of indigenous communities that rely on forest products for their livelihoods (Table 1), the implementation of laws providing legal access to forest resources and promoting their sustainable management, and the needs of national and international institutions and projects. Deforestation pressures from expanding and intensifying agriculture in **Brazil** drove ES research in the Amazon basin (Davidson et al., 2012). Specifically, the importance of the Brazilian Amazon for global climate regulation fostered ES research highlighting links between deforestation and biogeochemical cycles, which was strongly fostered by the Proambiente program (Hall, 2008) and a relatively large budget allocation to research (Table 2). The growing importance of ES research in the United States strongly influenced economies with strong links to the US including **Costa Rica**, **Panama** and **Puerto Rico. Costa Rica** was the first country to establish a national PES program. **Panama** has a long history of research in ecology and much success in preserving forest cover throughout the country, resulting from the work of the Smithsonian Institution and possible from the US presence in the Panama Canal watershed before 1999. Research in **Puerto Rico** has been influenced by the presence of a Long Term Ecosystem Research site with the participation of several US federal agencies including the US forest service, the EPA (Environmental Protection Agency), and USGS (United States Geological Service). ES research in the island has been primarily focused on the impacts of reforestation, urbanization and high population growth rates on ES, reflecting the agricultural abandonment and the rapid urban development in the island (Uriarte et al., 2011). In **Chile**, the strong pressures to convert native forests to fast growing plantations using exotic tree species for export (*Pinus radiata* and *Eucalyptus* spp.) coupled with steep terrain motivated a focus on water yield and water quality, freshwater native and introduced fish diversity, and forest

[1] Throughout the text indicative examples rather than exhaustive and comprehensive lists are provided. The use of "e.g." is shown here to call attention on this subject but removed hereafter to avoid repetition.

productivity under different forest management regimes (Lara et al., 2009). **Mexico** was quick to promote the MA framework because of the personal involvement of several Mexican scientists in this initiative (MA, 2003). ES supply and delivery was assessed at the national scale (Balvanera et al., 2009), and at selected sites (Maass et al., 2005). In the case of **Colombia**, ES research has been hampered by the low budget allocated to that activity (only 0.16% of GDP; Table 2). Yet, interest around PES has been burgeoning among self-organized buyers, sellers, and intermediaries, with little involvement by the central state (Southgate and Wunder, 2009). Finally, ES research in **Uruguay** remains underdeveloped relative to other countries in the Region.

4. ES supply, delivery and value

4.1. Supply

Research on ES supply, which encompasses the analysis of the ecosystem components and processes underpinning the potential flow of benefits to societies, is well developed in LA (Fig. 2).

Research on potential supply of ES in LA has primarily focused on timber (Guariguata et al., 2009), NTFP (Acebey et al., 2010), water provision (Blume et al., 2008), and carbon storage (Soto et al., 2010). Pollination (Garibaldi et al., 2009) and pest regulation services (Avelino et al., 2012) have received much less attention.

The impact of native ecosystem conversion (forests, wetlands, and grasslands) on ES supply has been emphasized across LA (Portela and Rademacher, 2001). The emphasis has been put on the consequences of such land use change on carbon stocks and primary production (Eaton and Lawrence, 2009) and water flow and quality (Uriarte et al., 2011).

The effects of management of native forests and plantations on ES have been assessed. **Bolivia** has emphasized the impacts of forest management on timber and NTFP (Soriano et al., 2012), **Chile** the effects of forest management (afforestation, introduced species) on water provision and soil loss (Lara et al., 2009), and **Uruguay** the effects of replacing grasslands with pine and *Eucaliptus* plantations (Cespedes-Payret et al., 2009). The potential for forest restoration and reforestation to replace ES supplied by mature tropical forests is being analyzed in **Panama** (Cespedes-Payret et al., 2009).

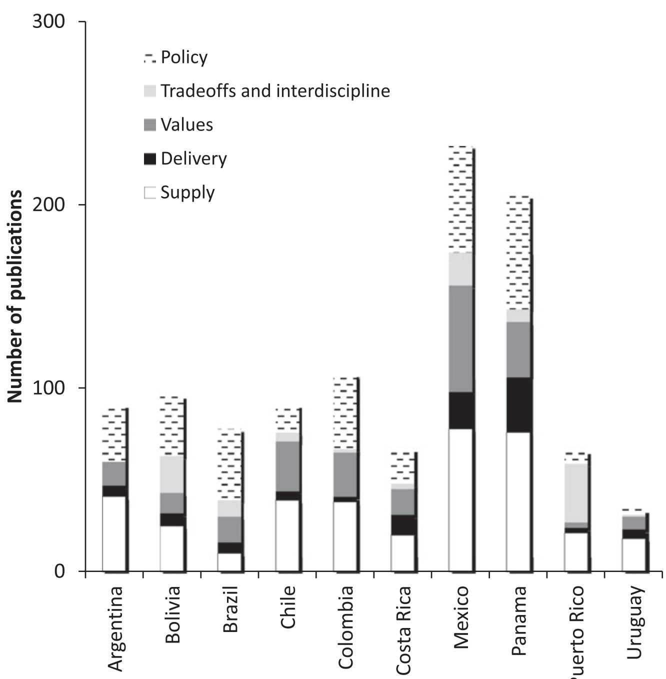

Fig. 2. Number of publications used in this literature review per theme covered in ecosystem services science in ten political entities of Latin America. Categories are non-exclusive, and thus a same publication can be found in various themes or countries.

Ecological processes underpinning ES supply are increasingly being understood. Assessments of stand level timber dynamics under different climatic, disturbance and management regimes (Dauber et al., 2005) have contributed to understanding timber supply by **Bolivian** forests. In **Panama**, emphasis has been placed on the processes underpinning carbon dynamics (Potvin et al., 2011), and on hydrological services for the Panama Canal Watershed (Kunert et al., 2012). In **Puerto Rico**, the study of soil formation, weathering and nutrient cycling (Stallard, 2011) has provided important information on the processes underpinning the regulation of soil fertility and erosion.

New conceptual or methodological approaches have been developed in LA. Research in **Argentina** has been central to account for the role of plant functional traits on ES supply (Díaz et al., 2007), to map ES supply from proxies of primary productivity or biomass (Paruelo et al., 2011), and to assess landscape effects on ES supply (Laterra et al., 2012). In **Panama**, assessment of landscape level carbon pools (Mascaro et al., 2011b) rely on data from mature (Mascaro et al., 2011a) and secondary forests (van Breugel et al., 2011), and plantations (Potvin et al., 2011), and airborne high-resolution data (Light Detection and Ranging; Asner et al., 2012).

The quantification and mapping of ES supply at different spatial scales has been undertaken in many countries in the Region. National-scale maps of selected ES are also available for **Argentina** (Carreño et al., 2012), **Colombia** (Tallis et al., 2012) and **Mexico** (Balvanera et al., 2010). Long-term monitoring is underway in the Panama Canal Watershed (Stallard et al., 2010), and selected watershed in **Chile** (Lara et al., 2009), and **Mexico** (Maass et al., 2005).

4.2. Delivery

Research on the actual delivery of ES to societies, including the use of resources as well as the regulation of the conditions where human enterprise takes place, has received much less attention than supply in LA.

The use of timber of non-timber forest products by rural populations (Caballero et al., 1998), as well as the domestication, management and benefits derived from agro-biodiversity (Harvey et al., 2011) have frequently been assessed across LA. Yet, this literature does not often use the ES terminology.

Assessments of delivery of ES to societies include those associated to coastal protection in Puerto Rico (Martinuzzi et al., 2009), fuelwood consumption in **Mexico** (Ghillardi et al., 2007), and pollination impacts on crop yields across the globe (Garibaldi et al., 2011).

Governmental initiatives in collaboration with the World Bank **in Colombia** and **Mexico** are aimed at integrating natural capital and ecosystem services indicators into GDP estimations (BSR, 2012).

4.3. Values

The assessment of societal values of ES is quite well developed in LA.

A suite of conceptual and methodological approaches has been used for economic valuation of ES across LA. Transfer value approaches inspired by work by Costanza et al. (1997), that rely

Table 4
Programs of payments for ecosystem services in ten political entities of Latin America.
Sources: Corcuera et al. (2002), Cottle and Crosthwaite-Eyre (2002), Hay et al. (2002), Pagiola and Ruthenberg (2002), Miranda et al. (2004), Robertson and Wunder (2005), CONDESAN (2006), Zapata et al. (2007), Asquith et al. (2008), Blanco et al. (2008), Hall (2008), Muñoz-Piña et al. (2008), Pagiola (2008), Estrada et al. (2009), OAS (2012), http://waterandfood.org/basins/andes/.

Country	Number of PES programs found	Scale of PES programs[a]	Services targeted (# of programs)	Buyers	Sellers	Date(s) of creation	Aproximate total budget in USD[b]	Aproximate total area in ha[c] (% of country area)
Argentina	0							
Bolivia	9	International	Hydrologic services (5)	Hydroelectric and water suppliers	Local communities	1993–2003	$10,857,000	669,305 (0.6)
		National	Biodiversity (4)	Water users	Landowners/ producers			
		Regional	Carbon sequestration (Estrada et al.) Esthetic beauty (1)	International conservation donors				
		Local	General ES (unspecified) (1)	Carbon offset purchasers				
				Ecotourism operations				
Bolivia and Colombia	1	International	Hydrologic services (1)	Urban water consumers, successful agribusinesses, hydropower companies	Rural communities	2010		
Brazil	11	International	Hydrologic services (4)	State and national governments	Municipalities	1989–2005	$77,063,384	2,079,327 (0.2)
		National	Biodiversity (5)	Hydroelectric and water suppliers	Local communities			
		Regional	Carbon sequestration (6)	International conservation donors	Landowners/ producers			
		Local	Production services (3) Fire prevention (1) General ES (unspecified) (4)	Carbon offset purchasers				
Colombia	19	International	Hydrologic services (13)	Hydroelectric and water suppliers	Protected Area managers	1988–2005	$121,898,958	1,156,960 (1.0)
		National	Biodiversity (11)	Water users	Local communities			
		Regional	Carbon sequestration (7)	International conservation donors	Landowners/ producers			
		Local	Production services (6) Esthetic quality (Estrada et al.) General ES (unspecified) (3)	Carbon offset purchasers Ecotourism operations GEF—Silvopastoral program				
Costa Rica	28	International	Hydrologic services (17)	National government	Protected area managers	1989–2007	$108,308,692	521,124 (10.2)
		National	Biodiversity (13)	Hydroelectric and water suppliers	Local communities/ NGOs			
		Regional	Carbon sequestration (6)	Water users	Landowners/ producers			
				International conservation donors				
		Local	Production services (3) Esthetic quality (3)	Carbon offset purchasers Commercial bioprospectors Ecotourism operations				
Mexico	15	International	Hydrologic services (5)	National government	Local communities	1993–2006	$82,119,316	2,437,695 (1.2)
		National	Biodiversity (Estrada et al.) Carbon sequestration (5)	Hydroelectric and water suppliers	Landowners/ producers			
		Regional Local	Production services (5) Esthetic quality (Estrada et al.) General ES (unspecified) (Estrada et al.)	Water users International conservation donors Carbon offset purchasers Ecotourism operations				

Table 4 (*continued*)

Country	Number of PES programs found	Scale of PES programs[a]	Services targeted (# of programs)	Buyers	Sellers	Date(s) of creation	Aproximate total budget in USD[b]	Aproximate total area in ha[c] (% of country area)
Panama	2	Regional	Hydrologic services (1)	National government	Landowners/ producers	2004–2006	No information	No information
		Local	Biodiversity (1)	International conservation donors				
			Production services (1)					
Puerto Rico	0 (specific to PR)	National (USA)						
Uruguay	0							

[a] *Scale of PES programs*: This column shows the various scales at which PES programs are implemented in each country. International means that the country has been party to one or more international conservation efforts, national means that the country has sponsored one or more programs at the national level, regional means that within the country PES programs have been developed that encompass multiple provinces or states, and local means that the country has developed one or more local PES programs, typically at the scale of a watershed, municipality, or village.

[b] *Total budget*: This column gives the total budget for PES programs for which budgets are released. Not all programs include total budgets, therefore the amount spent on PES programs will be higher.

[c] *Total area*: This column gives the total area for PES program implementation for which areas are released (not all sources included areas). The total includes both implemented and targeted areas.

on compiling data from previous studies and transferring those to equivalent types of ecosystems, were used for the ES provided by coastal ecosystems in **Mexico** (Martínez et al., 2009), and the economic impacts of land use change in different biomes for the Rio de Plata Basin (Viglizzo and Frank, 2006). Contingent valuation, that evaluates people's preferences, was used for the case of water quality regulation in **Puerto Rico** (Gonzalez-Caban and Loomis, 1997). Production functions were used to value water quantity in **Chile** (Núñez et al., 2006). Willingness to pay was used to value coastal protection in **Costa Rica** (Barr and Mourato, 2009). The value of provisioning services for which markets already exist, as is the case of various timber and NTFP are commonly used (Naidoo and Ricketts, 2006).

Assessment of the economic benefits derived from timber and selected NTFPs (Duchelle et al., 2012), water (Figueroa and Pasten, 2008), carbon (Bautista and Torres, 2003) and ecotourism (Lobo and Moretti, 2009) are common across LA.

Beyond economic valuation, societal perceptions and preferences for different ES have also been studied in the LA. Human preferences for hydrological services (Murillo et al., 2011), or for the multiple services associated directly with biodiversity and scenic value (Koellner et al., 2010) have been examined. Local perceptions and attitudes towards ES have been evaluated for tropical dry forests in **Mexico** (Castillo et al., 2005), silvo-pastoral systems in **Colombia** (Calle et al., 2009) or marine ecosystems in **Panama** (Hoehn and Thapa, 2009). A conceptual and methodological frameworks was developed in **Argentina** to systematically assess and compare the preferences of individual stakeholders for the ES they obtain from different types of ecosystems (Díaz et al., 2011).

5. Tradeoffs among ES and interdisciplinary research

5.1. Tradeoffs among ES

The analysis of tradeoffs among ES is in general not well developed in LA (Fig. 2).

Tradeoffs that emerge from different land use choices and management alternatives on a suite of ES have been analyzed in a few case studies. Tradeoffs between agricultural intensification and the maintenance of regulating services and biodiversity have been assessed across the Region (Grau and Aide, 2008). In **Argentina**, increases in provisioning services (i.e., agriculture) have been shown to decrease regulating services (Carreño et al., 2012). Tradeoffs between biofuel production and the maintenance of biodiversity have been of particular importance for **Brazil** (Bell et al., 2010). Assessments of changes in tradeoffs among ES between different management regimes (Guhl, 2009), different land use/land cover classes (Quijas, 2012), and between mature and secondary tropical forest or native and exotic plantations are underway (Hall et al., 2011).

5.2. Interdisciplinary research on ES

Interdisciplinary research on ES is also increasingly common in LA. ES models in **Argentina** have integrated spatially-explicit influences of landscape attributes to local and regional societal values (Laterra et al., 2012). Interdisciplinary approaches are being used to analyze watershed services in **Chile** (Meynard et al., 2007), to develop new conceptual frameworks for ES research (Balvanera et al., 2011), and guidelines for watershed management (Jujnovsky et al., 2012) in **Mexico**. The role of various social and ecological drivers underpinning ES supply or delivery has been analyzed, for example, in **Puerto Rico** for the case of water quality (Uriarte et al., 2011), timber and NTFP in Bolivia (Pacheco et al., 2010), and people's livelihoods in Panama (Runk et al., 2007). In **Panama**, a long-term participatory project focuses on community forest management, carbon sequestration and the resulting social and financial tradeoffs (Coomes et al., 2008). Other interdisciplinary research projects are underway across the Region Nucleus Diversus- (http://www.nucleodiversus.org/, ROBIN—the Role of Biodiversity In climate change mitigation, www.robinproject.info).

6. ES research, policy and management design

Much emphasis has been placed on the development of policy and management interventions that can contribute to a sustainable flow of ES to societies in LA (Fig. 2). The range of options include involving local communities in sustainable management of their resources and services (Camargo et al., 2009), the sustenance of indigenous livelihoods and the biodiversity they manage (Armesto et al., 2001), the development of best management practices (Villegas et al., 2009), and the certification of such management approaches (Ebeling and Yasué, 2009).

6.1. Demand-driven research

Various LA countries have fostered demand driven research to contribute to management and policy interventions towards sustainable management. In **Brazil**, financial support coming from the Environmental (Ministério do Meio Ambiente, www.mma.gov.br), Agricultural (Ministério da Agricultura, www.agricultura.gov.br and Embrapa, Empresa Brasileira de Pesquisa Agropecuária www.embrapa.br) and the Science and Technology (MCT, Ministério da Ciência e Tecnologia www.mct.gov.br) ministries has been directed towards those goals. In 2008 the Brazil Science Council launched centers of scientific excellence dedicated exclusively to biodiversity and ecosystem services. In **Mexico**, financial support from the National Council for Research and Technology (CONACYT, Consejo Nacional de Ciencia y Tecnología www.conacyt.gob.mx) and the Ministry of the Environment (SEMARNAT, Secretaría de Medio Ambiente y Recursos Naturales www.semarnat.gob.mx) and programs within it (e.g., CONAFOR, Comisión Nacional Forestal www.conafor.gob.mx, CONAGUA, Comisión Nacional del Agua www.cna.gob.mx) have led to a development of demand driven research. In **Chile**, research on ES was the basis for preparing policy and law proposals, which in 2008 led to the establishment of a law that provided incentives for the management and conservation of native forests in private lands (Lara et al., 2003).

6.2. PES programs

Initiatives linked to PES programs are increasingly commonin LA, probably more so than in other regions of the world (see Table 4 for a summary and Appendix 2 for details; Southgate and Wunder, 2009).

Costa Rica was a pioneer in adopting a PES program in 1997. Since then, this program has fostered research on ES by forging close connections between researchers and the governmental agency in charge of the program (Fondo Nacional de Financiamiento Forestal, http://www.fonafifo.com; (Cole, 2010). In **Mexico** PES programs were established in 2003 with emphasis on linking forest cover and water provision (Muñoz-Piña et al., 2008). This program is fostered by the federal government, through the forestry section of the environmental ministry (Comisión Nacional Forestal, www.conafor.org), and includes payments for water, carbon, and the multiple services derived from agroforestry systems. In **Chile**, the strong emphasis on private enterprise (such as the 1994 law designed to encourage private protected areas) and the low political priority for ES has hindered the development of national PES programs (Corcuera et al., 2002). Instead, private agreements among ES providers and users have sprung up to conserve natural areas for recreation and esthetic quality (Cabrera and Rojas, 2010). In **Panama**, only two regional PES programs are underway, one of which is driven by the huge contribution of the Panama Canal to the country's economy (Hearne, 2009). In the absence of a legal mechanism to allow for direct payments for ecosystem services, the Panama Canal Authority (www.pancanal.com) is compensating landholders for the conversion costs from traditional agriculture to more ES friendly management systems (e.g., silvo-pastoral and shade coffee). In **Colombia**, rather than national PES schemes, a multitude of local and regional programs focused primarily on hydrologic services and biodiversity have sprung up. Also, an international program to protect biodiversity and carbon sequestration (the Guiana Shield Initiative, www.guianashield.org) includes forested areas in Colombia. In **Bolivia**, national-level conservation programs (Servicio Nacional de Areas Naturales Protegidas, www.sernap.gob.bo) are not true PES but do reflect an appreciation of the value of ES. However, the government of Bolivia is a partner in the Noel Kempff Mercado Climate Action Project (www.forestcarbonportal.com), an international initiative to foster and maintain carbon stocks in areas threatened by forest degradation and deforestation (Cottle and Crosthwaite-Eyre, 2002). In **Brazil**, a national program (Imposto sobre Circulação de Mercadorias e Serviço) first adopted by the state of Paraná in 1989, provides a tax revenue-sharing method that compensates municipal governments for designating protected areas (OAS, 2012). A number of small-scale, local initiatives have begun with a focus on hydroelectric power and watershed services, while the largest spending on ES in Brazil continues to come from international projects designed for carbon sequestration in the Amazon (Hall, 2008). Despite its close association to the US and the existence of a number of regional PES programs are in the mainland US (mostly targeted to production services or biodiversity), our research did not reveal any PES programs in **Puerto Rico**. In **Argentina**, compensations for ES in the form of subsidies to conservation were incorporated into federal law on land use planning in 2007 (Ley Nacional 26.331) but no formal PES programs have been implemented. Challenging PES approaches, biophysical evaluation of ES is now part of mandatory impact assessment for areas under extensive deforestation (Viglizzo et al., 2011) and rural land planning policies have considered patterns of ES supply and delivery (Basso et al., 2012). In Uruguay, the ES concept has been limited to its incorporation into new norms to the potential for carbon sequestration in tree plantations (Decreto 238/009).

Payments for water services are the most developed across LA (Table 4, Appendix 2). Fostered by a partnership between Brazils national water agency (ANA) and The Nature Conservancy a number of Water Funds have been set up in the Atlantic Forest of Brazil where municipalities collect payments from water users (farmers) to help conserve and restore areas of forest (Gavaldão and Veiga, 2011). This experience led to the creation of Latin American Water Funds Partnership (TNC, 2012) with an initial investment of some USD$ 27 million to create, expand, implement and capitalize on at least 32 Water Funds in LA (Ecuador, Colombia, Peru, Brazil, Mexico and other places in LA and the Caribbean), with the goal of conserving ca. 7 million acres of watersheds that will potentially benefit ca. 50 million people.

Collaborations between governmental agencies, research institutions and non-governmental organizations have been critical in the development and implementation of PES programs. The design of the PES programs has relied on the academic community at various phases from creation (Kosoy et al., 2007) to evaluation (Alix-Garcia et al., 2010). Decision support tools are increasingly being developed to identify key areas for investing on ES (Estrada-Carmona and DeClerck, 2011). Collaborations with the universities and federal research institutes across LA (Amazon Environmental Research Institute, IPAM, www.ipam.org.br; Instituto Nacional de Tecnología Agropecuaria, INTA, inta.gob.ar; Universidad Nacional Autónoma de México, UNAM, www.unam.mx; Smithsonian Tropical Research Institute, STRI, www.stri.si.edu) have been instrumental to the development of ES policies. Also, the participation of global conservation NGOs (World Wildlife Fund, WWF, www.worldwildlife.org; The Nature Conservancy, TNC, www.nature.org), and regional NGOs (Fundación Natura, www.naturabolivia.org) have also been key. The state of Acre and Amazonas in **Brazil** have passed new law to foster implementation of PES programs (BSR, 2012).

7. Challenges ahead

7.1. Increasing our understanding of ES

ES research in LA has been growing steadily but much more information is still needed. Further studies are needed to connect ecological processes, potential ES supply, actual ES delivery to societies, and ES values. Research on ES supply is still limited to a few services, largely those of global (http://www.ctfs.si.edu/group/Carbon/) and regional (water) impacts. Particular importance needs to be placed to locally relevant services such as the regulation of human diseases, microclimatic conditions, and floods, as well as coastal protection. Systematic comparisons across countries, studies and services are hindered by the lack of information, and the use of comparable methods. Tools to assess tradeoffs among ES that take into account the contrasting scales at which different services are supplied and delivered are urgently needed.

7.2. *Responding to the particular needs of LA stakeholders*

Both large cultural diversity as well as strong inequities among stakeholders in LA bring about particular challenges. Many studies have linked cultural values of multiple NTFPs with the identity, legacy, sense of belonging of the very diverse population groups that co-exist in LA. These efforts, however, have not been adequately mainstreamed into the ES literature and thus not explicitly incorporated into the associated decision making processes. Tools to assess tradeoffs among services, and to explore how different stakeholders value ES are the focus of much research attention. Despite these advances, explicitly incorporating the needs of all the different stakeholders into decision-making remains a challenge. This is in part because very little is known about the wide variety of perspectives and how the large power inequities are hindering such integration.

7.3. *Assessing ES under future scenarios*

Evaluating how ES supply, delivery, values and their tradeoffs change under future scenarios of climate and land use change is sorely needed to support long-term decision-making and planning in the Region. Climate change predictions are highly variable across the Region; large parts of LA are particularly sensitive to, and impacted by climate extremes including hurricanes, floods and droughts (Jupp et al., 2010; Rammig et al., 2010). The effects of different management regimes, and future land use change decisions need to be further explored to identify the most suitable policies. Those associated with the increasing insecurity and un-governability of the region remain to be tackled.

7.4. *ES and biodiversity conservation*

Conservation of the very large biodiversity hosted by LA countries is of paramount importance. While the importance of this biodiversity for people's livelihoods has well been established, much less is known of how biodiversity underpins service supply and delivery, or whether interventions to sustain ES have had positive or negative effects on biodiversity conservation. In particular, addressing food security and water security needs, while at the same time maintaining the elevated biodiversity, is a major issue in the region.

7.5. *ES and human well-being*

Our understanding of the contributions of ecosystems to the different components of objective and subjective well-being (Stiglitz et al., 2010) is its infancy. Different stakeholders ranging from indigenous rural populations and mestizo slum dwellers to large agricultural, industrial and financial corporations depend on ecosystems in different ways. Assessments of the differential vulnerability of different regions and stakeholders to future climate and land use scenarios are needed. Corresponding mitigation and adaptation strategies need to be considered.

7.6. *Implementation of PES programs*

Further emphasis is needed on coastal and marine ES (Trends and Group, 2010), as well as those derived from agroecosystems (Oberthür et al., 2008). More data is needed on baseline conditions and on how these evolve as the programs are implemented. Targeting and monitoring protocols to develop PES that are cost effective while providing sound evidence that purchased services are actually delivered are needed (Sierra and Russman, 2006; Estrada-Carmona and DeClerck, 2011; Robalino et al., 2011). Yet, the temporal scales over which ecosystems respond to PES interventions (e.g., effects of changes in land cover on hydrological services) can be longer than those associated to payments, as is the case of hydrological services (Guariguata and Balvanera, 2009), infrastructural investments or political will for investing in ES. Key to the success of ES-based strategies is to understand who provides and who desires (or consumes) ES benefits (Kosoy et al., 2007, Koellner et al., 2010), as there are mismatches between national scale programs and the finer scale at which services are supplied and delivered. The recent emphasis on local-scale PES schemes in many countries including Brazil, Colombia and Mexico, with well-defined buyers (beneficiaries of services) and sellers (providers of services) reflect a better tuning to the scales of service supply and delivery, and to the large heterogeneity of the region. However, the cumulative benefits of these small-scale programs remain to be seen.

PES programs are constantly faced with the need to secure stable sources of funding. The elevated costs associated with implementation, the lack of clear directives and achievement criteria for program participants, limited funding, insecure land tenure and weak legal support are some of the major hindrances to the effectiveness and adoption of these programs (Hall, 2008; Southgate and Wunder, 2009; IIED, 2012). Also mismatch between opportunity costs and payments value (Murillo et al., 2011), are often associated with rapid changes in the demand for globally traded agricultural commodities.

7.7. *Limitations of PES programs*

Top-down, national level PES programs have often been received with hostility in many Andean areas with large indigenous communities and insecure land tenure (Southgate and Wunder, 2009). The national governments of Bolivia and Venezuela among other LA countries are skeptical of commoditization of nature in general (e.g., http://climate-connections.org/2012/06/01/venezuelan-declaration-toward-rio-20-against-the-green-economy/). The anthropocentric view of nature that underpins the PES approach, that is reducing all cultural, societal and non-tangible values to economic valuation has been seen as a commoditization of nature. The PES approach has recently been challenged by the Constitutions of Bolivia and Ecuador (Zaffaroni, 2012). The strong focus on economic evaluation of ecosystem services has caused some consternation amongst Latin American states (Boliva, Ecuador and Cuba in particular), seen as mechanisms for indirect privatization (Gentes, 2005), discouraging these nations from joining the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES; Turnhout, 2012 #1153).

Also, whether PES should also be aimed at reducing poverty and how that could work, has been the subject of heated discussion (Bulte et al., 2008; Ferraro and Hanauer, 2011; Rolón et al., 2011). Projects with emphasis in both services and poverty reduction are being implemented (Estrada et al., 2009). Yet, PES

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payments have sometimes been shown to reproduce rather than decrease power asymmetries in the access to environmental benefits (Kosoy et al., 2008).

7.8. Integrating across disciplines, sectors and stakeholders

Ensuring the maintenance of biodiversity and functioning ecosystems, the flow of services to societies and the well-being of different stakeholders is a very complex task. Further research on the economic, political, institutional, cultural, social, cognitive and cultural drivers underpinning ecosystem management decisions is critical to design the best interventions suited for the wide variation of contexts, stakeholders and spatial scales across LA. An understanding of non-linear or abrupt transitions in ecosystem structure (Morello and Adámoli, 1970) and in the ability of ecosystems to supply services (Viglizzo et al., 2012) is needed. Interventions to sustain ES should also go beyond the promotion of individual ES, such as food, water, or carbon for climate regulation, to consider the full portfolio of ES that sustain societies. Development must proceed across governmental sectors, linking those associated to the ministry of agriculture, or that of the environment, and aiming at the sustainability of the whole social–ecological system,. In this manner, PES could be integrated into larger policies aimed at conserving biodiversity and ES and at reducing poverty (Pattanayak et al., 2010). While meeting a wide range of goals may not be feasible for a single type of intervention (Wunder, 2012), a combination of knowledge, institutional, societal, and financial interventions may be developed to tackle the complexity of real social–ecological systems (Ferraro et al., 2011). Novel governance arrangements must be developed to integrate decision making across different government levels, across private and civil society partnerships, and between sub-national governments (Brondizio et al., 2009). The private sector is increasingly active in this realm. For instance, tools to asses company's dependence and impacts on ES have been developed (Hanson et al., 2012). Guidelines for the integration of ecosystem services into environmental and social impact assessments are underway (BSR, 2012). New policy interventions would benefit from further collaboration between ES researchers, the private and public sectors, and civil society (Lara et al., 2011).

7.9. Capacity building

Achieving all the above will heavily rely on training a new generation of scientists, government officials, NGO teams, and business leaders with a set of new tools. This goal may be achieved by a combination of academic and practitioner exchanges among LA countries or among sites where new insights have been gained and efforts have been successful.

8. Conclusions

We have shown that ecosystem service science has grown rapidly in the past two decades in LA. Nevertheless, strong imbalances remain among the attention paid to individual ES, information availability, and countries. Further research is needed to systematically assess the supply, delivery and values (social as well as economic) of the suite of services derived from the ecosystems found in the region. The particular needs of the diverse populations and the diverse ecosystems of LA need to be further taken into account. Sharp tradeoffs between increasing the supply of agricultural products, the maintenance of other services and the livelihoods of stakeholders are evident, and assessments of these tradeoffs in the present and under alternative future scenarios should be a research priority. Payments for ecosystem services have initially been broadly adopted in the region as a mechanism to sustain the flow of benefits to societies from services, although scientific, ethical and policy limitations have emerged. Yet, interventions that encompass the wide diversity of perspectives, including those reservations associated with the commodification of nature inherent in many PES programs, and that operate across sectors are needed for success of larger spatial scope (e.g., global or regional). The future of the ecosystem service paradigm in Latin America will largely be dependent on its capacity to demonstrate effectiveness in meeting both conservation and development goals.

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Appendix A. Supplementary materials

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.ecoser.2012.09.006.

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