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Economically valuing nature resources to promote conservation: An empirical application to Chile's national system of protected areas*

Eugenio Figueroa[1], **Roberto Pasten**[2]

[1] Department of Economics, Universidad de Chile, Diagonal Paraguay 257, Santiago, Chile (e-mail: efiguero@econ.uchile.cl)
[2] Department of Economics and Finance, Universidad de Talca, Avda. Lircay s/n, Talca, Chile (e-mail: rpasten@utalca.cl)

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Abstract. Starting from the framework proposed by the Millennium Ecosystem Assessment (MEA) – which conceptually links nature's services with human wellbeing – we design and also apply empirically what we have called the total economic value calculating matrix (TEVCM) to estimate the monetary value of the annual flow of benefits provided by Chile's national system of protected areas (NSPA). The calculated economic value of this flow amounts to US$2.55 billion per year. We also analyse the relevance and usefulness of the methodology we propose and use the valuation exercise presented to extract some normative lessons regarding nature conservation in Chile as well as in developing countries rich in natural resource endowments.

JEL classification: Q20, Q51, R52

Key words: Ecosystem services, economic value, nature conservation, protected areas

1 Introduction

The purpose of this paper is to present a novel conceptual and empirical framework – the total economic value calculating matrix (TEVCM) – to guide and facilitate interdisciplinary work to economically valuating nature's contribution to society, a need that is recognized by the most recent literature in natural as well as social sciences.[1] We developed this conceptual framework and empirical tool in a two-year interdisciplinary research effort to calculate the economic value of the annual flow of ecosystem services provided by Chile's national system of protected areas (NSPA) to the Chilean population. The results of our research are presented here to illustrate the

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[1] Economic valuation of currently overlooked ecosystem services can be instrumental in re-framing decisions and prompting improved management of natural capital (Aylward and Barbier 1992; Chee 2004; Ingraham and Foster 2008).

practical implementation of the proposed conceptual framework. Moreover, the study provides relevant policy insights and implications for nature rich countries in general, and for developing countries in particular, that are far more reaching that those of a mere study case.

1.1 Nature, ecosystem services and their deterioration

The Earth's ecosystems produce and generate a large quantity of goods and services which satisfy different human necessities and wants, from the most basic ones, such as breathing air, consuming food and drinking water, to others apparently less indispensable, such as spiritual realization, aesthetic enjoyment and recreation. Additionally, they provide fundamental life-supporting services related to the regulation of atmospheric gases, climate, hydrological cycles, the mechanisms and processes determining the productivity and stability of soils, forests and wetlands, etc. (Holling 1996). In this way, the goods and services provided by ecosystems are crucial to determining human welfare (MEA 2003). Moreover, in the absence of ecosystems, their indispensable ecosystem functions would cease to exist and, with them, the provision of goods and services they generate would also disappear, rendering life on Earth impossible (Cairns 1997).

In spite of this, there is increasing evidence of the mounting deterioration of the planet's ecosystems and their capacities to generate such indispensable goods and services to humans (MEA 2003, 2005a; IPCC 2007; WWF 2008; FAO 2008, 2009). This undesired trend is the result of an inadequate appraisal of ecosystems' contributions to human wellbeing, which provokes their undervaluation and, therefore, the assignment of a much lesser priority to their care and conservation than the one they deserve given their relevance for human current welfare and future survival.

1.2 Nature and ecosystem services value

Costanza et al. (1997) estimated the economic value of the world ecosystems' contribution to human welfare. They calculated the annual economic value of the services provided by global ecosystem at US$33 trillion, or the equivalent to 1.8 times the global gross national product (GDP). The majority of the value of services identified by these authors has been and is currently outside the market system; this includes services such as gas regulation (US$1.3 trillion/yr), disturbance regulation (US$1.8 trillion/yr), waste treatment (US$2.3 trillion/yr) and nutrient cycling (US$17 trillion yr/). About 63 per cent of the estimated value is contributed by marine systems (US$20.9 trillion/yr), most of which comes from coastal systems (US$10.6 trillion/yr); and about 37 per cent of the estimated value comes from terrestrial systems, mainly from forests (US$4.7 trillion/yr) and wetlands (US$4.9 trillion/yr).

A clear message of this study was that if one were to try to replace the services of ecosystems at the then (1997) current margin, global GNP would need to be increased by at least US$33 trillion, partly to cover services already captured in existing GNP and partly to cover services that are not captured in GNP figures. This impossible task would lead to no increase in welfare because we would only be replacing existing ecosystem services, ignoring the fact that many ecosystem services are literally irreplaceable (Krutilla 1967; Cairns 1997; Costanza et al. 1997; Heal 2000; Palmer et al. 2004).

Generally, individuals and societies valuate ecosystems and ecosystem goods and services less than their real social values. This undervaluation by individuals and society is due in large part because these assets and goods and services have the characteristic of being 'public goods' or 'common-pool resources' and/or because they are not traded in formal markets in which their relative scarcities are properly gauged and assessed (Stenberg 1996). This contends that ecosystems fall outside the sphere of markets and tend to be 'invisible' in economic analysis (Chee 2004) and political decision-making (Figueroa 2007). This oversight also causes the 'market failures' that never correct the suboptimal utilization, care and conservation of these resources granted by nature (Balmford et al. 2002; Turner and Daily 2008). Moreover, lack of knowledge, society's inappropriate managerial capacities, or even plain vested interests avoid or obstruct the design and implementation of the necessary measures to correct the absence and/or the failures of markets, and then, 'regulatory' or 'government' failures allow the deterioration of ecosystems to continue rampantly (Pearce 2001; MEA 2005a; Palmer et al. 2008; CBD 2010; TEEB 2010a; UNEP 2012).

In fact, in economic terms, ecosystems are valuable precisely because the goods and services they provide affect human welfare; and the decisions that individuals and society make in the scarcity context they inevitably live 'reveal' their relative valuations of these goods and services (as well as of other goods and services, such as those produced by the economic system, leisure, etc.) (Krutilla 1967; MEA 2003, 2005b; Chee 2004; Figueroa 2007; Fisher and Turner 2008). Moreover, economic science has developed different techniques to reveal and measure the value of goods that do not have explicit markets and which therefore, do not have explicit market prices either (Henry 1974; Rosen 1974; Fisher and Hanemann 1986; Hanemann 1989, 1991, 1994; Mitchell and Carson 1989; Chichilnisky 1997; EPA 1997; Bookshire et al. 1982; Arrow et al. 1993; Johansson 1993; Kopp and Smith 1993). These techniques use actual (real-life) and/or constructed decisions of individuals and society to reveal their relative valuations of these goods and services with no market *vis-à-vis* their valuations of those goods and services that do have (and are traded in) formal markets (Henry 1974; Hanemann 1984; Rowe et al. 1985; McConnell 1990; Cameron 1992; Champ et al. 1997). Using these estimating techniques, economists calculate quantitative expressions of the individual and social valuations of the different ecosystem goods and services, which provide extremely valuable information, not only on the relative appreciation by people of these ecosystem goods and services, but also on their relative scarcities and the relative willingness of people to care for the current and future supply and conservation of each one of them (Clawson and Knetsch 1966; Ellis and Fisher 1987; Arrow et al. 1993; Freeman 1993; Ready 1995; NRC 1997, 2012; Louviere et al. 2000; Haab and McConnell 2002; Carson et al. 2003; Figueroa 2007).

Adequate valuation of ecosystem goods and services constitute then a crucial need to properly assess society's conservation decisions, policies and projects. As Arrow et al. (1996) pointed out, economic efficiency, measured as the difference between benefits and costs, is one of the fundamental criteria for evaluating proposed or existing environmental regulations and projects, among which nature conservation policies and projects are becoming increasingly important due to the alarming worldwide trend in biodiversity deterioration and extinction (MEA 2005b). In fact, because society has limited resources to spend on environmental regulation and nature conservation, cost-benefit analysis can help illuminate the trade-offs involved in making different kinds of social investments. In this regard, it seems almost irresponsible to not conduct such analyses, because they can inform decision-makers about how scarce resources can be put to the greatest social good and therefore maximize attainable social welfare.

Moreover, cost-benefits analysis can also help to answer the question of how much conservation is enough. The answer to this question is simple: regulate until the incremental benefits of conservation are just offset by its incremental costs (Johansson 1993; Turner et al. 1993; Azqueta and Perez 1996; Field 2001). In practice, however, the problem is quite difficult, in large part due to the difficulties in measuring marginal benefits and costs, a problem which is compounded when dealing with ecosystem goods and services due to their characteristic of often being common-pool resources and not having explicit markets (Chichilnisky 1997; Dasgupta et al. 2000; Tietenberg 2000; Crafton et al. 2004).

In most countries, protected areas and national systems of wild protected areas constitute the most common instrument of environmental management to protect ecosystem goods and services and biodiversity (Coad et al. 2008; Figueroa et al. 2009; CBD 2010; UNEP-WCMC 2010). To properly apply these instruments, it is necessary to economically valuate the benefits they provide and the costs they impose on society. By far, the greatest obstacles to valuation are encountered in valuing the benefits of conservation policies and projects, since their costs are more readily appraised because they are mostly related to the administrative and operating expenses of protected areas systems, which generally have direct market prices (Figueroa 2011). Moreover, when economically valuing the benefits of ecosystem services one generally faces two additional problems: the lack of clarity regarding the conceptual framework within which values are appraised; and, the usual technical controversies regarding the use of economic techniques to value non-market goods (Loomis et al. 2000; Bräuer 2003; Gómez-Bagghetun et al. 2010; TEEB 2010b).[2]

Fortunately, the Millennium Ecosystem Assessment (MEA 2005b) generated and proposed a consistent conceptual framework that brought together the views of natural and social sciences and which, in spite of some weaknesses, has created which seems to be a generally and across-disciplines accepted framework to understanding the contribution of nature and ecosystem goods and services to human welfare and an adequate conceptual and consistent way to approaching their valuation.[3] This framework has brought closer the views of natural and social sciences to improve both the valuation of nature and ecosystem goods and services and their allocations in social decision-making processes. Moreover, researchers from different disciplines and in different parts of the world have been using and improving the MEA (2003, 2005b) conceptual framework. In this paper we present a conceptual framework which we have called total economic value calculating matrix (TEVCM), which we developed, using the MEA framework as its starting point, to economically value the annual contribution of Chile's national system of protected areas to the Chilean population. This conceptual framework allows for calculation of the value of an ecosystem, a group of ecosystems, a natural park, or any other arrangement of nature assets.[4]

In the empirical part of this paper, the TEVCM is used to calculate the value of the annual contribution of Chile's national system of protected areas, a system poorly treated in terms of political priority and budget allocation. In fact, in 2005, Chile's public budget to protect biodiversity and landscapes was only 2 per cent of the US$2.55 billion per year of benefits estimated in the present paper. Therefore, it is important for decision-makers then to learn about the figure calculated and to understand that its NSPA renders annually the equivalent of 2.2 per cent of the country's GDP. Country authorities need to know this value in order to decide how much money is convenient to invest in redesigning the NSPA, a project that has been in the public discussion for many years.

1.3 Nature, ecosystem goods and services and human welfare

In the context of the rational behaviour paradigm of economic science, human beings care for and conserve nature when they value it based on their own perspective and interest (Chee 2004;

[2] For a discussion of these issues, see Figueroa (2007, 2011).

[3] The MEA was produced between 2001 and 2005 by more than 1,360 recognized world specialists and constitutes the most recent and widely accepted appraisal of the conditions and trends in the planetary ecosystem and the services they provide

[4] For a discussion of this point, see the report of a consulting project for the Chilean government, the United Nations Development Programme (UNDP) and the Global Environmental Fund (GEF) under whose umbrella we did the research work presented here (Figueroa 2007) and a research paper presented at an international conference (Figueroa and Pasten 2009).

Figueroa and Aronson 2006; Horowitz et al. 2008);[5] otherwise we depreciate nature and destroy it (Daly and Farley 2004), usually until the pains and sorrows provoked by its then too costly scarcity make us retrace the unwise route. However, undoing the destructive, unsustainable previous way is often far more costly than the alternative route of taking intelligent and timely protective measures tailored to maximize our long-term wellbeing (Walker et al. 1990; Ostrom 1990, 2000; Hueting 1996; Hardin 1968; El Serafy 1991; Palmer et al. 2008; Abbott and Wilen 2011). Furthermore, there does not always exist the possibility for restoring what is already degraded or destroyed, since nature very often exhibits no-return points or thresholds which are most of the time unknown to our limited scientific understanding and technologies (Jackson et al. 1995; Lamb et al. 2005). All this underscores the importance of properly and timely assessing and appreciating the contribution of nature, ecosystems and ecosystem goods and services to human wellbeing, so due account of them is taken when every day decisions are made to allocate nature and human made resources (Arrow et al. 1996; Fisher et al. 1972).

1.4 Valuating nature

Valuating or appraising something is, in general, a comparative exercise, since we determine its value with respect to a known and meaningful yardstick. Economic science does exactly this when it valuates a thing (a good, a service or an asset). The yardstick used in economics is individual (and/or social) welfare, which makes economic value a (individual and/or social) preference related concept (Von Wright 1963; Brown 1984). This allows economics to express the value of a good, a service or an asset that is traded in the market in terms of the units of other goods, services or assets that are also traded in the market and which the individual (and/or society) considers (at least) as equivalent (or valuable) (Hicks 1946; Boulding 1956; Arrow 1963). Moreover, as money is a universally known and accepted currency, the economic (trade) values of different goods, services or assets can also be expressed and are commonly expressed in monetary terms.[6]

1.5 Multidisciplinary state of the art for valuating nature

As previously mentioned, economic science has developed methodologies available for calculating or revealing the valuation of ecosystems and ecosystem goods and services, many of which are not traded in the market and therefore, do not have explicit market prices (Bergstrom and Randall 2010). These methodologies use information on related goods that do have markets, or obtained from specially designed surveys applied directly to those whose valuations we want to know or determine (Crafton et al. 2004). The technique to be used in each case depends on the type of ecosystem good or service to be evaluated and the type of contribution it makes to the wellbeing of individuals or society. Therefore, it is important to appropriately characterize the ecosystem good or service to be evaluated in order to choose the adequate technique. One

[5] Due to space limitations, we do not address here the vast research from behavioural economics, psychology, anthropology, sociology and neurosciences, among other disciplines, regarding the determinants of human behaviour and decision-making beyond or outside the economic paradigm of rationality with respect to nature and the environment. For discussions of this issue, see Simon (1956), Downs (1972), Dunlap and van Liere (1978), Coursey et al. (1987), Smith (1991), Tversky and Simonson (1993), Rabin (1998), Gowdy and Mayumi (2001), Braga and Starmer (2005), Harrison (2005), Elger and Teichert (2007), Shogren and Taylor (2008), Hasler (2012).

[6] However, this last step of translating the value of the item into monetary units is not strictly necessary for economic valuation, and it is generally done because of the universal knowledge (perception) that people have of the value of their countries' monetary units. However, economic values can be stated in terms of units of any good, and this is why some authors have expressed economic values in terms of energy units, for example (see Pimentel 1980).

key characteristic of the good or service to be determined is the way it affects the welfare of individuals or society (Boyd and Banzhaf 2007). However, to define precisely the ultimate welfare determinants of the individual and/or social welfare affected by a given ecosystem good or service is not trivial (Ingraham and Foster 2008). Moreover, the lack of clarity or ambiguities that remain in the definition of the same concepts of goods and services as well as of the roles in determining the individual and collective welfare, seem to be central to the difficulties of finding a common language between the natural and social sciences (Figueroa 2007; Wallace 2007; Fisher and Turner 2008). For social sciences in general, and for economics in particular, these are core concepts with generally quite precise definitions from which an important part of their conceptual architectures are built.

In recent decades, natural scientists have made efforts to introduce these concepts in their analyses. Moreover, there have been attempts from economics, ecological economics and natural sciences to bring together languages and visions in order to produce a common interdisciplinary approach. The Millennium Ecosystem Assessment (MEA 2003, 2005a, 2005b) is the most important recent attempt in this line which has had and will continue to have a significant effect.[7] The MEA relates the ecological functions of ecosystem, ecosystem processes, ecosystem services and ecosystem production of goods and services that have explicit markets, and proposes for their assessment an analytical model with two prominent features. The first is the emphasis it places in what it calls 'ecosystem services'.[8] The second is the change it introduces to the usual economic meaning of the 'ecosystem goods and services' concepts. Regarding the first of these two aspects, the MEA in fact places great importance on what are commonly referred to as 'environmental services', 'ecosystem functions' or 'ecosystem services'. In addition, it places them in three categories: regulating services, supporting services and cultural services. This represents a contribution in the sense that it calls attention to the importance of these ecosystem services, since some are so crucial to human life and well-being as the mechanisms that regulate the impacts of stress or sudden shocks – such as disease regulation – and other services related to air quality regulation, regulation of hydrologic cycles, floods, aquifer recharge, soil erosion, etc. (Boyd and Banzhaf 2007).

With respect to the second aspect, however, by including all goods and services that are produced by planetary ecosystems in a single category that it refers to as 'services' or 'ecosystem services', the MEA ignores the usual differentiation between goods and services defined and employed by economic science. As Figueroa (2007) has pointed out, this is a mistake, because on the one hand it creates a source of imprecision; and on the other hand, it restricts and diminishes the conceptual richness of the economic nomenclature that employs both terms – goods and services– instead of only the latter. In fact, economic science distinguishes between goods and services to differentiate, among the elements that determine the welfare of individuals or society, between those that are tangible (goods) and those that are intangible (services). Goods such as bread, fruit and cars contribute to human welfare by meeting a specific necessity, such as satisfying hunger or providing mobilization. Services such as a hair cut or a concert also satisfy personal needs, and for that reason they also generate welfare to persons and society. Sometimes the term 'service' is used to refer to the entire process or activity that generates or produces the 'element' that finally affects welfare (i.e., as Wallace 2007 puts it, processes (means) for achieving services and services themselves (ends) are mixed). Analytically it is

[7] Perrings (2006, p. 8), for example, believes that 'MEA has changed the way we think about the interaction between social systems and ecosystems'. Norgaard (2008) in turn, believes that the MEA demonstrated that multidisciplinary scientists can adapt deliberative and democratic approaches in order to learn together and develop a shared understanding of complex systems; it helped in expanding our understanding of the nature of science, the role of judgment in science, and the nature of the boundary between science and democratic choice; and, it also produced well-reasoned conclusions and trained a new cadre of more thoughtful and interdisciplinary (also more humble and more comfortable with irresolvable ambiguity) scientists.

[8] For a discussion of this concept, see (Daily 1997; Daily et al. 2000).

important, however, to distinguish that welfare is ultimately affected and determined by that element and not by the entire process or activity that generated such an element. Moreover, when dealing with nature, ecosystems and the goods and services they provide to individuals and society, there are many significant aspects of their relationship with human welfare for which it is analytically useful and meaningful to maintain the distinction between good and services. Thus, here we do not follow the MEA suggestion of using the unique category of 'ecosystem services' and we use the usual economic science nomenclature of goods and services. However, in order to facilitate further discussion, we employ both nomenclatures simultaneously in the TEVCM used here for empirical work.

To classify the goods and services that ecosystems provide to people and society, the TEVCM adopts the four categories the MEA (2005) uses for classifying its 'ecosystem services':[9] (*i*) Provisioning (goods and) services: tangible goods (foods, water, fuel, fibres, raw materials, genetic resources, etc.) that are obtained from ecosystems, a large proportion of which are traded in structured markets; (*ii*) Regulating services: services (water purification, and regulation of floods, drought, land degradation, and disease, etc.) related to ecosystem processes and their contribution to regulating the natural system; (*iii*) Cultural services: services that humans obtain from ecosystems through spiritual enrichment, cognitive development, internal reflection, recreation and aesthetic enjoyment. These are closely linked to human values, identity and behaviour; and (*iv*) Supporting (or base) services: services (climate regulation and hydrological regulation, etc.) necessary for ecosystem functioning and adequate production of provisioning goods and services and regulating services. Their effect on welfare is apparent in the long run through the impact on the provision of other ecosystem goods and services.

2 Method

The conceptual framework we propose here to carrying out the empirical work necessary to economically valuate ecosystems or ecosystem services corresponds to a method we developed to guide and facilitate the interdisciplinary tasks involved in calculating the economic value of Chile's national system of protected areas. We designed a matrix to calculate the total economic value (TEV) of a natural area (an ecosystem or an arrangement of different ecosystems). Table 1 presents a specific example of our TEVCM, which integrates three aspects that are key to calculating the economic value of any natural area: (*i*) a typification of ecosystem good and services in three explicit categories following the MEA (2003, 2005b) nomenclature (regulating, provision and cultural); (*ii*) a standardization of these three categories of ecosystem goods and services with the three usual categories (or sources) of value considered in economic science (direct use value, indirect use value and existence value); and (*iii*) a systematization of the procedure used to calculate the economic value of ecosystem goods and services by type of ecosystem present in the natural area that is being economically valuated (as proposed by Costanza et al. 1997), by type of ecosystem services (as proposed by the Millennium Ecosystem Assessment, MEA 2003, 2005b) and by the economic categories of the TEV approach (see, for example, IUCN-UNDP-GEF-WISP 2008).

In the empirical implementation presented below, the TEVCM in Table 1 was specifically elaborated to calculate the TEV of the annual contribution made by the NSPA to the Chilean population in terms of the annual flow of ecosystem goods and services provided by the system to Chileans distributed along the country. The first column of this specific TEVCM lists the 15 ecosystem types (and subtypes) that exist in the country's NSPA and for which it was possible to calculate at least one component of its TEV. Thus, for each one of these ecosystem types or subtypes,

[9] Goods and services, according to our nomenclature.

	TOTAL ECONOMIC VALUE																						
	USE VALUE																					NON USE VALUE	
	INDIRECT USE VALUE											DIRECT USE VALUE											
	Regulating Services											Provisioning Services						Cultural Services					
Well-being determinants (Ecosystem good or service) / Ecosystem	Water Purification	Biological Control	Pollination	Regulation of Human Diseases	Waste Treatment	Climate Regulation	Water Regulation	Air Quality Maintenance	Erosion Control	Nutrients Regulations	Bird Schelter	Food and Fibre	Fresh Water	Fuelwood	Biochemicals	International Tourism	Genetic Resources	Cultural Diversity	Domestic Tourism	Recreation	Science and Education	EXISTENCE VALUE	TOTAL (TEV OF ECOSYSTEM)
FOREST																							
Temperate broad-leaf forest																							
Andean																							
Coastal																							
Temperate deciduous forest																							
Temperate evergreen forest																							
Mediterranean schlerophyllous forest																							
WETLANDS																							
SALAR																							
PEATS																							
OTHER WETLANDS																							
DESERT																							
MARINE AND DUNES																							
SCHRUBLANDS																							
GRASSLANDS																							
ICE/ROCK																							
																							PA TEV
TOTAL (TEV OF WELL-BEING DETERMINANT)																							
TOTAL (TEV OF ECOSYSTEM SERVICE TYPE)																							
TOTAL (TEV OF VALUE CATEGORY)																							
TOTAL (TEV OF PA)																							

Table. 1. Total economic value calculating matrix (TEVCM)

each row reports the economic value estimated for each of the welfare determinants (ecosystem goods and services) listed in the fifth row of the matrix. On the other hand, the fifth row of the matrix lists the determinants of individual and/or social welfare, that is, the ecosystem goods and services provided by the area.[10] Therefore, each column of the matrix reports for one of the welfare determinants the estimated values of the annual provision of that welfare determinant (ecosystem good or service) by the different ecosystem types and subtypes listed in the first column.

Each row in the far right column, ‘Total’, shows the TEV calculated for each of the 15 ecosystem types and subtypes considered. On the other hand, the last four rows of the TEVCM represent different ways of reporting the TEV produced by the NSPA. These four rows thus show and highlight the conceptual and empirical correspondence between the sources of value typically used in the natural sciences on the one hand, and the sources of value employed by social sciences, and particularly, by economic science, on the other. In fact, each column of the first row of these four ‘Total’ rows at the bottom of the matrix reports in each of its column the TEV calculated for each of the 22 welfare determinants included. The cell at the far right of this row represents the TEV calculated for the entire NSPA of Chile.

The second ‘Total’ row at the bottom of the matrix reports the TEV for each of the MEA (2005b) categories of ‘ecosystem services’. The third ‘Total’ row reports the TEV separated into the three categories of value normally used by economic theory, which are also shown in the third row from the top of the TEVCM: direct use value, indirect use value, and non-use (existence) value. Finally, the bottom row shows the aggregate TEV calculated for Chile’s NSPA. This shows explicitly the conceptual and numerical correspondence between the cell in the middle of the last row, which represents the TEV annually provided by the system (the sum of the different categories of values), and the far right cell of the last row (which is also the bottom cell of the last column), which represents the TEV calculated as the sum of the values contributed by the different types of ecosystems contained in Chile’s NSPA.

The grey cells correspond to goods and services which cannot exist in the respective ecosystems. For example, pollination services or provision of food and fibres is not possible in glacier ecosystems. The value of these cells is known to be zero in advance. Furthermore, we deleted the columns of the matrix corresponding to those ecosystem goods and services for which there was no data available to calculate at least one value.

In the following section we present the results of the estimation of the specific value of each of the cells of the TEVCM in Table 1, indicating summarily the specific method employed in each case.

3 Results

The total area protected by Chile’s NSPA that we valued economically is about 15 million hectares. The economic valuation was performed using the frame methodology described in the previous section. In addition, we used one or more valuation techniques to estimate the value of the cells in TEVCM presented in Table 1. Because of resource and time constraints, we mostly used benefits transfer analysis, performing a comprehensive search of data sources to determine the existence of studies relevant to the problem at hand.

The remainder of this section describes in a very general way the valuation techniques used and the results obtained in estimating the cells of the TEVCM. The description follows the structure of the matrix in Table 2, which is identical to the TEVCM in Table 1 but without those columns corresponding to ecosystem services for which it was not possible to calculate the cell value in at least one row of the column and, second, those rows corresponding to ecosystem

[10] Only those goods and services for which it was possible to calculate their economic value are included.

Well-being determinants (Ecosystem good or service) / Ecosystem	TOTAL ECONOMIC VALUE												
	USE VALUE											NON USE VALUE	
	INDIRECT USE VALUE						DIRECT USE VALUE						
	Regulating Services						Provisioning Services				Cultural Services		
	1	2	3	4	5	6	7	8	9	10	11	12	
	Water Purification	Regulation of Human Diseases	Climate Regulation	Water Regulation	Air Quality Maintenance	Bird Shelter	Food and Fibre	Fresh Water	International Tourism	Genetic Resources	Domestic Tourism	EXISTENCE VALUE	TOTAL (TEV OF ECOSYSTEM)
FOREST			122				4.911					10.821	15.853
Temperate broad-leaf forest								3.653					3.653
Andean					39.259								39.259
Coastal					21.425								21.425
Temperate deciduous forest					125.904			7.801					133.705
Temperate evergreen forest					203.966			4.818					208.784
Mediterranean schlerophyllous forest					23.607								23.607
Thorn forest					309								309
WETLANDS													
SALAR	6.635	4.930			8.406	4.631		1.037					25.639
PEATS	144.812	604.462		233.308	21.150	567.743	792	22.627					1.594.894
OTHER WETLANDS	24.026	17.853		38.708	30.436	16.768		3.754					131.545
MARINE AND DUNES							19.043						19.043
SCHRUBLANDS					235.914								235.914
PRAIRIE					20.275								20.275
GRASSLANDS					6.381								6.381
GLACIERS					551								551
													TEV
TOTAL (TEV BY WELL-BEING DETERMINANT)	175.473	627.245	122	272.016	737.583	589.142	24.747	43.689	53.663	6.189	9.997	10.821	2.550.685
	6,9%	24,6%	0,0%	10,7%	28,9%	23,1%	1,0%	1,7%	2,1%	0,2%	0,4%	0.4%	100,0%
TOTAL (TEV BY ECOSYSTEM SERVICE TYPE)	Regulating Services						Provisioning Services				Cutural Services		
	2.401.581						128.287				20.817		2.550.685
	94.2%						5.0%				0.8%		100,0%
TOTAL (TEV BY ECONOMIC VALUE CATEGORY)	INDIRECT USE VALUE						DIRECT USE VALUE					N-U V	
	2.401.581						138.284					10.821	2.550.685
	94.2%						5,4%					0,4%	100,0%
TOTAL (TEV BY ECONOMIC VALUE CATEGORY)	USE VALUE											N-U V	
	2.539.865											10.821	2.550.685
	99,6%											0,4%	100,0%
TEV (TEV OF NSPA)	TEV												
	2.550.685												2.550.685
	100.0%												100,0%

Source: Own elaboration with data from Figueroa (2007).

Table 2. Total economic value calculating matrix (TEVCM): Implementation for protected areas in Chile (thousand US$/year)

types for which the lack of information precludes the calculation of any cell value (i.e., desert ecosystem).[11]

3.1 Valuation of forest ecosystem services

Forests provide ecosystem services such as timber and non-timber products, water provision, water regulation, carbon storage, recreation, climate regulation, soil protection, atmospheric regulation, habitat protection and others (Nasi et al. 2002).

3.1.1 Fresh water provision

The calculated economic values of the provision of water for human consumption provided by the temperate forests included in the NSPA are shown in column 9 of Table 2. The estimations

[11] For a more detailed and technical analysis, see the original project report listed as Figueroa (2007) in the references section below.

do not include Northern forests and Mediterranean sclerophyllous forests due to lack of information. The valuing technique used was the 'Change in productivity method' – also known as the production function approach. This technique was implemented by Núñez et al. (2006) for the Llancahue watershed, which provides drinking water to the city of Valdivia. This watershed is used as the study site for the transfer of value to the rest of forest types in Chile's NSPA (Núñez et al. 2006; Figueroa and Pasten 2008).

The study site considered by Núñez et al. (2006) is located in the Valdivian eco-region of temperate rain forest. This watershed contains hardwood (broad-leaved) and deciduous perennial species. The watershed includes 1,117 hectares of woodland, with meadows and degraded areas. It provides water to an estimated population of 33,000 families in the city of Valdivia. The annual average willingness to pay (WTP) per family reported by Núñez et al. is US$8.2 corresponding to the annual flow of water provided by the Llancahue watershed. We transferred this value to similar types of forests prevalent in the protected areas between the country's 8th and 11th regions. In order to establish the potential beneficiaries of this ecosystem service, the entire population within a radius of 40 kilometres around the forests was recorded, and therefore we did not consider those forests in relatively isolated areas. Finally, population was expressed as the number of families and this figure was multiplied by US$8.2. Details of these estimations are provided in Table 3.

Table 3. Estimated value of 'fresh water' forest ecosystem of the Valdivian eco-region

Ecosystem	Protected area (ha)	Number of families	WTP per family (US$/year)	Economic value of water supply ecosystem service
Temperate broad-leaf forest	366,709	445,423	8.2	3,652,469
Temperate evergreen forest	1,184,385	587,573	8.2	4,818,099
Temperate deciduous forest	867,267	951,285	8.2	7,800,537
Total	2,418,361	1,984,280	8.2	16,271,104

The total annual estimated value provided by this ecosystem is about US$16.2 million per year. Column 8 in the TEVCM in Table 2 under the heading 'Fresh water' displays the economic value per type of forest observed. It is worth mentioning that these figures represent a floor value since they consider only a subset of forests in protected areas. Moreover, other uses associated with water supply (i.e., irrigation, hydropower and so on) have not been taken into consideration due to lack of information. In spite of this, the US$16.2 million annual value estimated is quite important because it shows that the social significance of forests' contribution in terms of fresh water provision is far different from the zero value usually assigned to it in political decision-making.

3.1.2 Non timber forest products (NTFP)

According to the Forestry Institute (INFOR 2004), the aggregate value to the national economy provided by non-timber forest products in 2003 was equivalent to US$35.2 million (in 2005 US$). Therefore, this estimated value corresponds to the total value accrued to NTFP extraction from Chilean forests. Because forests in protected areas – where extraction is possible – are only a proportion of total forests in Chile, we can use this proportion to estimate the total value corresponding to forests in protected areas. This percentage corresponds to a 13.5% of Chile's native forest (CONAF-CONAMA-BIRF 1999). Following this procedure, we arrive at the figure of US$4,911,025 as the annual value of NTFP in protected areas. This value is reported in column 7, of the TEVCM in Table 2 in the 'Food and fibre' column and the 'Forest' row. The estimated figure is relevant from a policy perspective because, despite being relatively low, it represents a frequently ignored contribution of the NSPA to poor rural and indigenous communities engaged in harvesting, consumption and commercialization of NTFP.

3.1.3 Forest genetic resources

Simpson and Craft (1996) used a model of monopolistic competition calibrated with information from the pharmaceutical industry in order to estimate the marginal value of one species with potential pharmaceutical use. We used the value for the Chilean biodiversity hotspot estimated by these authors, converting this value to a marginal value per hectare and adjusting it by power purchasing parity (PPP).[12]

We use the Simpson and Craft (1996) study to transfer benefit values originally expressed by species to a value expressed in hectares. Using the theory of the biogeography of islands (Preston 1960, 1962; MacArthur and Wilson 1967), the economic value was estimated to be US$2.29 per hectare.[13] The calculated values use specific information for the Chilean hotspot identified by Myers (1988, 1990) and Myers et al. (2000).

The relevant area within the hotspot of Central Chile and the Valdivian eco-region corresponds to about 2,702,426 hectares. Multiplying this value by US$2.29 per hectare yields a total economic value of US$6,188,555.54 as the annual flow for the ecosystem service 'Genetic resources'. This total estimated value is reported in column 10 in Table 2, 'Genetic Resources' and in the last row labelled 'Total'. This value appears in the 'Total' column because it is calculated for all ecosystems present in the Chilean hotspot; there are no separate estimates of the value of each type of ecosystem. This estimated annual value of almost US$6.2 million in genetic resources contributed by the forest ecosystems to the country's population sends a strong message to the national authorities in charge of protecting domestic genetic resources, a public task which has historically been assigned a low priority in the public agendas of Chile, other Latin American and developing countries in general, despite their value (PHI 1984; Yeatmann et al. 1985).[14]

3.1.4 Forest climate regulation

Biodiversity increases the provision of ecosystem services and reduces their variability, and therefore plays a role similar to financial insurance by reducing fluctuations in ecosystem services supply (Perrings 1995; Swanson and Goeschl 2003; Baumgärtner 2006). We estimated econometrically a monetary value for the climate regulation services provided by forests using data (provided by Agricultural Insurance Commission, COMSA) on insurance premiums paid by farmers to cover losses due to extreme climatic events. This agricultural insurance covers losses caused by the lack of or excess rain, damaging winds, snow, hail and ice. Data on forest coverage was obtained from the National Forestry Corporation (CONAF), and on municipalities

[12] PPP is a methodology developed to translate a given currency into US dollars such that the purchasing power remains constant.

[13] For details, see the original project report listed as Figueroa (2007) in the references section below.

[14] Since the 1970 corn blight in the United States, it has been clear that the preservation or loss of genetic diversity in the developing world has material consequences for advanced industrial nations, since what is being lost is the raw material needed for developing responses to future pest and pathogen challenges to genetically uniform and vulnerable crop varieties (Kloppenburg and Kleinman 1987).

areas from the National Institute of Statistics (INE). Through the regression analysis we estimated that the farmer's value of a marginal hectare of forest is US$0.046 per year, and because the total area of forests in the NSPA between the 5th and 10th regions of Chile is 2,647,092 hectares, we obtained a total value for climate regulation of US$121,766 per year.[15] This value is reported in the TEVCM in Table 2 in the column 3 (climate regulation) and in the 'Forest' row.

The estimated figure of US$121,766 may seem low, but it is consistent with ecosystem services whose impact on climate is more significant on a global rather than a local scale. Moreover, due to lack of data, several other benefits associated with climate stability and accruing to several other types of agents have not been accounted for in our estimations (i.e., climate regulation benefits accrued to agents other than farmers). Thus, the estimated values must be used with caution and considered conservative estimates, corresponding only to a floor value.

3.1.5 Forest carbon sequestration

Another important ecosystem service provided by forests is carbon sequestration. There is ample literature on the economic value of damages due to global warming and the translation of these estimates to an economic value per marginal ton of carbon. A good estimate of the marginal benefits of carbon uptake is the international market price. As Zhang (2000) suggests, if there were no limitations to international trade, a ton of carbon would be traded at about US$10, a conservative estimate that is accepted worldwide.[16]

However, it is necessary to adjust this value to the willingness to pay for Chileans. Therefore, consistent with other sections in this paper (see subsection 3.1.3 on genetic resources), the figure of US$10/tonC is adjusted by a weighted average for purchasing power parity index, yielding an adjusted price of US$5.04 per ton of CO2[17]. Table 4 presents yearly uptake (column 2), price per hectare (column 4), total area (column 5) and total economic value for each of the types and subtypes of forests regarding their ability to provide atmospheric regulation. In addition, the estimated economic values are displayed in the TEVCM in column 5 of Table 2, labelled 'Air Quality Maintenance' and for each type of forest.

Table 4. Estimation of the economic value of the carbon uptake ecosystem service by NSPA forests

Ecosystem	Uptake ton/ha/year	Price (US$/ha)	Value/hectares (US$)	Forest area (has)	Total economic value (thousand US$/year)
Temperate broad-leaf forest (Andean)	44.3	5.04	226	173,485.34	39,260
Temperate broad-leaf forest (coastal)	22	5.04	111	193,223.7	21,425
Temperate deciduous forest	18	5.04	91	1,387,834.96	125,904
Temperate evergreen forest	22	5.04	111	1,839,515.87	203,966
Mediterranean schlerophyllous forest	11	5.04	55	425,820.19	23,607
Thorn forest	1.3	5.04	7	47,199.57	309
Total					414,470

[15] All econometric and technical details regarding these estimations are readily available from the authors upon request.

[16] For example, the International Emissions Trading Association (IETA) set the average value of a ton of carbon at US$10.50 (in 2005 US$).

[17] Details may be requested from the authors and are also available in the original project report listed as Figueroa (2007) in the references section below.

The estimated value of almost US$738 million per year for all forest ecosystems included in the NSPA demonstrates the importance of this forest ecosystem service to Chilean society, which is consistent with international estimates and also indicates the prominence of forests in addressing climate change challenges (FAO 2012; WWF 2012).

3.1.6 Forest existence value[18]

To estimate the existence value of the Chile's native forests we used a study by Lira and Estay (2000) that measures this value among the population of the Santiago metropolitan region of Chile and then transferred those values to similar classes of forests in the NSPA. Lira and Estay (2000) used contingent valuation to estimate the willingness to pay for a one-time project devoted to increasing the current forest area by 5 per cent. Because the survey was applied in an urban metropolitan area, we transferred Lira and Estay's original value only to urban centres with more than 100,000 inhabitants and located within a reasonably short distance from protected forest areas.

In Lira and Estay's original study, a one-time payment was assumed and hence the original figures represented present values of an annual monetary flow. We annualized figures using a 7 per cent interest rate. Finally, the values obtained represent conservative estimates of the existence value of native forest since a large proportion of the country's population was excluded.

The results are presented in Table 5, where it can be observed that the willingness to pay (inflation-adjusted) of a typical family is about US$3.17. This figure, multiplied by the total households considered, yields the total value that populations of large cities in the country are willing to pay for a project similar to the one of Lira and Estay (US$7,717,172). Because the project considers a 5 per cent increment (203,394 hectares), the average WTP per hectare is US$37.94 expressed in present value. The corresponding annualized value, assuming a 7 per cent interest rate, yields US$2.66 per hectare. If we consider the total relevant area of protected forest in the country, the existence value is estimated at US$10,820,578 per year. This value is recorded in column 12 of the TEVCM in Table 2 and row 'Forest'. This estimate of the existence value of the NSPA is relevant for Chile's future investment decisions regarding its protected areas because it quantifies a benefit that each year is provided by the system to all Chileans and which has previously been ignored in public decision-making.

Table 5. Existence value of the NSPA forest ecosystem (in 2005 US$)

Population	8,690,946
N° of Families	2,434,439
Existence value (per family)	3.17
Existence value(total)	7,717,171.63
Additional hectares considered in expansion plan (5%)	203,394
Present value of native forest per ha	37.94
Annual monetary flow per ha[a]	2.66
Hectares of forest in protected areas	4,067,886.56
Existence value of forest in PA	10,820,578

Note: [a]Annualized based on a 7% discount rate.

[18] 'Existence value' is a concept broadly used in economic as well as environmental sciences. It was first introduced by Krutilla (1967) when he discussed the possibility that people obtain utility from resources they do not use and hence would exhibit a willingness to pay for them. It is now generally defined as a person's willingness to pay for the preservation, protection, or enhancement of resources for which he or she has no personal use motives (McConnell 1997). There is still controversy regarding what existence value exactly is. Other closely related terms are intrinsic value, preservation value, bequest value and passive use value.

3.2 Valuation of wetlands ecosystem services

We use benefits transfer to estimate the value of the ecosystem goods and services provided by the wetlands of Chile's NSPA, implementing the meta-analysis by Brander et al. (2006), which includes a large number of studies (89) and is the most comprehensive so far (Anielski and Wilson 2005). The values – per hectare – of those ecosystem services considered originally by Brander et al. (2006), expressed in 2000 dollars, are shown in the second column of Table 6. These values, adjusted by inflation and adjusted by PPP, are reported in columns 3 and 4 respectively. Furthermore, these figures are used to estimate the economic values of the ecosystem services provided by wetlands in Chile's NSPA.

Only five of the 10 ecosystem goods and services reported in Table 6 were considered in our estimations: flood control, water filtration, biodiversity, habitat/nursery and water supply. The remaining ecosystem goods and services were not considered either because they do not apply to the protected areas (recreational hunting, wood for fuel) or because the item is already included in other welfare determinants (recreation is included in tourism, etc.). However, we do include the 'material extraction' ecosystem service in the case of peatlands (27,830 hectares) because some extraction is allowed in Chile in this ecosystem. To estimate the annual economic value for each subtype of wetlands we first determined the relevant area where each type of ecosystem service is produced. Table 7 shows the total area of wetlands valuated here for each ecosystem service.

For the 'salar' ecosystem the ecosystem services 'Flood control' and 'Materials' were not taken into consideration due to the relative isolation of these salt flats and because extraction is not allowed in protected areas. In the case of peatlands, the ecosystem goods and services of 'Flood control', 'Water filtration' and 'Fresh water' were only considered when the resource is close to urban areas. Finally, material extraction was only considered for peatlands where some type of extraction is allowed.

Table 8 shows the final annual value of the ecosystem services provided by wetlands in the NSPA. The estimated value for the ecosystem service 'Flood control' is recorded in the TEVCM of Table 2 in column 4, 'Water regulation' and for both salars and other wetlands. The estimated values for water filtration are reported in column 1, 'Water purification' and for each of the types of wetlands analysed. The estimated values for the ecosystem service 'Biodiversity' are reported

Table 6. Unit values (WTP) of ecosystem services provided by wetlands

Ecosystem service	Economic value		
	US$/hectare/year[a] (2000 USD)	US$/hectare/year[b] (2005 USD)	US$PPP/hectare/year[c] (2005 USD PPP)
Flood control	464	524.32	293.57
Recreational fishing	374	422.62	236.63
Amenity/recreation	492	555.96	311.29
Water filtering	288	325.44	182.22
Biodiversity	214	241.82	135.40
Habitat/nursery	201	227.13	127.17
Recreational hunting	123	138.99	77.82
Water supply	45	50.85	28.47
Materials	45	50.85	28.47
Fuel wood	14	15.82	8.86

Notes: [a] Brander et al. (2006); [b]Rate of inflation in the U.S. between 2000 and 2005 = 113.41. Source: http://www.bls.gov/cpi; [c] PPP = 1.78644. Source: World Development Indicators (World Bank, 2005); (PPP = power purchasing parity).

Table 7. Area of wetlands included in the NSPA object of Valuation

Ecosystem service	Type of wetlands		
	Salar (hectares)	Peatland (hectares)	Other wetlands (hectares)
Flood control		794,720	131,853
Water filtration	36,414.17	794,720	131,853
Biodiversity	36,414.17	4,464,352	131,853
Habitat/nursery	36,414.17	4,464,352	131,853
Water supply	36,414.17	794,720	131,853
Materials		27,830	
CO2 uptake	36,414.17	4,464,352	131,853

Table 8. Economic value by wetlands in protected areas

Ecosystem service	Type of wetland		
	Salars	Peatlands (thousands US$/year)	Other wetlands
Flood control (water regulation)[a]		233,308	38,708
Water filtration (water purification)[a]	6,635	144,812	24,026
Biodiversity (regulation of human disease)[a]	4,930	604,462	17,853
Habitat/nursery (bird shelter)[a]	4,631	567,743	16,768
Water supply (fresh water)[a]	1,037	22,627	3,754
Materials (food and fibre)[a]		792	
CO2 uptake (air quality maintenance)[a]	8,406	21,150	30,436

Note: [a]Name of the ecosystem service in the Total Economic Value Calculating Matrix (TEVCM) (Table 2) following the typology of the Millennium Ecosystem Assessment MEA (2005).

in column 2, 'Regulation of human disease' and for each type of wetlands analysed. The estimated values for the 'Habitat' ecosystem service for each of the ecosystems are in column 6, 'Bird shelter' of the TEVCM in Table 2. Similarly, the corresponding values of the 'Water supply' ecosystem service are recorded in column 8, 'Fresh water' in Table 2. In the case of 'Materials' the estimated economic value is reported in column 7 of Table 2, corresponding to the 'Food and Fibre' ecosystem service and for the peatland ecosystem.

The estimated carbon sequestration values for peatlands are based on information on peatlands in boreal forests in Canada that are similar to Chilean temperate forests in their capacity to provide this ecosystem service. The original source of data is Anielski and Wilson (2005), who estimated the annual uptake at 0.94 tons of CO_2/ha. The annual uptake in both salt flats and other wetlands is estimated to be 45.8 tons/year based on Smith and Smith (2001). The last row in Table 6 displays the economic values for carbon absorption. These values for each type of wetlands are reported in column 5 of the TEVCM in Table 2 under the label 'Air quality maintenance'.

3.3 Valuation of marine and dunes ecosystem goods and services

There are a variety of ecosystem services provided by marine and coastal areas but limited information precludes a more detailed analysis. Hence, we estimate only the food provision ecosystem service. Information on extraction and prices of benthonic products extracted from protected areas was recorded. Only sale prices of first transactions were considered as a measure of direct benefits provided by these resources. The estimated annual value of this is US$19,043,327, which is recorded in column 7, ‘Food and fibre’ and row ‘Marine and dune’ of the TEVCM in Table 2. This estimated value of more than US$19 million per year shows that the NSPA’s contribution in terms of these ecosystem goods and services is socially relevant because some coastal communities depend heavily on this food provision.[19]

3.4 Valuation of goods and services of other ecosystems

Because limited information is available on ecosystem services, the only economic value estimated for the remaining ecosystems in the NSPA corresponds to air quality regulation. We employ a similar methodology to the forests methodology described in subsection 3.1.5. Table 9 presents the estimated capture (second column), unitary values (third column) and the total economic value (last column) for each ecosystem providing the carbon sequestration service. These values are presented in column 5, ‘Air quality maintenance’ of the TEVCM in Table 2 and for each of the ecosystems displayed in Table 9. Similar to the forest ecosystems presented in subsection 3.1.5, the technical consistency of our estimates of the economic value of the air quality regulation ecosystem service is supported by the widespread and generally accepted use in the literature of the methodology employed here.

3.5 Economic valuation of tourism ecosystem services provided by the NSPA

In the particular case of Chile, where significant future development of the tourism sector is projected, it is essential to know the contribution of protected areas to the industry. Unfortunately, the available information is scarce. Therefore, the approach followed was to estimate the tourism benefits of the NSPA based on estimations of spending by tourists visiting the country’s protected areas. This estimation represents a conservative figure for the true value of the contribution of protected areas to tourism in Chile. The total annual contribution of all tourism ecosystem services provided by ecosystems in the NSPA is estimated to be on the order of US$63.7 million, comprised of US$53.7 million spent by international tourists and US$10 million in spending by Chilean tourists. These two figures are displayed in the TEVCM in Table 2, in column 9 ‘International tourism’ and column 11, ‘Domestic tourism’ respectively. Moreover, both figures are displayed in the total (last row in the TEVCM in Table 2) since it is

Table 9. Economic value of CO2 uptake from other ecosystems

Ecosystem	Uptake Ton/ha./year	Price/ton (US$)	Value/ha. (US$)	Area (thousands of hectares)	Total economic value (thousands US$/year)
Scrublands	12.80	5.04	64.5	3,656.9	235,914
Prairie	9.20	5.04	46.4	437.3	20,275
Grasslands	9.20	5.04	46.4	137.6	6,381
Glaciers	0.06	5.04	0.3	1,822.4	551
Total					264,849

[19] Personal communications with Paulina Reyes and Francisco Pizarro of the University of Chile and Stefan Gerlich of the Catholic University.

not possible to disaggregate the total value of tourism ecosystems among the different types of ecosystems.[20] This estimate of almost US$64 million per year for tourism ecosystem services provided by the NSPA each year is significant because it highlights an economic contribution previously unquantified and overlooked, which could justify placing a higher priority on public investment in Chile's NSPA in the future.

4 Discussion

We built on the initial interdisciplinary effort of the MEA to elaborate a consistent conceptual framework relating ecosystem goods and services to social welfare. Our two-year research effort that proposed using the Total Economic Value Calculating Matrix (TEVCM) a conceptual framework and methodology to conduct the necessary interdisciplinary work to obtain empirical estimates of the economic values of the ecosystem goods and services provided by nature. As explained above, the matrix we designed incorporates the analytical categories of ecosystem services from the natural sciences as well as the analytical categories of value sources from the social sciences in a unified framework. Thus, on the one hand, the TEVCM allows for calculation of the monetary values of regulation, provision and cultural ecosystem services according to the categories used by the MEA (2005) and, on the other hand, it also allows for empirical estimation of the value categories of economic science: direct use, indirect use and non-use value.

The empirical application of the TEVCM to calculating the annual economic contribution of the national system of protected areas to Chile's population that we have reported here illustrates the practical merits of the proposed analytical and empirical framework. A set of economic valuation techniques was implemented to produce reliable estimates of the benefits provided by Chile's NSPA. The total annual economic value of goods and services provided by the NSPA is estimated to be close to US$2.551 billion per year. This amount is significant, not only in absolute terms but in relative terms as well. It is equivalent to 2.2 per cent of Chile's GDP; is 20 per cent higher than the annual production value of the country's communication sector, 15 per cent higher than that of its fishing sector, and represents almost 80 per cent of the annual value produced by the national electricity, gas and water sectors and more than 70 per cent of annual agricultural production. Moreover, because of the lack of information which precluded the estimation of economic values for several ecosystem goods and services, on the one hand, and the approach implemented here for the estimation process to avoid any possibility of an overvaluing bias, on the other hand, the estimated values represent conservative figures for the real economic values provided by the NSPA in Chile. Therefore, the real TEV provided each year by the NSPA is likely to be considerably larger.

As previously mentioned, economic valuation should be used to assess and determine social investments for nature conservation. An interesting initial exercise is to compare the US$2.551 billion value estimated here for the NSPA's contribution to Chilean society to the limited budget that the country devotes to nature conservation. The US$53.3 million annual budget of the National Forestry Commission (CONAF) and the US$6.1 million allocated annually to the State National System of Protected Areas (SNASPE) reveal that public investment to conserve the country's natural areas is not at risk of being economically inefficient. This is consistent with existing evidence indicating that lack of knowledge about the benefits that nature and protected areas provide has produced a systematic undervaluation of nature and the NSPAs in Chile and elsewhere (Rozzi et al. 2003; Crisci and Katinas 2011; Figueroa 2011).

[20] Details are provided in the original project report listed as Figueroa (2007) in the references section below or can be requested directly from the authors.

Moreover, the fact that the NSPA's annual contribution is 45 times public spending on conservation and more than 140 times spending on pollution abatement indicates that Chile has a broad margin for investment in ecosystem protection with high social returns. This is more evident if we take into consideration that the country contributes less than 0.03 per cent of the total public budget to the state national system of protected areas, which is responsible for managing 75 per cent of the protected areas evaluated in this study. The SNASPE's budget shows that the country invests annually an average of US$0.5 per hectare while at the same time, according to our results, the economic benefits generated per hectare are at least US$1,400 per year. It is highly likely, therefore, that public investment in the development and efficacy of the NSPA will generate high social rates of return to Chile.

Finally, the contribution of the NSPA to tourism services was estimated here to be US$63.7 million per year. The growing demand for tourism services – particularly for eco-tourism or 'green' tourism – experienced in the last decades and increasing interest by foreign visitors in the country's natural landscape are also indicators of the high social returns that should be expected from public investments in this sector. Additionally, an increase in tourism activities is also likely to increase the revenue contributing to the SNASPE budget, through entrance charges to national parks and protected areas. Moreover, as the country grows economically, it is expected that the willingness of Chile's population to pay for ecosystem services and other natural amenities will increase. Hence, high social returns should be expected from future investments in a renewed, integral NSPA through both an increasing share of tourism in country's GDP and from greater revenues directly accruing to the NSPA in Chile.

The implications of the figures estimated here were considered by Chilean economic and environmental authorities when the government decided to launch a three-year programme to restructure Chile's NSPA with investment of more than US$80 million. This programme is expected to improve ecosystem and species representation within the NSPA, incorporate private areas into the national conservation effort, secure financing resources for the system and enhance more consistent oversight and control of the country's public natural resources.

Undoubtedly, Chile provides an example for other developing countries in Latin America and other regions of the world with large endowments of natural resources that are crucial to the welfare of present and future generations, but are currently subject to high pressure and deteriorating at a fast pace. When the high implicit economic value of the contribution of these natural resources to society is duly quantified and made explicit to the decision-makers and populations, the possibility of aligning their attitudes and behaviours with a more consistent and comprehensive social welfare maximization is increased.

The TEVCM framework proposed here for guiding and facilitating the interdisciplinary work needed to economically valuate the contribution of nature to human welfare can also be useful for policy-makers when making decisions about the geographical allocation of investments for nature conservation. This is because the TEVCM allows for identifying the relative contribution of the different regions of a country (by the types of ecosystems existing in the different regions) and highlighting the most promising regions for investing public (and private) conservation resources. This can be especially relevant for developing countries where administrative centralization usually implies that investment decisions are often made with little regard for the needs of remote regions and their relative social profitability.

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Resumen. A partir del marco propuesto por la Evaluación de Ecosistemas del Milenio (MEA, por sus siglas en inglés), que vincula conceptualmente los servicios de la naturaleza con el bienestar humano, diseñamos y aplicamos aquí empíricamente lo que hemos denominado como la matriz de cálculo del valor económico total (MCVET) para estimar el valor monetario del flujo anual de los beneficios proporcionados por el sistema nacional de áreas protegidas (SNAP) de Chile. El valor económico calculado de este flujo asciende anualmente a 2550 millones de dólares estadounidenses. También analizamos la relevancia y la utilidad de la metodología que proponemos y utilizamos el ejercicio de valoración presentado aquí para extraer algunas lecciones normativas en relación a la conservación de la naturaleza en Chile, así como en los países en desarrollo con una riqueza abundante en recursos naturales.

要約 ミレニアム生態系評価（MEA）は、概念的に自然が提供するサービスと人類の福祉を結びつけるものであるが、このMEAが提示するフレームワークを出発点として、いわゆる総経済価値計算マトリックス（TEVCM）を設計し、これを適用して、チリの国家の保護地域システム（NSPA）が提供する年間利益の貨幣価値を推計する。推計によれば、この利益フローの経済的価値は、年間25.5億米ドルに達する。また、我々が提示する方法論の関連性と有効性を分析するとともに、この方法による計算を行い、チリの自然保護および豊富な天然資源を持つ発展途上国に関する規範的な教訓を得る。