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## Global and Mexican analytical review of the state of the art on ecosystem and environmental services: A geographical approach

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Maria Perevochtchikova\*  
Julia Oggioni\*\*

**Abstract.** Within a strong international movement for conservation of natural resources, the term of Ecosystem Services (ES) which refers to all benefits that nature offers to society, was introduced at Rio Conference, 1992. After this, the first compensation scheme for ES, as one of the tools of the new environmental policy directed towards the principles of sustainable development, was proposed in Kyoto Protocol, 1997. Its objective is to prevent the reduction of natural resources' availability, and to improve human well-being by means of monetary compensation for conservation activities. Since then, the theme of ES found a global response, which was reflected in the implementation of payment programs and development of studies in many countries worldwide, where it's possible to note the different perspectives of analysis and aspects included, as well as methodology used.

In this regard, this paper presents the state of art on ES and Environmental Services research (specific term adopted in public policy) in global and Mexican perspectives. It is based on the review of 1 781 scientific papers published in international peer-viewed journals between 1992 and 2012 (twenty years since Rio Conference). Furthermore, the work provides a sound geographical overview of the main ES topics studied and the relative contribution of papers per region, country and Mexican states.

The presentation of results is helped by the construction of multi-scale maps and tables to show the evolution of studies in time and space, where a gradual continuous growth in numbers of publications with different focus and theories is detected, and use of distinct techniques from various disciplines, according to the specific objectives of each research. On the other hand, the social and economic standpoints dominate the global scene, with recent interest in integral analysis and ES compensation schemes.

Geographically, ES research appears concentrated in North America, Europe, China and Australia, with social and economic focus of analysis predominant; followed by physical and interdisciplinary approaches. In the relation to the ecosystem function, the biodiversity studies prevail, followed by hydrological and carbon. Developing countries have published moderate or low amounts of papers, but are often the areas of interest for outside research. It is important to highlight that half of the papers are focused on one or more study cases, which allows for better understanding and analysis of local issues. Moreover, applied research combines experiments, sampling, surveys and interviews. It all contributes to providing better quality and more quantity of information for a successful study.

In Mexico the situation is similar to the global trends, which is reflected in the growth trend of studies (since

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\* Center for Demographic, Urban and Environmental Studies, El Colegio de México A.C., Camino al Ajusco No. 20, Pedregal de Santa Teresa, 10740, Tlalpan, México, D.F. E-mail: mperevochtchikova@colmex.mx

\*\* Faculty of Geography and History, University of Barcelona, C. Montalegre, 6, 08001, Barcelona, España. E-mail: msgoggioni@gmail.com

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implementation of federal payment scheme in 2003) with social and physics focuses predominant and biodiversity and hydrological functions prevailing; and their very sharp heterogeneous territorial distribution and few publications about payment programs. Their spatial distribution appears less consistent with the totals than the distribution of article focus; the geographic allocation of ecosystem services seems more related to each area's history and issues. For example, hydrological services are most studied in states that have problems with water scarcity and distribution: Federal District, Mexico, Baja California and Querétaro. Biodiversity is more the object of study in regions with high levels of species richness or a history of conservation programs, as Chiapas, Michoacán and Veracruz.

After this revision it is possible to mention the following challenges: the necessity of a mayor analysis of

carbon capture function, development of the focus of economic and interdisciplinary researches, more homogeneous space studies, and in collaboration with institutions from other countries and internal. Also it is important to recognize other problems that limit study achievements, and consequently the general knowledge of the ES and ecosystem functions, for instance lack or misuse of information, scarcity of financial, technical or human resources, shortage of time, safe access to study case territories, as in Mexico, as in many others. We believe that the future of ES is in the endorsement of interdisciplinary publications, focused on analysis of socio-ecological system with a long-term vision.

**Key words:** Environmental and ecosystem services, geographical approach, global level, Mexico.

## La revisión analítica del estado de arte en los servicios ecosistémicos y ambientales a nivel mundial y de México: un enfoque geográfico

**Resumen.** El término de los servicios ecosistémicos (SE) se introdujo en la Declaración de Río en 1992, dentro de fuerte movimiento internacional por la gestión de los recursos naturales. En aquel entonces, el innovador principio se refirió a las funciones ambientales que mantienen a los sistemas de soporte vital. Para ilustrar esto, la polinización, la producción de oxígeno, la regulación de la temperatura, el almacenamiento, la filtración y la distribución del agua, entre otros, se enumeraron y se tomaron previamente por concedidos hasta que la acción humana los impugne. Los primeros esquemas de compensación por servicios ambientales se propusieron en 1997 como una de las herramientas de la nueva política ambiental dirigida hacia los principios del desarrollo sustentable. Desde entonces, el tema de los SE ha recibido notable respuesta a nivel mundial, que se refleja

en la aplicación de programas de pago y en el desarrollo de los estudios en muchos países del mundo. Este trabajo en particular analiza el estado de arte de la investigación llevada a cabo hasta ahora en el tema de SE y servicios ambientales desde la perspectiva global y de México. Lo que se basa en la revisión de 1 781 artículos científicos publicados en revistas arbitradas de corte internacional entre 1992 y 2012. Además, ofrece un enfoque geográfico de análisis de los principales temas estudiados dentro de ES y de la emisión relativa de los artículos por región, país o estado. Los resultados son finalmente presentados y discutidos a la luz de las limitaciones encontradas y los retos a futuro.

**Palabras clave:** Servicios ambientales y ecosistémicos, enfoque geográfico, nivel mundial, México.

### INTRODUCTION

Over the past five decades the environmental degradation caused by human activities has been acknowledged and emphasized (Carson, 1962). However, for nearly a century, from Yellowstone National Park declaration in the United States in 1872 until the late of 1980s, nature conservation has not been understood in relation to the survival of life on the planet. The environmental dimension was first introduced as both limit and indispensable condition of the traditional economic development model in the United Nations Conference on the Human Environment in Stockholm (UN, 1972). As a result, the debate around the importance of ecosystems for the survival of humanity and all

life on the Earth has engaged the political scene globally; furthermore, urgency has been added to the need for changing the paradigms of natural resource management and environmental conservation.

During the following two decades the necessity of linking economic and ecological principles became evident (Costanza, 2003) and was reflected by the adoption of the concept of *Sustainable Development* by the United Nations World Commission on Environment and Development in the report "Our Common future" (UN, 1987). In the report sustainable management goals were sought by recognizing that human action jeopardizes the well-being of future generations in terms of natural resource depletion and pollution.

At that time the term Ecosystem Services (ES) referred to all the benefits that nature offers to society. It was introduced as a new way to assess the role of nature, and it was installed as one of the challenges in the Rio de Janeiro United Nations Earth Summit in 1992, where principles of respect towards the integrity of the Earth's environmental system were conveyed (Costanza, 1991; Ponayotou, 1994; Daily *et al.*, 1997). Ten years later, in the Earth Summit in Johannesburg (UN, 2002), an ecologically orientated speech was given about the importance of sustainable development; and lastly, the Conference on Sustainable Development Rio+20 (UN, 2012) focused on defining "The Future We Want", a document that promoted human progress and global well-being through conservation of nature.

This process prompted the creation of the first compensation schemes, named Environmental Services by the Kyoto Protocol (UN, 1998), as one of the tools of the "new" environmental public policy (EPP) that would act within principles of sustainable development. Since then, the notion of ES encountered great global response, which has been reflected by the implementation of payment schemes, and research carried out in many countries and accredited by consistently growing volumes of publications on the topic of Ecosystem and Environmental Services (MEA, 2005; Martínez and Balvanera, 2012).

It has to be noted that studies of ES and of payment schemes for environmental services analyze the topic from a wide range of perspectives, according to various methodologies and applied techniques from different discipline, such as social, economic, environmental, institutional, legal and cultural. This paper aims at analyzing the state of the art on ES research at global and Mexican level. Furthermore, it provides a sound geographical overview of the main ES topics studied and of the relative emission of papers per region, country or state, with a final discussion of the results in the light of their deficits and of the challenges ahead.

## **ENVIRONMENTAL AND ECOSYSTEM SERVICES**

Ecosystem services were first defined in the field of ecological economic two decades ago as *the conditions and processes that natural ecosystems supply to people and society in general* (Constanza and Daly, 1992; Constanza *et al.*, 1997; Daily, 1997; Daily *et al.*, 1997; Greenwalt and McGarth, 2009; Garay, 2010). This initiated and promoted the academic and political debate around the economic and ecological value of ES for human wellbeing, and about the importance of maintaining and preserving ecosystems.

In particular, Daily *et al.* (1997) classified the benefits supplied to human society by natural ecosystems as: *i*) goods consumed directly from ecosystems (seafood, animals, timber, and fuel wood, among others), *ii*) goods as part of the economy (according to the economic value of products), and *iii*) goods and services that are fundamental life-support system for human civilization. In this case, the ES include purification of water and air, regulation of climate, contribution to soil fertility, pollination, pest control, mitigation of flooding, aesthetic beauty, and many other aspects. In summary, ES and ecosystems are very important for the human economy and development and consequently also for decision-making.

Because of complexity of ecosystems, ES can be approached from several angles: environmental (climate regulation, soil retention, and water storage), economic (provision of food, materials, water), public health (physiological and psychological conditions), landscape (aesthetical gratification), recreation, and socio-cultural. The Millennium Ecosystem Assessment (2005) classifies ES according to their value to human society:

- i*) Provision: water and food.
- ii*) Regulation: biogeochemical, carbon and hydrological cycles.
- iii*) Cultural value: aesthetic, recreational and spiritual.
- iv*) Support: ES that are necessary for the existence of all other services.

From this classification, four major groups of ES have been drawn, in relation to biodiversity, landscape, carbon sequestration, and hydrological functions.

Since its establishment, the concept of ES has been accepted and ratified by numerous internationally influential political events and documents, such as:

- The Rio Declaration, when then concept of ES was defined (UN, 1992).
- The Kyoto Protocol, where the first payment schemes for Environmental Services (PES) were created for carbon sequestration (UN, 1998).
- Johannesburg Earth Summit, which introduced the poverty dimension to mechanisms of PES (UN, 2002).
- The Millennium Ecosystem Assessment (2005), where the efforts of 1 360 experts gathered to outline the fundamental concepts of ES, to uncover the state of the art in the field, and to conceive scientific recommendations for future action in conservation.

The most recent events, in particular, inspired the implementation of environmental conservation programs at global level, where the difference in terminology, for instance between *Environmental Services* and *Ecosystem Services*, is clearly detected. It is important to comment that the first concept is used more widely within the political debate, in relation to the economy and environmental management, whereas the second term is mostly adopted in the ecology field, under the notion of *ecosystem*. As a matter of fact, studies of ecosystem and environmental services are approached from several theories: ecological economics (Costanza *et al.*, 1997; Panaytoui, 1997; Costanza and Farber, 2002), power networks, neo-institutionalism, collective action, etc. (Merino, 2005; Muñoz *et al.*, 2008; McElwee, 2012; Poteete *et al.*, 2012); conversely research on ecosystem services is mostly linked to ecological disciplines (Mertz *et al.*, 2007; Balvanera *et al.*, 2012; Martínez and Balvanera, 2012).

## PAYMENT SCHEMES FOR ENVIRONMENTAL SERVICES

PES mechanisms are only one of the environmental policy tools that have been developed in order to prevent natural resources depletion, and to simultaneously improve human wellbeing (Constanza *et al.*, 1997). Within this framework conservation activities are aimed at ensuring long-term existence and quality of ecosystems in exchange for monetary compensation (Fregoso, 2006). Several stakeholders are directly implicated in PES schemes: service providers, who usually are landowners who own and preserve the natural resources, and who benefit from the payment; and service users, who could be the dwellers of an urban area (Rosa *et al.*, 2004; Wunder, 2005; Wunder *et al.*, 2008). Other stakeholders are involved in mixed investments, including non governmental organizations and the private sector, when they have the common interest on environmental conservation, as it happens in Costa Rica, Ecuador and Nicaragua.

Nowadays evidence of PES programs implementation and research is found in many countries from all continents, for example in America (Argentina, Bolivia, Brazil, Canada, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panamá, Perú and the United States), in Europe (Denmark, France, Germany, The Netherlands, Norway, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom), in Asia (China, India, Indonesia, Japan and Vietnam), in Africa (Madagascar, South Africa and Tanzania), and in Oceania (Australia and New Zealand), (Ulgiati *et al.*, 2011, Balvanera *et al.*, 2012; Gross-Camp *et al.*, 2012; McElwee, 2012; Molnar and Kubiszewski, 2012).

In Mexico the National Forest Commission (Spanish acronym: CONAFOR) has implemented the federal PES program in 2003 under the socio-economic and environmental justice assumption, where society has the right to benefit from ES, and landowners receive compensation for conservation of natural resources in their properties, for instance forest resources (70 percent of which are communal property); any other form of land use is forfeited, even though more economically profitable.

The Mexican PES program was based on hydrological services, and over the years it has been expanded to carbon and biodiversity related services; finally it was made one of the 45 headings supporting forest conservation in the ProÁrbol program, 2006-2012. Since 2013 the project has been included in the National Forest Program. Through time the scheme has undergone annual changes in its operational rules and in the selection criteria for eligible zones. Nonetheless, goals set for 2012 were achieved in 2010, when the project covered 2 767 million hectares, involved 5 400 landowners, and was worth about of 5 289 million Mexican pesos ([www.conafor.gob.mx](http://www.conafor.gob.mx)). This achievement validated it as one of the world's most important and successful national (federal) PES programs.

Several problems have arisen during the implementation of the scheme, such as deficiencies in evaluating, quantifying and monitoring ES and their benefits, together with lack of professional training, institutional empowerment, and scientific research (Muñoz-Piña *et al.*, 2008; Perevochtchikova and Vázquez, 2012). Therefore PES schemes are not to be considered a panacea, but rather one of the policy tools for tackling environmental degradation and deforestation that should be integrated with other activities and actions within a strategic spatial planning framework.

## **METHODOLOGY**

The present study was inspired by reading recent articles by Balvanera *et al.* (2006), Fisher *et al.* (2009), Balvanera *et al.* (2012) and Martínez and Balvanera (2012). These four papers review publications on ecosystem services and portray a diversity of approaches at contrasting spatial and temporal scales. In this paper the analysis covers the last 20 years, from the Rio Declaration to today (1993-2012). The perspective is also shifted from global to national, using Mexico as a case study. Papers published in peer-reviewed international journals with an abstract in English were used as unique and main source of analysis. Independently of the terminology used, ecosystem services are the main focus of the publications selected.

The study has been given the geographical perspective by considering the “scale” as the main reference in spatial, temporal, and analytical dimension of phenomenon (Fernández, 2006:13). This fact leads to reassess the role of geography (Ortega, 2000; Capel, 2012) in the development and evaluation of initiatives (programs and other instruments) related to environmental conservation, both at the political and scientific levels. In order to support this approach, multi-scale and multidisciplinary research is required, with results represented in the maps and other graphic resources that show the evolution of a phenomenon (or process) in time and space.

To find publications from the first few years various online search engines have been used: *Google Scholar*, *J Stor*, *Science Direct*, *Science Mag*, *Social Science Research Network*, *Wiley Online*, *Web Of Knowledge*. As it has become clear that in the 1990s the term “ecosystem services” was not widely used yet, searches have also included different terminology, as *ecological services*, *environmental services*, *ecosystem functions*, *environmental functions*, *ecological functions*, *ecosystem value*, *natural capital*, *hydrological services*, *carbon sequestration*. Having noticed that the volume of papers has become consistently bigger, it has been decided that Google Scholar is comprehensive enough to cover other search engines when searching for papers published in recent years.

Selected articles have been classified according to the year of publication, the country affiliated to the authors (with a three-digit country code that could be identified by the mapping software ArcGIS), the ecosystem function or functions that were mostly covered by the study (in relation to biodiversity, carbon sequestration or hydrological services), and the general focus of the paper. Four main areas of study have been identified: economic, physical (including environmental), social (including institutional), and interdisciplinary (when the focus combined two or more of the former three subject areas). Moreover, publications that present case studies have been further labelled with the country code of the place where the research has been carried out. Files for all selected papers have been named accordingly, sorted in folders per

year, and are available online at: <http://esanalysis.colmex.mx>

In the first phase the selected papers have been analysed at the global level, and then at the national level for Mexico. When analysing the spatial distribution of papers where authors have affiliations in multiple countries (or Mexican states), one point has been assigned to each country. The same method has been adopted when mapping multiple case studies reported in the same paper. However, fractions have been used when calculating annual total number of papers, and when estimating the weight of ecosystem functions in papers that focused on more than one ES. Visualization of spatial distribution was made possible by mapping the results with the Geographic Information System software ArcGIS.

After gaining an overview of the temporal and spatial patterns in the production of papers, particular attention has been given to case studies. The number of papers that present case studies has been identified and mapped. Divergences between the origin of the publications and the country where the research was carried out have been observed; maps of article production and case studies have been joined in order to compare the findings. For articles where authors have a Mexican affiliation, the study and mapping has been carried out at smaller scale, identifying the associated states and institutions.

## RESULTS

The number of papers selected for this study totals 1 781. Given the criteria and methods of the selection process, it is believed that this number is not far from the actual total number of papers published on the matter in the period from the beginning of 1993 to the end of 2012. Their analysis is presented below at two levels: global and Mexico.

### Global perspective

The global temporal trend of the papers production is consistently ascending, as shown in Figure 1, where it is possible to observe that until 1997 (year of redaction of the Kyoto Protocol) the publication on “ecosystem services” has been extremely

scarce. It has to be pointed out that in those years the phrase was not commonly accepted yet, and even some of the selected papers use different terminology for the same concept. 1 558 papers use the phrase Ecosystem Services (with exponential growth) and only 223 refer to them as Environmental Services (with consistent linear growth). Out of the total articles, only 209 are about PES schemes, whereas the remaining 1 572 are about other topics (Figure 2<sup>1</sup>).

The growth of academic interest in ecosystem services (ES) is not only due to historic international public policy acts, but it is more related to a few relevant scientific publications from the 1990s. The works of Costanza and Daly (1992), Daily (1997), Postel and Carpenter (1997) and Costanza *et al.* (1997) initiated an important discussion about the economic value of ecosystem services for humanity and received numerous responses, reflected on the actual booming of studies on ES. Worthy of mention are the following authors: J. Cairns Jr., P. M. Fearnside, H. A. Mooney and W. V. Reid.

In 2002 the journal of Ecological Economics published the special issue “The Dynamics and Value of Ecosystem Services: Integrating Economic and Ecological Perspectives” that contributed to the increased publication of papers (Costanza and Farber, 2002). Moreover in 2003 the Millennium Ecosystem Assessment (MA) was issued, after which academic interest in ES rose significantly and consistently (Mooney *et al.*, 2004).

In the second half of the 2000s the number of journal papers escalated steadily and their accessibility has increased accordingly. In 2006 the MA sponsored a feature of Ecology and Society on “Scenarios of global Ecosystem Services” (Carpenter *et al.*, 2006), which is the earliest special issue dedicated to ES. In the following years many journals have dedicated special features to ecosystem services, including: *Agriculture, Ecosystems & Environment*, 2012; *Ecosistemas* (a Spanish journal), 2007; *Ecological Complexity*, 2010; *Ecological Economics*, 2002, 2008 and 2010; *Ecological Indicators* in 2012; *Ecology and Society*, 2011; *Environmental*

<sup>1</sup> All graphic material is available on the web page: <http://esanalysis.colmex.mx>

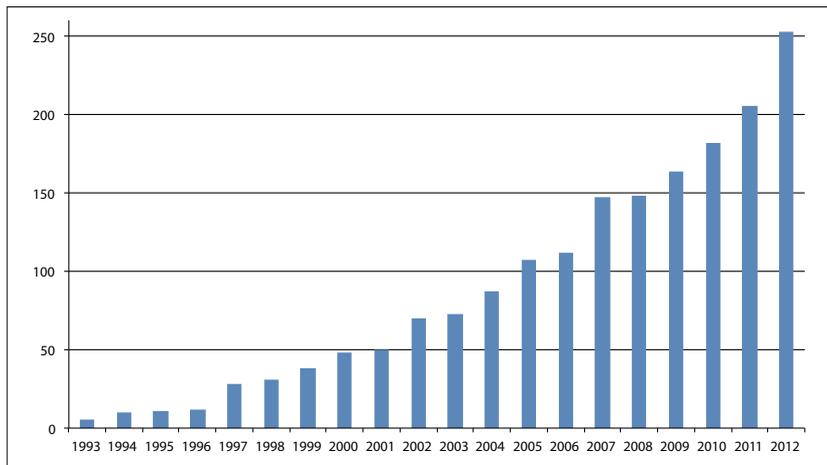


Figure 1. Annual number of published papers about ES.

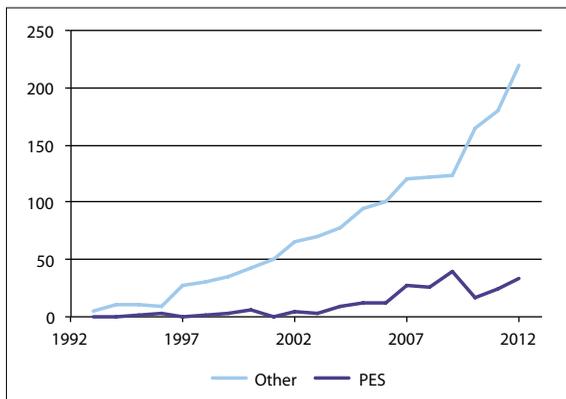


Figure 2. Annual number of published papers about PES schemes versus papers on other topics.

*Conservation*, 2011; *Environmetrics*, 2011; *Gaceta Ecológica*, 2007; *Hydrological Science Journal*, 2011; *International Journal of Biodiversity Science, Ecosystem Services & Management*, 2011 and 2012; *Philosophical Transactions of The Royal Society*, 2010; and *Science of the Total Environment*, 2012. Furthermore, in 2010 the *International Journal of Biodiversity Science & Management* changed its name to *International Journal of Biodiversity Science, Ecosystem Services & Management*, and in 2012 a journal called *Ecosystem Services* was born. To the list of recurring authors in more recent years B. Fisher, S. Pagiola and P. Balvanera can be added.

As far as terminology is concerned, it has to be noted that the concepts “environmental services”,

“ecological services” and “hydrological services” have often been misleading, since they would often direct to results related to hospital science, mental health, or sewage systems. Nonetheless the phrases have been initially kept because, among all results, they also led to relevant papers for the purpose of the study. Conversely, it has been observed that since 2006 most authors have broadly adopted the phrase “ecosystem services”, hence all other terminology has been dismissed.

Countries such as the United States (US), China and the United Kingdom (UK) have produced over 200 papers on ecosystem services in the 1993-2012 period, with respectively 762, 301 and 262 papers. Australia, Germany, The Netherlands and Sweden also stand out for their amount of publications (between 101 and 150), whereas quantities of papers from Canada, Switzerland, Spain, France, Italy, Mexico and South Africa are moderate (between 51 and 100). Of the remaining countries, only nine have published on average two publications per year, and for exactly half of all countries in the world no papers have been found. It is important to point out that the linear annual growth reported in Figure 1 is the result of compensation of production from different countries.

It has to be mentioned that it is possible that some countries have published more than the papers selected for this study. However, one of the selection criteria has been for the abstract of the article to be publicly available online in English,

which excludes not only abstracts that are not available on the web, but also all papers that have not had their summary translated. A note has to be made for the case of Chinese publications, as most of Chinese articles are only available in Mandarin. However, an outstanding amount of abstracts has been found translated, albeit often poorly, into English; no significance of the bad quality of the translation can be determined. Lastly, it has to be pointed out that assessment of the quality of the studies selected is not an objective of this research; so long as articles have been published in a peer reviewed journal and meet the selection criteria, they have been made part of this analysis.

Spatial distribution of papers was determined by authors' affiliations and it is remarkably uneven at the global level (Figure 3). It has been observed that neither national population nor its density would seem to have any significance in the total

number of papers issued per country; the most obvious case is India, which is highly and densely populated, but has only published an average of less than two papers per year.

One important remark is necessary in relation to authors affiliated to international organizations. Such papers have been associated to the country where the organization's headquarters are located. In some ways, this association could be deceiving, as for some countries the results include publications sponsored by international entities. Examples are: the Centre for International Forestry Research in Indonesia; the Food and Agriculture Organization of the United Nations, and the European Institute for Environment and Sustainability in Italy; the World Wide Fund for Nature, and the International Union for Conservation of Nature in Switzerland.

It is interesting to note that more than a half of the 1 781 selected papers are focused around

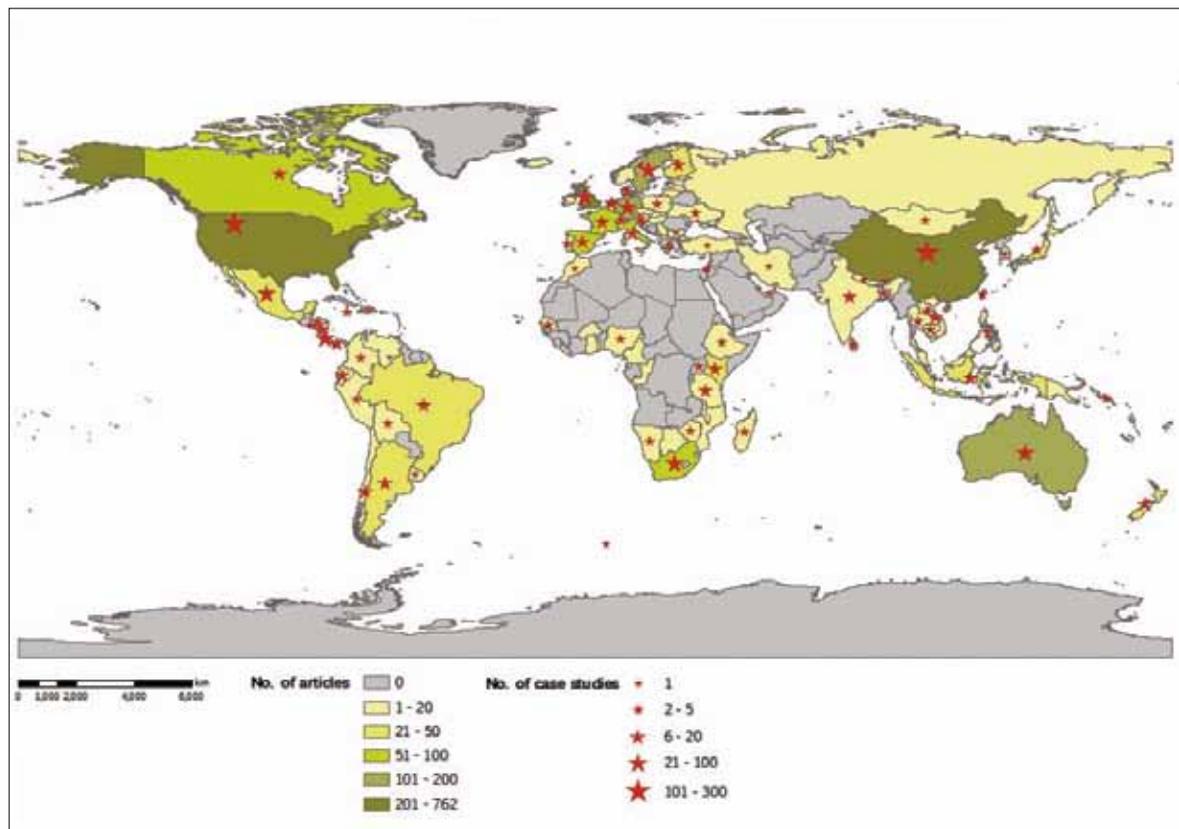


Figure 3. Geographical distribution of published papers about ecosystem services, and number of case studies per country.

one or more case studies. When one site research is covered by a small section of the paper, it has not been extrapolated. For being of supranational character, 75 of the total of 906 case studies extracted from the papers are not illustrated in Figure 3: 14 cover African regions; 12 are centred in the Americas, of which 10 in Latin America; 16 studies cross Asian boundaries; and 23 cover areas of Europe.

Very often the case studies have been carried out in a different country from the one associated with the authors; similarities and discrepancies between origin of the papers and destinations studied are shown in Figure 3. In line with their scores for production of papers in the period of interest, the US, China and the UK present top volumes of case studies: respectively 237, 150 and 50. Large amounts of onsite research have also been detected in Australia, Germany and Sweden, whereas The

Netherlands scored significantly higher for article production than for case studies.

Similarities between the geographical distributions of the two variables can be perceived in areas that issue moderate quantities of papers, especially Canada and European countries. Many developing countries show very low article production as opposed to moderate or high numbers of case studies, for instance in central America (with the remarkable case of Costa Rica), East and southern Africa, and South-East Asia; these are all regions with high levels of biodiversity. Costa Rica's distinctiveness is due to the fact that it was the first country in Latin America to implement payments for Ecosystem Services (PES) schemes (in 1996), and it has often been taken as an example to follow or to analyse. Lastly, it is interesting to observe that two case studies have been reported from Bangladesh and four from Uganda,

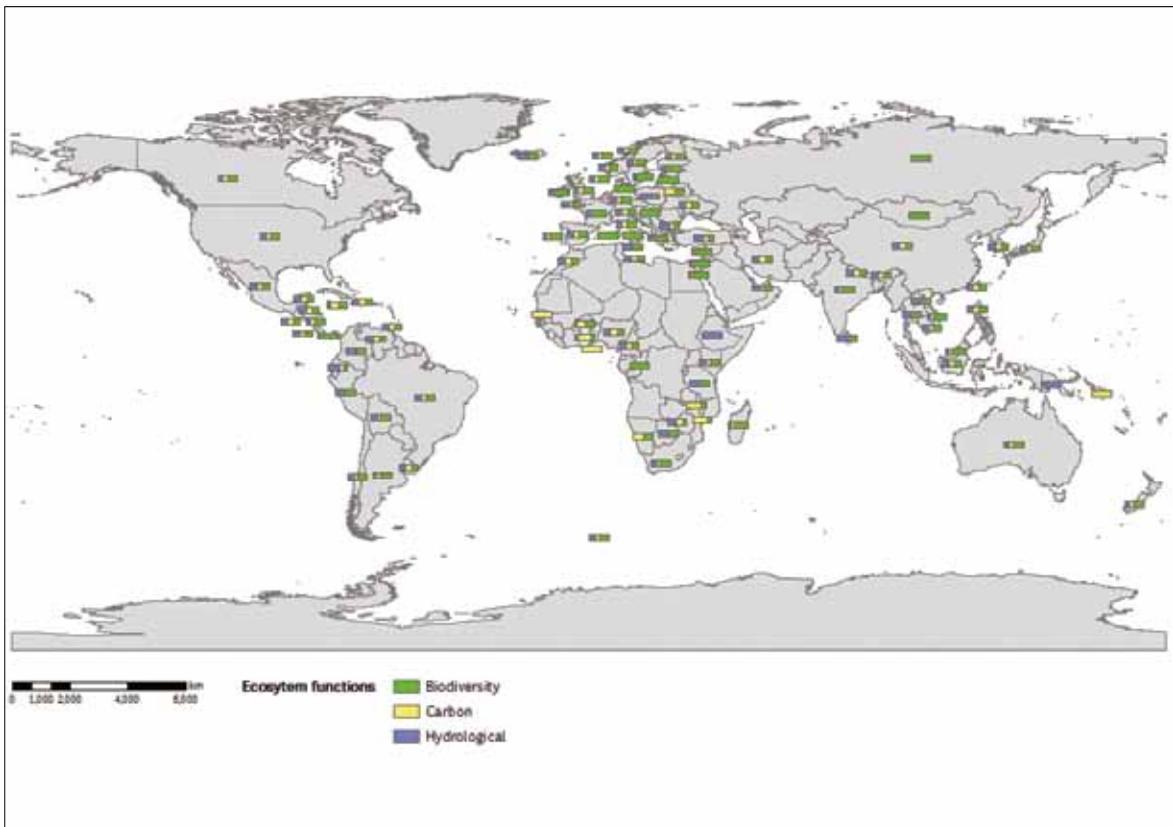


Figure 4. The main categories of ecosystem functions on the published papers about ES.

although no paper publication has been observed for either country.

Investigation used different methodologies and special techniques, in order to fulfil specific aims and needs (Poteete *et al.*, 2012). For instance, the use of interviews, surveys and informal conversations is becoming more common (Kosoy *et al.*, 2007; Martínez-Tuna, 2008; Perevochtchikova and Ochoa, 2012); on the other hand, technological advances facilitate and encourage the use of tools like GIS mapping systems (Chen *et al.*, 2009; Kareiva *et al.*, 2012; Troy and Wilson, 2006). The adoption of sophisticated models for exploring ES has also been increasing recently, especially in the studies of hydrological functions (Martínez and Balvanera, 2012; Vigerstol and Juliann, 2011).

Once the spatial distribution of papers and of their case studies could be visualized, their topics and subjects were explored, as shown in Figures 4 and 5 (where one point has been assigned to every country affiliated to each publication). Ecosystem functions have been summarized into three broad categories, according to their relation to biodiversity, carbon, or hydrological services, labelled respectively as “Biodiv”, “CO2”, or “Hyd” in the file names (available at <http://esanalysis.colmex.mx>). Most publications either focused on all or none of the mentioned categories (1 009 papers) and have been labelled “3F”; during the analysis each function has been assigned a corresponding fraction of a point. In total, approximately 781 papers are centred on biodiversity, 586 on hydrological services, and 438 on carbon.

The predominance of biodiversity on all ecosystem functions is most evident in Europe, northern Asia and Oceania. In several countries the entire article production focuses on species biology, including five European countries, Russia, Mongolia, and Congo (the only one in Africa). When cataloguing the papers, an outstanding number of studies on pollination as an ecosystem service has been noticed. Even though in Africa there seems to be an overall balance among the three categories, in comparison to other regions the continent is one where the greatest interest in services is related to carbon, which is the least studied ecosystem function. The selection of publications from Se-

negal and Togo, albeit small, is entirely concerned with carbon sequestration, and so is the production of the Solomon Islands in the Pacific Ocean.

The proportion of hydrological services in academic papers seems to be the highest between the tropics, especially in developing regions as East Africa, Central America, northern South America, and South-East Asia, which are also the regions where the total production of papers is the lowest. North America and Central America appear to be the regions where the study of functions is the most balanced at the national level, although overall papers on services related to biodiversity prevail. With a few exceptions, and considering that biodiversity is the predominant function at the global and national level, the distribution of the three categories of services can be considered reasonably even.

The same cannot be said when observing the global distribution of focal areas of papers (Figure 5). According to the point of view that the papers take, they have been classified into four broad categories: economic, physical, social and interdisciplinary analysis. The overall repartition of their importance at the national level is extremely irregular; in numerous cases from all continents national production is entirely centred in one focus.

Before analysing the mapped results, it shall be noted that papers with a social focus are the most numerous (539), followed by papers with physical and economic focus, respectively 488 and 462. The 292 interdisciplinary publications are the smallest number, and consist of papers that cover more than one of the former three categories. The temporal trend of foci is not homogeneous either: social and economic approaches started to grow first, especially the economic focus, which was predominant until 2007, followed by the environmental approach, and finally by interdisciplinary studies of more recent years, with exponential growth trends of social and physical topics in the last five years.

Papers with a social and institutional focus prevail in developing countries, especially in Central America (a pioneer region in implementing of PES schemes), East Africa, and South-East Asia. The case of Costa Rica is very interesting, as all the papers from the country and most of the

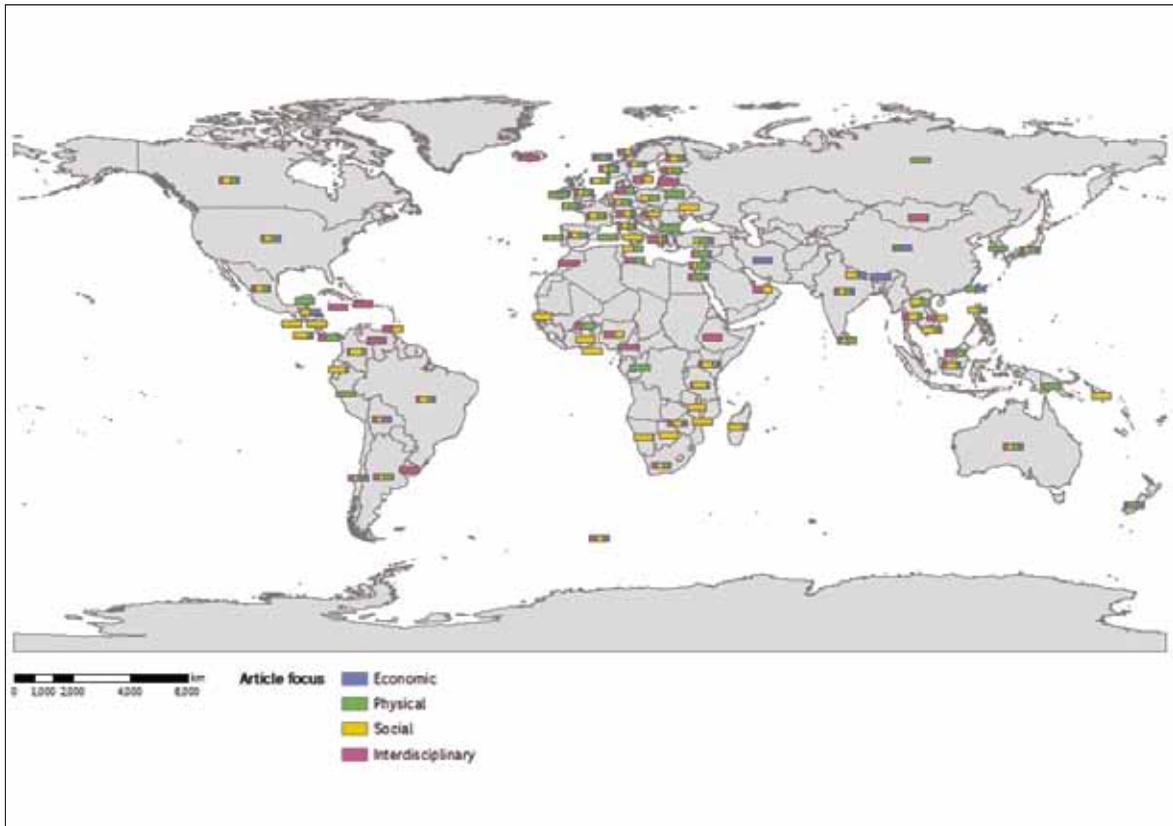


Figure 5. The focal areas of the published papers about ES.

numerous case studies carried out there fall into this focus category. Spread interest in the implementation of policies related to ecosystem services with the aim of reducing poverty also explains the concentration of social focus in third world or developing countries. In the developed world, most of the papers in this category relate agriculture to ecosystem services. The physical focus is mainly concentrated in Europe and the Mediterranean region, in addition to of Belize, Colombia, Congo, Papua New Guinea, Russia and South Korea, where the article production focuses exclusively on environmental issues.

Although globally the economic approach weighs almost as much as the physical one, at the national level its proportion is of much less significance. The monetary focus is mostly spread across South Asia, where Iranian and Bangladeshi publications treat ecosystem services exclusively

from this point of view. China is also an interesting case, as its volume of production is extremely high, and an outstanding percentage of it consists of papers that aim at evaluating ecosystem services in its territory. It is recognized that historically the economic focus has been preponderant from when the Nature's article on service evaluation was published (Costanza *et al.*, 1997) until the mid 2000s.

The interdisciplinary focus appears to be the most spread across all continents. Its proportion is balanced with the other three focal areas in North America, Europe and Oceania, whereas it seems to be prevailing in several countries of low article production. Overall, developed countries appear to have a more balanced division of focal areas compared to third world countries; one of the reasons is the larger volume of papers published in the former, with more variety of points of view.

A brief analysis of the relationship between the distribution of functions and focal areas shows that more than a half of the biodiversity related ES papers approach the subject from a physical standpoint. Similarly, almost a half of environment orientated papers focus on biodiversity. Economic, social and interdisciplinary papers tend to treat the three functions equally, or not to cover any in specific. As a matter of fact, monetary evaluation usually covers whole ecosystems and their functions, and policies rarely focus more on preservation in general than on one single category of services.

### Mexican perspective

The second aim of this study was to gain an understanding of how ecosystem services (ES) have been studied in Mexico over the past two decades. A total of 49 papers have been separated from the original selection of papers, which in the global scene puts the country at 14<sup>th</sup> place. There are 15 papers that used of the phrase Environmental Services and 34 that used Ecosystem Services, 10 of which focus on payment schemes and 39 on other topics, with clear relationship between the use of “Environmental Services” and quantity of PES studies.

Publication of papers in Mexico over the period does not reflect the linear growth observed at the global level (see Figure 6). This confirms the perception that production has been irregular in different countries with overall moderate volumes of papers.

It can be observed that only four papers have been found for Mexico from the first decade searched. Three of them are based on case studies carried out in the country and focus on carbon sequestration policies. After a four-year gap without any results (2001-2004), publications then started to be more frequent, with peaks in 2007 and in 2012. In this respect it is necessary to remember that the federal PES scheme started in 2003, based on the Costa Rican Hydrological PES model. Because the copied model was not appropriately adapted to the social, political, legal and institutional national conditions, over the following few years academic concern about the failure of many programs spread, which could explain the rise in numbers of publications. In particular, in 2007 the Mexican journal *Gaceta Ecológica* published the special issue about “Servicios Ecosistémicos” (INE-SEMARNAT, 2007). Conversely, the volume of production of 2012 is attributable to the continuous growth due to increased awareness and interest in the subject, and is more in line with global trends.

It is very interesting that of the 49 selected papers from Mexico, 27 are co-written with authors from 31 foreign countries. The US is the most common affiliation, with 20 cases of cooperation; followed by Canada, the UK, Chile, Japan and Switzerland. And 25 countries share at least one publication with other authors from Mexico.

Spatially the production of shared papers has concentrated mostly in three of the 32 Mexican

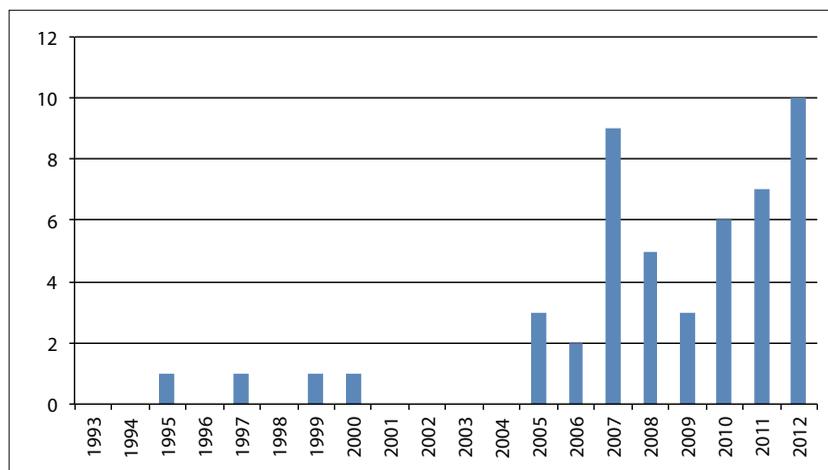


Figure 6. Annual number of published papers on ES in Mexico.

States: the Federal District, Michoacán and Veracruz, with respectively 21, 18 and 9 published papers involving participation of different institutions (Figure 7). The National Autonomous University of Mexico (Spanish acronym: Universidad Nacional Autónoma de México, UNAM) is the affiliation of the majority of publications from the Federal District (Distrito Federal-D.F.), followed by the National Institute of Ecology of the Ministry of Environment and Natural Resources (INE-SEMARNAT). The high number of papers associated to Michoacán is almost entirely related to the re-location of different research centres and very qualified scientific personnel onto the local campus of the UNAM, specifically to the Centre for Ecosystem Research (CIEco-UNAM) and to the Environmental Geography Research Centre (CIGA-UNAM). Lastly, publications from Veracruz are nearly entirely attributable to the work of Institute of Ecology (INECOL) based in Jalapa, the state capital.

Papers on ES have been found for seven more states, which have published between one and three papers in the period (Figure 7). No production has been detected from the remaining 22 states; reasons for such geographical disparities in publishing are disputable. The fact that over the past twenty years Mexican environmental academic focus has been

mostly centred on forest ecosystems could explain the very low production in the deserted northern part of territory; further explanations are open to debate.

Figure 7 shows the spatial distribution of the 41 case studies carried out in Mexico; 26 of these are found in the 49 selected papers (national on site research), and the rest form part of papers affiliated to other countries. In specific, the US, the UK and Spain have published studies about Mexico in respectively 16, 8 and 3 papers; Canada, Chile and Costa Rica have produced one article each over the 20 years. As observed, discrepancies between production of papers and quantity of onsite research per state are conspicuous. No publications have been detected for eight states that have been the main target of at least one national or international case study: Chihuahua, Coahuila, Guerrero, Nuevo León, Oaxaca, Sinaloa, Tamaulipas and Yucatán. Furthermore, Baja California, Chiapas and Sonora have scored low for production of papers, but medium to high for number of case studies carried out in them.

Conversely, Michoacán published 18 papers, but only one research paper about its territory has been detected. Consistency can be observed in a few states: the Federal District and Veracruz published relatively high volumes of papers and



Figure 7. Geographical distribution of published papers in Mexico, and number of case studies per state.

were object of several case studies; Jalisco, Mexico and Querétaro scored medium to low in both categories. Lastly, in the selection of Mexican papers, another four case studies about Canada, Chile, Costa Rica, and Latin America have been found. The spontaneous question that arises from this analysis is: Why is the Mexican academia not publishing in indexed international journals about ES? However there are many publications in Spanish about environmental and ecosystem services, and hundreds of papers related to study of biodiversity, agricultural, hydrological and forestry subjects exists, although most of them do not use the phrase ES.

As far as article focus and ecosystem functions studied in the papers are concerned, trends and patterns have been analysed from both the temporal and the spatial perspective (Table 1, and Figure 8).

The two most productive states, the Federal District and Michoacán, reflect overall national patterns in terms of article focus. Similarly to global trends, papers about social and institutional issues, in particular about PES schemes and other forms of environmental policy, are the most numerous. Their count almost triples publications centred on economic or monetary questions related to ES, which are the lowest number. Proportion of papers

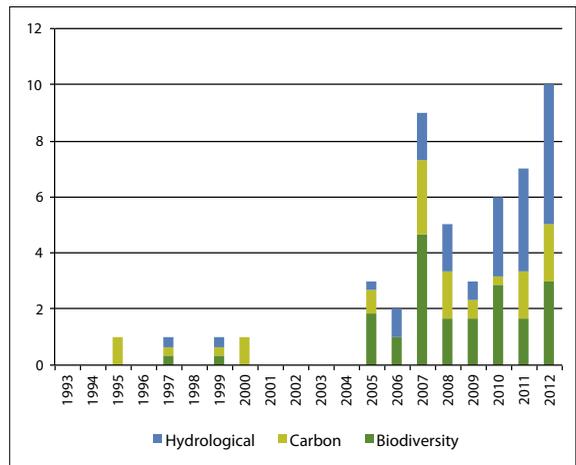


Figure 8. The papers categories of ecosystem functions on published papers in Mexico.

with physical and interdisciplinary standpoints is medium. There would not seem to be any discernible patterns or rationales for the different scores of article focus in low-production states. Conversely, Veracruz's higher than average score for papers on purely environmental questions might be related to its numerous conservation cases.

The ecosystem functions almost perfectly reflect the global patterns. However, their spatial distri-

Table 1. Total number of papers about ES in Mexico per state, according to their institutional affiliation, focus and to the significance of ecosystem function

State	Paper Focus				Ecosystem Functions		
	Econ.	Phys.	Social	Interd.	Biodiv.	Carbon	Hydrol.
Baja California (BC)	1	1	1	0	0.7	0.7	1.7
Baja Cal. Sur (BS)	1	0	0	0	0.3	0.3	0.3
Chiapas (CS)	1	0	1	0	0.3	1.3	0.3
Distrito Federal (DF)	2	5	8	6	7.0	3.0	11.0
Jalisco (JA)	0	0	0	1	0.3	0.3	0.3
Mexico (ME)	0	0	1	0	0.0	0.0	1.0
Michoacán (MI)	0	4	8	6	8.3	5.8	3.8
Querétaro (QE)	0	1	0	1	0.0	0.0	2.0
Sonora (SO)	0	1	0	0	1.0	0.0	0.0
Veracruz (VE)	2	3	1	3	3.3	2.3	3.3
Total (from 49 papers)	6	13	19	11	19	11.5	18.5

bution appears less consistent with the totals than the distribution of article focus; the geographic allocation of ecosystem services seems more related to each area's history and issues. For instance, hydrological services are most studied in states that have problems with water scarcity and distribution: Baja California, the Federal District, Mexico, and Querétaro (states where the water supply is an important issue). Biodiversity is more the object of study of regions with high levels of species richness or a history of conservation programs; whereas academic interest in carbon sequestration is highest where proportion of forest cover is greater: Chiapas, Michoacán and Veracruz.

Moreover, despite carbon related ecosystem functions are the least studied; the category is the most consistent over time, and the predominant one in the first decade. As shown in Figure 8, papers centred in biodiversity peaked in 2007, when the special issue of *Gaceta Ecológica* was published (INE-SEMARNAT, 2007), and although it is the most studied category, its temporal patterns are the most irregular. Interest in hydrological services has been growing almost linearly all throughout the past eight years. The four different article focal areas are spread very irregularly over the 1993-2012 period, with 2012 being the only year where at least one article per focus has been published (Figure 9).

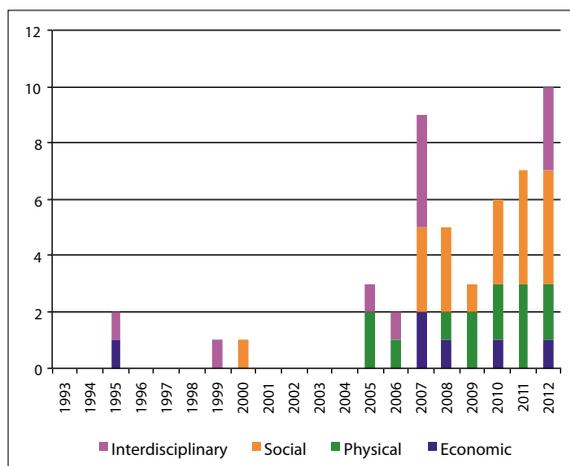


Figure 9. The papers focal areas on published papers in Mexico.

As far as authors are concerned, the most recurring name is P. Balvanera, researcher at CIEco in Michoacán, who is also noteworthy at the global level, having co-published 14 of the state's 18 papers on ecosystem services. Most of the author's publications are of interdisciplinary focus and centred in biodiversity related services. However, some of the remaining authors with Mexican affiliations have also published more than one article.

Finally, a comment has to be made about some limitations mentioned in many studies on the matter of ES that should be tackled in the near future: there is not enough available information, and it is not easily accessible; the available information is used incorrectly; the right levels and dimensions are not matched to specific objectives; the studies are only approached from a single perspective, focus or methodology, instead of being interdisciplinary; there is neither enough academic cooperation nor adequate cross-sector partnerships; professionals and academics carry on "refusing" to learn how to use and update the technology they employ; funding for research is scarce; time and human resources directly related to the study are limited.

## FINAL OBSERVATIONS

The concept of ES first appeared in the international political scene in 1992, as the result of a long debate that ended with the recognition of global environmental degradation, which inspired natural resource management to be based on sustainability and integrity. The compensation schemes for Environmental Services (PES) were designed in 1997, as public policy tools aimed at reducing concentrations of greenhouse gases. Since then, PES have been implemented in many countries throughout the world, assuming different modalities that include, among others, federal programs, joint investments, and property funds.

It has been observed that many studies and publications on ES have been produced over the past 20 years, with a gradual continuous growth in numbers in the last decade. On the one hand, different focal areas and theories have been detected, along with the use of distinct techniques

from various disciplines, selected according to the specific objectives of each research. On the other hand, the social and economic standpoints dominate the global scene, and recent interest in integrated analysis is remarkable.

Geographically, ES research appears concentrated in North America, Europe, China and Australia, where social and economic focus predominated the analysis, followed by physical and interdisciplinary approaches. In the relation to ecosystem functions, biodiversity studies prevail, followed by hydrological and carbon studies. Developing countries have published moderate to low amounts of papers, but are often the areas of interest for foreign research. It is important to highlight that half of the papers are focused on one or more case studies, which allows for better understanding and analysis of local issues. Moreover, applied research combines experiments, sampling, surveys and interviews, which all contribute to providing better quality and more quantity of information for successful studies.

Similarly to the global growth trends, in Mexico studies with social and physical foci predominated, and within them biodiversity and hydrological functions prevailed; their territorial distribution very sharply heterogeneous. Some future challenges worthy of mention are: the need to increase analysis of the function of carbon sequestration, development of research with economic and interdisciplinary focus, more spatial homogeneity of studies, and more cooperation among institutions from different countries and backgrounds.

In this final part a reflection about the evidence that the concept of ES and the development of PES mechanisms were born within the fusion of the fields of economics and environmental policy is presented (Martínez Alier and Roca, 2006), in the form of the proposal for an instrument that would give economic value to the goods and services that nature provides for humanity (Panayotou, 1994; Daily *et al.*, 1997). This approach is situated within a capitalist perspective of sustainable development (Ayala and Tenthoff, 2012) where the proposed schemes are the responsibility of society, based on receipt of payment or allowance for some actions of conservation as market tools. Also society is

seen as a unique actor who has the final say on the management of natural resources, which demonstrates the anthropocentric vision of current environmental politics (Constanza *et al.*, 1997; Vitousek *et al.*, 1997).

However, as practice shows, this perspective has only led to the destruction and deterioration of ecosystems, and it has caused many social problems worldwide (Poteete *et al.*, 2012; Adams, 2004; Hayes and Ostrom, 2005). This is due to lack of consideration of the complexity of environmental dimensions and of social reality, especially in developing countries (Brockington *et al.*, 2008). In this regard it is necessary to think about reconceptualization of PES schemes that currently focus only on the provision of services (within the capital perspective) and do neither reflect the dynamic and integrated notions of environmental conservation nor incorporate the main user of their benefits, which are the ecosystems themselves. This all contributes to the “devaluation” of the sense of ecosystem functions and wilderness.

In conclusion it is necessary to mention that academic interest in the study of ES is noteworthy and growing. However, a lot of research faces problems that limit its achievements, and consequently the general knowledge of the topic of ES and ecosystem functions, for instance lack or misuse of information, scarcity of financial, technical or human resources, shortage of time, security access to study cases, as in Mexico (given the drug-traffic), and many more. It is believed that such obstacles should be tackled in the near future, in order to endorse interdisciplinary publications, focused on different areas and methods with a long-term vision.

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