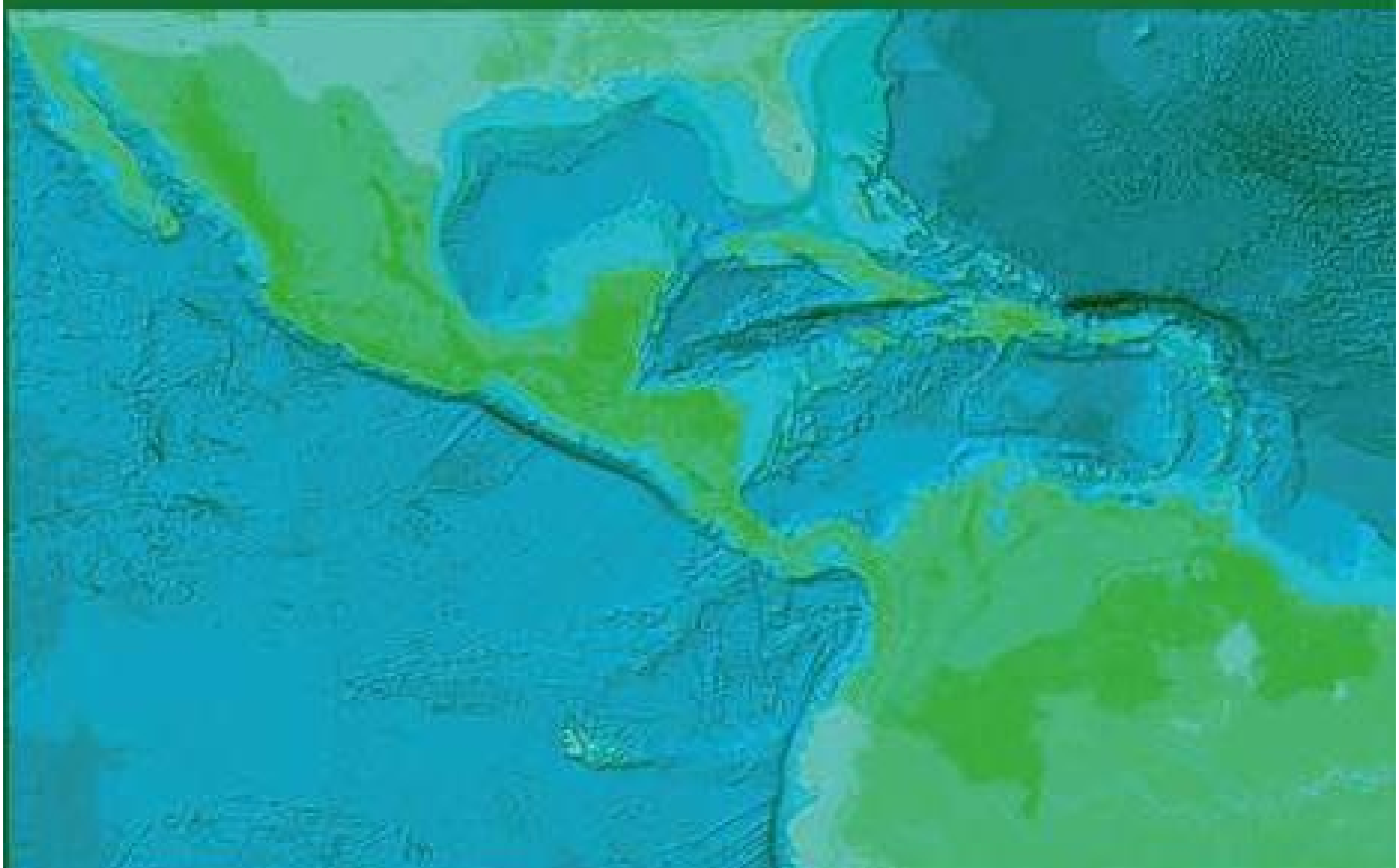
ECOSYSTEM SERVICES VALUATION OF MESOAMERICA AND THE CARIBBEAN



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SCIENTIFIC AND REVIEW COMITTEE

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Primera edición 2019

ISBN: 978-84-17840-25-9

Impreso y hecho en México
Printed and made in México

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PREFACE

Ecosystem services are nature's gifts to society, services that do not appear in the market's price structures but that are indispensable for the very survival of any society. As Costanza et al stated in their seminal paper on valuation of the world's ecosystem services, "The economies of the Earth would grind to a halt without the services of ecological life support systems, so in one sense their total value to the economy is infinite" (Costanza et al, 1997: 253).

The Atlas of Ecosystem Services Valuation of Mesoamerica and the Caribbean is the result of a seminar organized by the Department of Economics of the University Center of Economic and Management Sciences of the University of Guadalajara in 2016 under the coordination of Paul Sutton[1]. In the Atlas, we calculated the value of the ecosystem services of several countries in the region for each subregional biome.

The introductory piece by Boris Graizbord, brings to the attention of economists and other social scientists the meaning and scope of geography and the usefulness of its approach to address the ongoing degradation of threatened life supports systems.

The question of valuation of nature and its services is at the core of a theoretical and ideological debate between mainstream and heterodox economists. Is valuation of ecosystem services necessarily perverse because it induces the overexploitation of natural resources or is it a useful tool of protection? Is it an innocuous economic approach or is it an instrument for market consolidation? Salvador Peniche addresses these questions in chapter one called "Ecological Economics, Political Ecology and Ecosystem Services Valuation"

In chapter two, "Ecosystem Services and Public Policy in Latin America: An Overview", Marco Berger focuses on the usefulness of this instrument for public policy. Governments are already using a set of tools proposed by environmental economists to prevent ecological destruction, biodiversity loss, climate change and water pollution, etc. These instruments include government intervention such as green taxation, certification and other legal regulations over market mechanisms. Berger emphasizes that the starting point for environmental public policy is a realistic valuation of the goods and services that nature provides and the related costs of any alternative futures.

Ecosystem Services Valuation sets a methodological challenge. Comprehensive valuation requires a multidisciplinary approach and a holistic perspective. In chapter three "Systems Thinking, System Dynamics and Ecosystem Services Valuation", Hector Cortes explains the systemic approach and the scope and importance of this philosophy to address the environmental challenges of today's world.

1 Participants: Dr. Jorge Mejía, Dr. Salvador Peniche, Dr. Héctor Cortés, Dr. Jesús Macías, Dr. Clemente Hernández, Dra. Ana Ramírez, Dr. Isaí Guízar, Dra. Margarita Célis, Dra. Gabriela Célis, Dr. Martín Romero, Dra. Carla Aceves, Dra. Erika Carcaño, Mtro. Héctor del Toro, Mtra. Eva Cruz, Lic. Monserrat González, Lic. Adriana Romero and Lic. Álvaro Ríos.

Finally, Paul Sutton explains the methodological foundation of "The Atlas of Ecosystem Services Valuation of Mesoamerica and the Caribbean" developed by Dr. Robert Costanza and his team at the University of Vermont.

Special thanks to Martin Romero, Dean of the department of Economics, for his support in the organization of the seminar of 2016 and the publication of its results.

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INTRODUCTION
MAPS, SPACE, GEOGRAPHY AND ECOLOGY

BORIS GRAIZBORD[◆]

The story of a map does not end with its creation... Map-readers will rely on their imagination to fill in real and perceived gaps; they will read between the lines and make judgements...
Those who acquire, organize, read, and use maps contribute enormously to the cartographic enterprise...

(Akerman and Karrow Jr., 2007: 12)

MAPS

The epigraph is meant as a tribute to this Atlas. The figure is the frontispiece of the 1595 atlas of Mercator.

An Atlas is a collection of maps, and maps are cartographic representations of data. But a map is also a representation of how a cartographer or a group sees the world[3]. To some, a map (the product of the cartographer) reflects the ideas that are imposed in a relation of power. And perhaps the ideal that a group has on its past, present or future.

Usually, an Atlas expresses the current ideas concerning reality or sometimes the new way thoughts –concerns– about the world are expressed from a new approach to the complexity of social, economic, and environmental surroundings.[4] This is precisely

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3 This is a geographical quest. The next four statements reflect different interests and approaches. The first in Chaliand and Rageau (1985), and the last three in Holt-Jensen (1981, p. 37):

1) "The policy of a state lies in its geography" (Napoleon);
2) "Geography is concerned to provide accurate, orderly, and rational description and interpretation of the variable character of the earth surface" (Hartshorne, 1959, p. 21);
3) "A traditionally held view –that geography is concerned with giving man an orderly description of his world—makes clear the challenge faced by contemporary geographers... The contemporary stress is on geography as the study of spatial organization expressed as patterns and processes" (Taaffe, 1970, pp 5-6);
4) "Geography can be regarded as a science concerned with the rational development, and testing, of theories that explain and predict the spatial distribution and location of various characteristics on the surface of the earth" (Yeates, 1968, p 1).

4 Two examples: Seager (1995) and Chaliand and Rageau (1985:7). Seager expresses her concern about the growing trouble she believes is the 'habitat earth'; while Chaliand and Rageau offer their perspective on [the] planet break "...with the Mercator projection, with its horizontal and almost pre-Galilean world, in which the land masses appear to cover a larger area than the seas."

the purpose of this Atlas. It is then an epistemological statement of a new paradigm questioning current thoughts and scientific approaches.

This questioning is perhaps best noted in the difference between physical and human geography, "...as social scientists produce qualified viewpoints... As facts are facts only in relation to a given scientific aim, which is itself structured by the values intrinsic [accepted?] in society... In social science *subjectivity* [italics in the original] or the problem of values is deeply involved in both theory and practice" (Holt-Jensen, 1981: 75, 86).

However, as Holt-Jensen concludes, values and interpretation will be applied differently in the various steps of the research process: design, data gathering, interpretation of results, conclusions and interpretation of meaning, and not less, the language and narrative to understand and convey produced knowledge.[5] It is clear now, as John McCarter Jr. President of The Field Museum asserts it in the foreword in Akerman and Karrow Jr. (2007), "that the content of a map is as much determined by culture, historical circumstances and the interest of mapmakers and map users as it is by the geography that it attempts to depict." In that sense maps "are artifacts of –and witness to– history".

Maps then, or a picture (remember Rene Magritte's: "ceci n'est pas une pipe"), are representations of an idea about "reality" as interpreted by the cartographer (subjected by technical constraints and noise, but residing in his cognitive and affective realms), as Woodward (*1992: 52*) rightly observes.

Scales of maps are crucial to understand people and environmental relations. Conventionally scales in maps are indicated in numerical fractions but can also refer to analytical sections that account for interrelated events as Callenbach (1998) does "... *Ecosystems scale*: In an ecosystem, such as a forest, [multiple] species in a vast interconnected network exchange nutrients and recycle residuals. Ecosystems provide habitat to innumerable beings that can be observed with the naked eye, while others are microscopic and others hidden in the subsoil where they live."

SPACE

Basic concepts in geography, according to Couclelis (1992: 215) are location, place, region, and space but "...space is probably the most fundamental." It certainly is, but it is not a neutral concept.[6] "Geographers –Couclelis continues– are not concerned with space for its own sake, only for what it may mean for the phenomena they study."

Massey (2005) adopts a "political" perspective when thinking about space. A map –she advices– is not the space... Anderson (2008) summarizes her approach to space as "an alternative non-euclidian imagination... that disrupts this and other problematic accounts...":

> *Space is the product of* **interrelations***; thus, we must recognize space as constituted through interactions, from the immensity of the global to the intimately tiny;*

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5 Woodward (1992: 52-3) gives a succinct definition of these terms: "*Knowledge* is the cumulative understanding of information". While "[i]*nformation* is data ordered and contextualized in ways that give them meaning". *Data*, then, "...are raw quantitative facts used as a basis to create information". He further offers an important clarification: "A geographical information system [GIS] commands data about the world, but real danger lies in assuming that a GIS is synonymous with geographical knowledge." (p 53)

6 Couclelis distinguishes four spaces and their terminology: mathematical, socioeconomic, behavioural, and experiential, from *point*, *line*, *area* through *location* and *region*, to *environment* and *spatial layout* and finally *place*, *territory*... in a nested hierarchy. (Op cit., pp. 231-2)

> *Space is the sphere of the possibility of the existence of* **multiplicity***; that is space as the sphere in which distinct trajectories coexist; as the sphere therefore of coexisting* **heterogeneity***;*
> *Space is always* **under construction***; it is always in the process of being made. It is never finished; never closed.*[7]

GEOGRAPHY

There are at least two reasons that question the longstanding nature-society dichotomy –ontologically separated realms–, from a geographical point of view. One is the ability of geography to transcend the discreetness of nature and society by its 'natural' and traditional interest in looking at relations in spatial contexts: "...the world is constituted by relations" (Dyer, 2008). The other derives from the growing interest in the complexity of environmental issues and the impact of climate change. This has led to *multi*, *inter* and *trans*-disciplinary attempts to understand and analyze, from social, political and economic perspectives, ecological changes and environmental degradation and resource depletion processes, at different scales in space and time.[8]

Two additional theoretical and disciplinary departures in relation to nature and society should be added. As Harvey (2006: 87) urges: when thinking in uneven geographical development, it is important "...to examine more closely the metabolic relations between capital accumulation and 'nature' as it is often and plausibly argued that this put us on a qualitative different terrain with respect of theory construction." As "[p]hysical and ecological conditions vary greatly across the surface of the earth...[t]he possibility to mobilize and appropriate physical surpluses varies enormously from one environmental context to another...but the possibilities also depend upon technologies, organizational forms, divisions of labour, wants, needs and desires as well as our cultural predilections (including those articulated in 'common sense')". But this relation is dialectical or rather reciprocal, as he further quotes Paul Burkett:

> Nature's capacity to absorb or adjust to the human production process is itself largely determined by the combined qualities of the material objects, physical forces, and life forms constituting particular ecosystems and the terrestrial biosphere as a whole...

In a more academic vein, Graizbord (2015) explored the pertinence of *environmental geography* as a sub-discipline. The author offers a review of the scope of those disciplines implicitly related to environmental geography, discusses the epistemological relevance of a specialized discipline and the importance of a hybrid fusion and a review of publications in Spanish language that can be considered to belong outright to environmental geography.

ECOLOGY

Callenbach (*Op cit*., p 1) offers a definition of ecology based on the idea that all living forms including man are closely linked with their environment, stating that "Ecology as a science studies the marvelous and complex interrelations between the living forms in the Earth..." Ecology as a concept dates from 1866 when the German biologist Ernst Haeckel used it to describe the study of these interrelations

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7 Italics in the original. Richardson (1992) presents empirical descriptive examples of a cultural ecology approach, based on this last point, in the tradition of American geography.

8 This concern about the human appropriation of nature is not new in geography. Some classic texts are Marsh, 1864; Thomas, 1956; B. L. Turner II, et al., 1990; Goudie, 2005 (o 1993). And, of course, an unavoidable text by Gregory, 2000.

between organisms and their surrounding environment or their 'external world' as well as the study of animals and plants in relation to themselves and their habitats.

Today 'ecology' has three meanings:

1) Ecology properly as defined in the above paragraphs;
2) 'Scientific ecology' understood as an academic subject and a sub-discipline of Biology; and
3) 'Political ecology' understood from the social sciences as a political, critical and normative position. Not conceived as a 'scientific endeavor' (but relating various disciplines in its narrative) it is considered as the philosophical base of a social movement.

According to Giddens (2009, p 5 in the 2010 Spanish version), the interest by social scientists in ecological processes is due to the problems posed by an ecological crisis in the global context. This is seen as a conflicting process that touches daily lives and affect social life or rather the physical and social environment.

The perception of an environmental crisis has turned out in three influential traditions: social ecology, global ecology, and political ecology. The first identified with Bookchin (1990), the second with Sachs (1993) and, the third as a term popular in academia since the sixties from Green, anarchist and Marxist roots centered in economic, social and political concerns surrounding causes, experiences and management of environmental problems (Forsyth, 2003:2).

In political ecology geographic scales (local, rural, urban, regional, national, supra national, global) are not ontologically given but produced socio-environmentally. Zimmerer and Bassett (2003), recognizing different approaches, think that environmental processes interacting with social processes create mutual relations in various scales and the outcome is distinctive political ecologies. They explain that nature –biophysical process– plays an active role but socially affected and understood by the political and cultural representation of "nature". (p.3)

This term is not safe of conceptual and semantic difficulties and inconsistencies. Sociologically, it appears in a debate on inheritance and environment (the context in which life occurs and is mediated by human action). Differences, according to Harvey (1996: 117-119), are not that clear. He then exemplifies the conflict between environment and nature by noticing the division between environmentalists and ecologists, as the first adopt an external position in environmental management, while the second group perceive human activities embedded, printed in nature.

EPILOGUE

The readers of this Atlas will probably find implicit relations to the above subjects. But will certainly realize the different approaches to understand the complexities of the dynamic interaction between man and nature/ society and environment.

The first chapter (by Peniche) considers the limited scope of mainstream economics in trying to explain why in multiple cases economic rationality leads to environmental degradation. In the second chapter (by Cortés) a systems approach is adopted to describe a methodology based on system dynamics to evaluate ecosystems services. The third chapter refers to "payment for environmental services" as a public policy instrument. It argues that its implementation follows user-based principles instead of the polluter pays principle and offers multiple advantages such as being institutionally simple, cost effective and, in the Mexican context in which property rights in a vast extent of the national territory are communal, it is potentially effective in poverty reduction.

Numerous maps and charts follow these texts. They provide useful information on the estimated value that environmental or ecological services can offer at national level for various countries in Meso America and the Caribbean.

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ECOLOGICAL ECONOMICS, POLITICAL ECOLOGY AND ECOSYSTEM SERVICES VALUATION

SALVADOR PENICHE CAMPS[◆]

Ecological distribution conflicts are studied by political ecology, a field created by geographers, anthropologists and environmental sociologists. The unrelenting clash between economy and environment, with its ups and downs, its new frontiers, its urgencies and uncertainties, is analyzed by ecological economics, another new field of study created mainly by ecologists and economists who endeavor to 'take Nature into account', not only in money terms but also in physical and social terms. Ecological economics puts incommensurability of values at the center of its analysis.

Martínez Alier, 2002: 7

INTRODUCTION

While mainstream economics –the cornerstone of Environmental Economics– focuses on prices and economically efficient choices to deal with the exploitation of nature, Ecological Economics is about social metabolism. Ecological Economics studies the significance of materials, and energy flows between nature and society. Under this paradigm, social production is considered not only a question of maximization of private benefits, but a process of the disruption of natural equilibria. For Ecological economics, production is primarily a perpetual connection between humans and their natural environment.

> "Authors working on "industrial metabolism" … or "social metabolism" …look at the economy in terms of flow of energy and materials. Together with the ecological economists, they see the economy as a subsystem of a larger physical system." (Martínez-Alier, 2003:1)

This difference has great theoretical and empirical repercussions. Mainstream economic theory considers that efficient choices made

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by economic actors guarantee not only maximum private benefit, but also minimum social costs. Under the theoretical developments made by the 19th and 20th century's *welfare economists,* such as Vifiredo Pareto (1848-1923), Ronald Coase (1910-2013) and Arthur Pigou (1877-1959), economic efficiency was introduced as the best way to achieve social wellbeing. As environmental conditions are at the basis of social wellbeing, a new tool was needed to deal specifically with environmental issues, which led to the creation of Environmental Economics. This served as the basis for action for economists who were trained to apply the principles of costs-benefit analysis to environmental management; therefore, mainstream environmental management has the main objective to create market scenarios for the exploitation of natural resources through the restoration of private property over "natural capital" and the determination of market prices on nature's goods and services. Under the view of Environmental Economics, environmental health is considered an outcome of free market economics.

ECONOMIC VALUATION OF ENVIRONMENTAL IMPACTS AND INTERNALIZATION OF EXTERNALITIES: TWO SIDES OF THE SAME COIN

Garret Hardin (1915-2003) stated that, under resource scarcity (or overexploitation), economic rationality leads to environmental degradation. Recent economic history shows that efficiency urges always give priority to profit maximization over the survival imperatives of the ecosystems. In the 21st century Hardin's ideas indicate that consumerism (demographic growth) and scarcity of almost every natural resource is at the root of most environmental problems.

> "We can make little progress in working toward optimum population size until we explicitly exorcize the spirit of Adam Smith in the field of practical demography. In economic affairs, *The Wealth of Nations* (1776) popularized the "invisible hand," the idea that an individual who "intends only his own gain," is, as it were, "led by an invisible hand to promote ... the public interest". Adam Smith did not assert that this was invariably true, and perhaps neither did any of his followers. But he contributed to a dominant tendency of thought that has ever since interfered with positive action based on rational analysis, namely, the tendency to assume that decisions reached individually will, in fact, be the best decisions for an entire society." (Hardin, 1968:4).

Mainstream theory gave the name of *externality* to this apparent paradox. An externality is, according to Coase, a market failure, i.e. a situation where economic efficiency is absent after an economic transaction. According to welfare economics, the causes of all externalities are flawed property regime systems or misleading price structure in the market. The result of an externality is always an impact (positive or negative) on a third party. The way to deal with externalities is to restore the market mechanisms that gave place to it and *internalize* it.

> "The traditional approach has tended to obscure the nature of the choice that has to be made. The question is commonly thought of as one in which A inflicts harm on B and what has to be decided is: how should we restrain A? But this is wrong. We are dealing with a problem of a reciprocal nature. To avoid the harm to B would inflict harm on A. The real question that has to be decided is: should A be allowed to harm B or should B be allowed to harm A? The problem is to avoid the more serious harm. I instanced in my previous article the case of a confectioner the noise and vibrations from whose machinery disturbed a doctor in his work. To avoid harming the doctor

> would inflict harm on the confectioner. The problem posed by this case was essentially whether it was worthwhile, as a result of restricting the methods of production which could be used by the confectioner, to secure more doctoring at the cost of a reduced supply of confectionery products. Another example is afforded by the problem of straying cattle which destroy crops on neighboring land. If it is inevitable that some cattle will stray, an increase in the supply of meat can only be obtained at the expense of a decrease in the supply of crops. The nature of the choice is clear: meat or crops. What answer should be given is, of course, not clear unless we know the value of what is obtained as well as the value of what is sacrificed to obtain it. To give another example, Professor George J. Stigler instances the contamination of a stream. If we assume that the harmful effect of the pollution is that it kills the fish, the question to be decided is: is the value of the fish lost greater or less than the value of the product which the contamination of the stream makes possible. It goes almost without saying that this problem has to be looked at in total and at the margin (Coase, 1960:2).

In Hardin's example, a group of shepherds destroyed the local environment of an island due to the increasing need for grass for the sheep. The struggle for survival of each individual producer lead to the overall growth of the consumption of a scarce resource (the grass), indispensable for the survival of all the producers. Under mainstream economics, this externality, the disappearance of the grass ecosystem, can be understood as the effect of the diffuse property of the grassland (no individual owner), or as a result of the specific wrong pricing of the grass for the sheep. In either case, the solution, the internalization of the externality, has to do with the restoration of the market structures, via the privatization of the grassland or the correct valuation of the grass.

From welfare economics theory we can understand the importance of natural resources (common goods) valuation for environmental management. In recent years pricing environmental goods and services has become a major concern in academic and governmental spaces. The reason for the growing interest in ecosystem services valuation is that data on environmental markets is the main input for cost benefit analysis and for policy decision making. In current environmental management the market prices of environmental goods and services are used as a guide and orientation to establish the economic rationality of any given development project.

Accordingly, in the year 2000 the United Nations called for the Millennium Ecosystem Assessment (MA) in which the ecosystem services were defined as "...the benefits people obtain from ecosystems" (UN, 2003:5). This anthropocentric bias, i.e. the valuation of nature in relation to the utility for socioeconomic development, is the main methodological feature of Environmental Economics ecosystem valuation model.

The UN approach to environmental services valuation is consistent with the neoclassical economic theory, with welfare economics and environmental economics. The principles and programs of this, and most of the UN environmental initiatives are used as model at all levels of institutions (from the institutions of global governance such as the OCDE, to national and local governments, private development programs and university curricula). Nevertheless, it is imperative to acknowledge that the utilitarian philosophy behind the mainstream environmental vision is the cause of the current ecological crisis.

> "A great symbolic danger exists in letting all parts insinuate the idea that all values are measurable and exchangeable. In the same way that the quantification of the value of our relations with our

> friends leads to the danger of diluting the notion of friendship. The reduction of nature as a simple provider of goods and services that are eligible to negotiating traders can only lead to its degradation" (Maris, 2011:32).

Economic valuation of nature is a useful tool that helps us understand a segment of the socio environmental reality. For example, the UN methodology has developed a categorization of environmental goods and services that may help to identify what services are suitable to enter the environmental markets and which not, which services and goods must be taken under consideration for ecological reasons and which mustn't. Economic valuation of ecosystem services might be a powerful tool to understand the market constraints and barriers related to the economic exploitation of any given resource.

Nevertheless, economic valuation cannot be used as the one and only criterion of decision making because it is partial and incomplete and disregards the basic principles of the ecological laws of nature. The traditional methodologies used for environmental goods and services valuation show this strong limitation. The direct valuation (declared preferences: contingent valuation) and the indirect valuation (revealed preferences: cost of trip) are focused on the recreation of imaginary markets, derived from shadow prices that create abstract models of economic behavior of stakeholders, actors that are set as dependent variables that perform to according to a set of fixed rules of economic efficiency, and profit maximization (Martínez-Alier, 1995).

ECOLOGICAL ECONOMICS VALUATION OF ECOSYSTEM SERVICES: CONSIDERING THE NONMARKET VALUES.

Ecological Economics sets new priorities for policy making. Under this paradigm it is recommended that economic decisions are taken beyond the narrow scope of price equilibrium.

Ecological economics is about valuation and about the establishment of eco sensitive prices over the social impacts of their exploitation. Market prices undermine social and environmental costs of productive exploitation of nature and socio-ecological impacts of development projects are taken under consideration only as parts of the monetary costs in the costs-benefit analysis. Ethical, humanitarian and ecological impacts are set aside.

The distortion of real socio-ecological prices is at the base of most ecological crises. Furthermore, economically efficient prices frequently impose the costs of environmental degradation to marginalized communities. Traditional social sectors, rural populations, indigenous groups and urban marginalized communities are the main victims of the impacts of environmental destruction because these social groups occupy regions where the remaining environmental resources are located. The rise of political ecology as an independent discipline - the study of the political effects of a given model of social metabolism- is a reaction to the proliferation of environmental distribution conflicts all around the globe.

> "...the industrial countries are dependent on imports from the south for a growing part of their growing requirements of raw materials or consumption goods, so that the oil and gas frontier, the aluminum frontier, the copper frontier, the eucalyptus and palm oil frontiers, the shrimp frontier, the gold frontier, the transgenic soybeans frontier . . . are advancing into new territories. This creates impacts which, before there is time to redress them through economic policy or changes in technology, have already been felt disproportionately by some social groups that often complain and resist (even though such groups do

> not necessarily describe themselves as environmentalists)" (Martínez-Alier, 2002:10-11).

Here we find another important difference between Environmental Economics and Ecological Economics: the rationale behind environmental management. Neoclassical economics considers the disruption of ecological conditions a natural result of economic development. Ecological Economics, on the other hand, suggests that the disruption of social metabolism, the metabolic rift[9], is not fixed. Rather, it is a result of each historical pattern of production and consumption. Consequently, the task of modern ecofriendly societies is to modify the way social production is related with the natural environment, i.e. to modify social metabolism and avoid the ecological rift.

The starting point of this new paradigm is the transformation of the perception of the place that human beings occupy in the natural world. The transformation of society and the abolition of the destructive dynamics of the current economic system is linked with the idea that humans cannot be separated from their intrinsic relation with the environment they depend on. Consequently, social reproduction has to be considered as an outcome of the health of surrounding ecosystems. Society's wellbeing is nature's development. The unity between humans and nature is a precondition of sustainable development.

> "The behavior generated by an anthropocentric cosmology that places human beings above nature is consistent with the traditional styles of development. Hence, the economistic view of development, measured by means of such aggregate indicators as the GNP, indiscriminatingly regards as positive any processes where market transactions take place, regardless of whether they are productive, unproductive or destructive. As an example, it is in this way that the indiscriminate depredation of natural resources makes the GNP grow, as in the case of a sick population when it increases its consumption of pharmaceuticals or use of hospital facilities" (Max-Neef, 1991:59).

Ecological economics expresses the principle of human relativeness in its productive philosophy. Valuation of environmental services, i.e. the cost of nature gifts to humans, is a secondary guiding principle for development policy. From this perspective, market prices of environmental assets are just a marginal part of the valuation. Human utility becomes also dependent of ecological preservation, and social distribution of environmental services is considered the main criteria of development policy after pursuing environmental health. For Ecological Economics, human wellbeing is meaningless without environmental preservation. This is how ecological economics approaches environmental justice. Intrinsic value of nature does not depend on human considerations. Humans benefit from the services that nature provides, and from the services that allow the existence of life. Nature itself is regarded as a part of human existence, as an extension of humanity.

CONCLUDING REMARKS

Ecosystem Services Valuation, the pricing of the services that nature gives to humans, has great importance for environmental management. It provides key information about the market conditions, the economic viability of exploitation of natural resources and the location of market barriers. Nevertheless, ecologically sensitive public policy should treat the outcomes of economic valuation with extreme caution. Economic information should serve as an important orientation about one of the

9 The Metabolic rift is a concept introduced by Marx to define the result of market utilization of natural resources.

aspects of environmental decision making: the economy. An ecologically sound development policy must prepend a set of criteria that allows incorporation of the ecological and social imperatives to the economic considerations. This will obviously have a great impact on price structures of current goods and services because it will mean the establishment of a proper pricing structure of everything we produce and consume. As a result, patterns of production and consumption will change inevitably in order to maintain the proper conditions of ecological sustainability, which in the end, is the *sine qua non* condition for life.

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ECOSYSTEM SERVICES AND PUBLIC POLICY IN LATIN AMERICA: AN OVERVIEW

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INTRODUCTION

One of the most common ways to introduce the concept of ecosystem services into the policy realm both at the developing and developed world contexts in the last two decades has been through design and implementation of payment for environmental services (PES) schemes. Payment for Environmental Services (PES) Programs in Latin America and Mexico have dominated the market-based environmental policy in the last years in part because they have been considered by policymakers as a new paradigm for solving the problem for ecosystem degradation. While the potential advantages of well-designed PES programs are attractive for policymakers, careful examination is needed in any case for their design and implementation. This is especially important in developing world contexts in order to measure the effects –positive, negative, intended or unintended- that these kinds of policies have in the interaction between social and economic dynamics on the one hand, and ecosystem services on the other.

There is a vast literature that shows that PES schemes offer several advantages: they are cost-effective, they are institutionally simpler, and they are potentially good for poverty reduction. Moreover, PES schemes embrace the user-based principle instead of the polluter-pays principle and, in some cases, they have elements of a conditional cash transfer program. From a geographical perspective, PES programs are flexible and adaptive to local, regional, national and international scales. Despite the advantages from a design perspective, PES programs present a set of issues and barriers at the implementation stage, especially within developing world contexts like Latin America where a set of preconditions must be in place in order for PES programs to work well. It is then particularly important to examine the effectiveness of PES programs in the specific context of Latin America in order to shed light about the role that institutional and social variables play to determine the equilibrium between ecosystem services conservation and socioeconomic intervention. Specifically, the property rights formal and informal rules of use significantly vary both between developed and developing world contexts as much as within developing world contexts (Libecap, 2006; Barzel, 2002). PES has become popular in developing world contexts because it is seen as a new paradigm for solving the problem for ecosystem degradation (Ferraro and Kiss, 2002). Moreover, under some circumstances, PES intervention has proven more cost-effective than traditional command-and-control instruments such as designating natural protected areas. As men-

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tioned, proponents of PES see it as a better course for environmental policy due to several *potential* advantages: cost-effectiveness, institutional simplicity, and poverty reduction. (Wunder et al; 2008). Each of these advantages is based mainly on theoretical grounds. In practice, though, institutional constraints and bureaucratic and implementation failures may hinder their effectiveness.

ECOSYSTEM SERVICES POLICIES IN LATIN AMERICA

Environmental policy preferences in Latin America and Mexico have recently shown a transition from traditional command and control policies to market-based environmental policy instruments. In a parallel way, this transition has trended from an exclusive government-based policy orientation towards integration of multiple stakeholders, including direct environmental service users. Under this context, a particular set of programs known as Payment for Environmental Services (PES) has emerged as a market-based alternative instrument to compensate local communities and private owners for the provision of environmental services. Such services may include biodiversity, hydrological, carbon sequestration, recreational or aesthetic investments on their own lands. Following Pigouvian and Coasian principles, the ultimate goal of PES programs is to compensate for the positive externality that is created by the provision of environmental services.

One of the key questions arising from PES programs in the last years is: Have PES schemes as public policy interventions changed the behavior of landowners where the environmental services are provided? If the answer is yes, then the PES program or scheme is in a good position to achieve additionality and effectiveness, in other words, to add value and achieve its intended effects. If not, it would only be a wealth transfer from the environmental service user to the environmental service provider in the form of a traditional subsidy. Proponents of PES schemes claim that behavioral change is nurtured through the intervention and market creation might come as a consequence (Shapiro et al, 2010, Shapiro & Garza, 2013). Skeptics argue that potential and actual barriers (what they call "leakages") mitigate the effectiveness of the program. Within this debate, it is also claimed that both the effectiveness and efficiency of PES schemes crucially depend on its design.

POTENTIAL RISKS OF PES AS A POLICY INSTRUMENT

At the implementation level, a thorough and careful examination of PES evidence and cases throughout Mexico and Latin America provide valuable guidance for policy-makers as they face the issues that emerge in transitions from government-based to user-based programs. For example, the Mexican Payment for Hydrological Services –hereafter PSAH- is the highest scale program within countries with high deforestation rates. From 2003 to 2013, ca. 5,800 forest communities have participated in PES programs in Mexico, with 3.2 million hectares enrolled and 600 million dollars allocated for PES programs in Mexico within the same period (CNF, 2014). Most program beneficiaries are Ejidos, the Mexican PES common pool resource property rights regime which is similar to other property rights regimes that held property in common throughout Latin American countries. This institutional arrangement entitles Ejidos to become environmental service providers, with profound implications in terms of environmental governance (Lemos & Agrawal, 2006), but also on decisions regarding the provision, appropriation and exclusion of environmental services (Libecap, 2006).

Regardless from particular property rights and environmental governance contexts, one of the issues that most scholars agree upon in the environmental policy literature is that a typical PES should have the following characteristics: a voluntary transaction; a well-defined environmental service 'bought' by a minimum of one ES buyer from a minimum of one ES provider; and if and only if the ES provider secures ES provision or conditionality. This framework, although useful, is a necessary but insufficient condition to achieve PES program effectiveness, since each condition might be linked with at least one market, government or institutional failure, especially under developing world specific contexts. At the policy implementation level, a consequence of the failures is that they might lead to poor selection and targeting of PES program participants and eventually lower its effectiveness and additionality levels. In this regard, one of the most striking failures regarding the management of public PES schemes is lack of sound targeting mechanisms. Target rules determine justice, distribution and access criteria for potential program participants. Ultimately, targeting criteria decide the magnitude and direction of potential environmental outcomes and impacts of the program. Overall, user-based, smaller scale PES schemes claim more substantial impacts and effectiveness than government-based large-scale PES programs. The transition from government-based towards user-based PES schemes, however, is complex.

Wunder et al. (2008) found that user-based and government-financed PES schemes have significant differences in terms of concrete performance indicators such as targeting; tailoring to local conditions and needs; monitoring and enforcement to achieve conditionality; and confounding objectives. In these four aspects, user-based schemes performed significantly better, on average. Other leakages may arise when PES beneficiaries are communities rather than individuals. There is a vast literature that studies common pool resources dynamics as well as the risks and opportunities that communitarian arrangements offer (Ostrom, 1990; Baland and Platteau, 2003). The fact that an agreed-upon contract takes place between a public sponsor and a community in order to guarantee and preserve conditions for ES provision tells us very little about the internal dynamics of the community itself and, ultimately, which outcomes and impacts will be generated as a consequence. Local rules of use may be incompatible with PES top-down designed program requirements (Cardenas, 2000; Farley & Constanza, 2010).

THE MEXICAN PAYMENT FOR ENVIRONMENTAL SERVICES PROGRAM

Payment for Environmental Services programs and schemes in developing world contexts such as Latin America have been attractive in the last 20 years both for policy makers and researchers. The appeal of these programs lies in the fact that PES schemes are a combination of two theoretical concepts in neoclassical economics, namely, the Coase Theorem and the Pigouvian subsidies. PES has even been considered as a tool for simultaneous poverty reduction, a permanent policy concern in Latin America (Ferraro and Kiss, 2002; Wunder & Albán, 2008). There is a need for a framework that encompasses the main conditions that a given PES scheme might face given its particular context, particularly under developing world conditions such as the Mexican Payment for Hydrological Services Program (PSAH). These constraints are faced both at the design and the implementation stage of the program. Following Wunder et al. (2007), there are at least five main characteristics that any payment for environmental service scheme should have in order to be workable, feasible and practical at the policy stage. These characteristics are taken from the literature review in Chapter 1 and listed in column 1 of table 1. These characteristics include: a voluntary transaction, a well-defined environmental service to be provided, bought by at least one environmental service user, sold by at least one environmental service provider, and conditionality (Wunder, 2005). By reviewing these characteristics, I propose that at least one assumption of the Coase theorem is linked with at least one of the five criteria proposed by Wunder et al. In the last row of the matrix, I add the concept of additionality as a desirable outcome for a PES scheme. If additionality is fulfilled, the other five previous conditions must hold. It is important to note that even if additionality –effectiveness- of the program is not achieved, there could still be a valid PES scheme that complies with the other five characteristics. In this sense, additionality is not the only criterion to evaluate a PES program overall, although it is the term that is used to specify an impact evaluation with baseline data[10]. Finally, it is undeniable that there are market, government and communitarian failures associated with each of Wunder principles and with a Coase theorem attribute as well. Hence, the third column of the matrix specifies which kinds of failures are associated directly or indirectly with each PES principle.

PAYMENT FOR ENVIRONMENTAL SERVICES IN LATIN AMERICA

There are a number of reasons why the majority of cases in the PES literature for developing world contexts are depicted in Latin America. First, it the Latin America is pioneered by Costa Rica, which is the largest laboratory for PES programs and schemes implementation in the last 20 years in any developing world context. Secondly, the region includes large government-based programs such as Mexico's Payment for Hydrological Services PSAH. Third, many government-based PES schemes in Latin America offer similar institutional contexts that in many cases eventually lead to common outcomes, especially in terms of spillovers and leakages and are likewise driven by underlying conditions, *i.e.* poverty levels of the targeted population and ill-defined property rights of potential beneficiaries. Finally, the region has been a robust laboratory to start "PES-like" schemes which include hybrid experiences that combine government and user-based schemes in Bolivia, Ecuador, Central America and Mexico. One of the main factors that has attracted attention from the international scholar community towards the region is its great environmental service potential reflected in its forest coverage and biodiversity "hotspots", many of which are endangered and therefore attract global attention through PES and PES-like programs.to tackle environmental problems and foster conservation practices and interventions. Especially important in this context are carbon sequestration PES schemes and Reduction of Emissions from Deforestation and Degradation (REDD+) initiatives, which are mainly funded by international organizations, firms and governments to offset carbon emissions and globally mitigate climate change (CNF, 2011).

Other important findings that can be drawn from the PES case study literature in Latin America are that environmental services projects attract, on average, four times more funding than traditional biodiversity projects such as natural protected areas, although, in some contexts, a significant number of PES

10 Other forms to measure effectiveness are, for example, cost-benefit and cost-effective analysis.

TABLE 1. CHARACTERISTICS, ASSUMPTIONS AND FAILURES THAT MIGHT BE ASSOCIATED WITH PAYMENT FOR HYDROLOGICAL ENVIRONMENTAL SERVICES (PSAH)

WUNDER ET AL., 5 MAIN CHARACTERISTICS OF A PES SCHEME PLUS ADDITIONAL FEATURES	COASE THEOREM ASSUMPTIONS THAT MIGHT BE ASSOCIATED WITH A GIVEN PES SCHEME	MARKET, GOVERNMENT OR COMMUNITARIAN FAILURE FOR THE MEXICAN CASE
1. VOLUNTARY TRANSACTION	Enforcement and rule of law if one economic agent deviates.	Willingness-to-participate is inhibited by sociodemographic and institutional factors (Kosoy & Brown, 2008). Poverty and Property Rights inhibit participation on the program.
2. WELL-DEFINED ENVIRONMENTAL SERVICES	Well-Defined Property Rights	Uncertainty about the causal relationships around the environmental service (Engel et al, 2008).
3. "BOUGHT" BY AT LEAST ONE ENVIRONMENTAL SERVICE USER	No Wealth Effects Low or Zero Transaction Costs Distribution doesn't matters. Complete Information No arbitrage Parties are price-takers	Incomplete Contracts and Asymmetrical Information. Principal-Agent problems
4. "SOLD" BY AT LEAST ONE ENVIRONMENTAL SERVICE PROVIDER		Middle Man Targeting Failures Program Service Delivery Collective Action Issues associated with Common Pool Resources at Ejido beneficiaries.
5. CONDITIONALITY	Enforcement and rule of law if one economic agent deviates.	Moral Hazard, Monitoring, Free-riding, enforcement and motivational crowding out.
ADDITIONALITY	Distributional Issues at Local Markets. Bargaining Platforms in CPR contexts	Market and Spatial Leakages and Slippage. Additional Goals i.e. Poverty Alleviation vs. Environmental Service Provision.

projects are located very close or even coexist inside natural protected areas. Second, government-financed PES have caused modest or no reversal of deforestation (Goldman et al., 2008). Pfaff, found this evidence for Costa Rica (Pfaff et al., 2008); while Shapiro et al estimated only a net 12% reversal deforestation rate for Mexico (Alix-Garcia et al; 2010:2012). On the other hand, case studies of user-financed, smaller-scale PES schemes claim more substantial impacts. Additionally, clear baseline data is very important for future success of any PES program. Evidence suggests that only a few countries in Latin America have sound baseline data in order to make appropriate comparisons based on monitoring, reporting and verification systems that also account for social capital indicators. Baseline is crucial to determine the impacts of any PES program. However, for government-based PES programs, baseline data has been difficult to gather due to implementation failures of the program and lack of sound monitoring, verification and report (MRV) systems (CNF, 2014).

A major issue in the region regarding PES is the role that side goals play in PES program design. Not only has poverty alleviation been proposed as the key side goal for PES programs, but also other side goals such as land tenure and local economic development (Pagiola et al 2005:2008). Other than local case study experiences that have shown that the PES government-based program served as an incentive for poor communities in southern Chiapas to improve their property rights situation (Kosoy & Brown, 2008), the main finding here is that, despite the importance of side goals, no broad evidence exists about environmental service effectiveness in addressing those side goals in addressing those side goals?

Despite these findings, institutional heterogeneity between and within countries have made comparisons between Latin American countries very difficult to establish. Insufficient data and the impossibility to control for institutional differences have made comparative quantitative models difficult to develop (Pattanayak et al., 2010). Still, some patterns emerge to explain the performance of PES programs in this region. Institutional environmental and economic preconditions of potential program beneficiaries face similar challenges across Latin America. These challenges include land tenure and property rights definition, lack of sound participatory arenas, and the implications of common pool resources for government-based schemes management.

DISCUSSION

Table 2 summarizes the most fundamental PES cases that have been put in place and evaluated over the last 15 years in Latin America in terms of scale and scope according to the international literature. It includes the main features of a PES scheme and follows the same approach discussed in Table 1 by emphasizing actual failures in terms of leakages and spillovers as well as the additionality impact that has been identified throughout the implementation of each program in its own particular context. These environmental services findings are either based on case study evaluations of PES in the region, or developed through rigorous econometric quasi-experimental analyses that include baseline and control group data.

Three types of schemes are identified with regards to their buyer-seller composition: i) market-based schemes were either financed by non-governmental organizations and/or international donors, who buy environmental services directly as in *Los Negros*, Bolivia and Pinampiro, Ecuador; or a private firm that buys the environmental service as in the PROFAFOR program ii) the government as the only or main buyer of the environmental service, namely, the Mexican Pro-Arbol program and all its derivatives, including PSAH and iii) the Costa Rican case using quasi-governmental or government-like scheme types (Pfaff, 2008). In this case, a semi-autonomous public agency or a public-private partnership funded by a mixture of public, private, and international resources is the main buyers of the environmental services. On the other hand, the providers of the environmental services are mainly local communities, some of them indigenous with their own rules of use.

Each of the most renowned cases in Latin American are integral as they try to encompass the four most important environmental services: carbon sequestration, biodiversity, agroforestry and hydrological services. While government-based and government-like cases such as the Costa Rican and Mexican experiences encompass the four main environmental services through different components, the NGO and private-based PES schemes are much more specific and focus on only one kind of environmental service at a time.

TABLE 2. LATIN AMERICAN MOST RELEVANT PES SCHEMES IN THE LAST 10 YEARS IN TERMS OF SCALE AND SCOPE.

CASE	BUYERS-PROVIDERS VOLUNTARY TRANSACTION	TARGETED RESOURCE	CONDITIONALITY	SPILLOVERS & LEAKAGES	ADDITIONALITY	SIDE-GOALS
COSTA RICA PSA (PFAFF ET AL, 2008)	FONAFIFO (Autonomous State Agency)/ Private Landholders, Indigenous Community.	Water, Biodiversity, Carbon Sequestration and Agroforestry Projects.	High and subject to future payments.	It is complemented with Command and Control policies.	Little Effect: Approximately 2% (Pfaff et. Al.)	Poverty Alleviation
MÉXICO PSAH (MUÑOZ PIÑA, 2008)	Federal Government as main buyer; Three Public Agencies interact directly with the Program.	Strategic threatened watersheds	High	Rent seeking by Communities with Timber Firms.	Explicit Baseline for the Program. However, divergent results from different evaluations.	Poverty Alleviation, -from 2007-ongoing) Natural Protected Areas (NPA's)
MEXICO. LACANDON FORREST (KOSOY ET. AL. 2007).	Federal and Local Governments Frame. Participatory Rules have an upper income bias.	Biodiversity and Carbon Fixation	Not Determined.	Increase in Land-Tenure Security. Neighbor Non-Participants feel Excluded Collective Action Issues at the Ejido level.	Not determined.	Poverty Alleviation (The Evaluation focused on one of the poorest regions of the Country).
PINAMPIRO, ECUADOR (WUNDER, ENGEL AND PAGIOLA, 2008)	NGO's and external donors buy services of local villagers	Watershed Protection	High in the first years but declining	Unmetered water Users tend to Free-Ride	Implicit Future Scenario	Complements weakly enforced forest rights.
PROFAFOR, ECUADOR	User-Based scheme. FACE, a Dutch Consortium, pays forest villagers.	Carbon sequestration through reforestation	Additional Funding after third year, subject to 80% reforestation rate.	Climate Change Mitigation Offset beneficiaries	"High"	No
LOS NEGROS, BOLIVIA (TURIANSKY, 2010)	Fundacion Natura (NGO)	Watershed and Biodiversity Protection	Untested	Low	"High"	Complements Weak Rules on Deforestation.

Adapted from various sources: Pattanayak 2010, Wunder et al. & Cabrera and Kosoy.

A remarkable result of program evaluations that have been carried out in Latin America, as Table 1 shows, is that all of them provide a "high" or "very high" level of conditionality as defined by a contract in which both parties agree to preserve the environmental services. Compliance with this provision is verified by monitoring, verification and compliance mechanisms which are also agreed upon between both parties, typically satellite images. However, in terms of additionality –the most difficult goal to achieve- significant differences might be found between the low levels of public-based programs in Costa Rica and Mexico compared with high levels that have been demonstrated in small-scale firm and NGO-based programs in Ecuador and Bolivia (Turiansky, 2010). *Ex ante*, this fact does not imply that user-based, small-scale schemes are superior as a general rule. Given the large scope and scale of government-based schemes, it might be the case that under the government-based scheme umbrella, there are particular projects that will eventually become PES user-based or Reduction of Emissions from Deforestation and Degradation (REDD+) projects at the local levels, and then have relatively higher effectiveness results. However, right now they depend on government for a transition process. In this sense, current projects that are beneficiaries of the program will eventually be transformed into actual environmental service markets with a user-based approach fashion and with an undefined time horizon (Alix-García et al; 2010; Pattanayak, 2010). Clearly, not all selected projects will automatically be transformed in user-based ES markets after five years of public intervention[11]. Still, the additionality levels for public programs are low, but positive, and they can increase in the next years if proper adjustments are made to the targeting criteria.

CONCLUDING REMARKS

All scheme types inevitably present some sort of spillover and leakages that are different in kind from the environmental service provision itself. In fact, user-based small schemes are not absent from leakages. For instance, in in Los Negros, Bolivia there is some evidence of negative effects of PES implementation such as job loss, competition for land and social tension between those receiving payments and those who do not (Grieg-Gran, et al; 2005).

Overall, any environmental service scheme either government or user-based needs to be constantly recalibrated and adjusted for actual and potential leakages. In the Mexican case, the main leakage sources that have been identified are: i) a set of targeting failures in the changing criteria selection throughout the recent history of the PSAH and ii) the low level of environmental market creation after public intervention through five-year PES programs. As for the Costa Rican government-based program, it is very interesting that FONAFIFO has been calibrated and adapted to the country's international tradition and worldwide leadership on the management of one of the main command and control instruments in forest policy: Natural Protected Areas. FONAFIFO is actually vastly implemented in a Natural Protected Area geography and basically, the program has accounted for the fact that, in principle, additionality is not achieved when a PES pro-

11 The main reason why this is very unlikely to happen is because there are targeting failures in the aim to achieve the "optimal" targeted population of the program. Therefore, projects that provide low, very low or null additionality levels during the project are also those with relatively lower incentives to attract potential private and NGO buyers and create a market.

gram is embedded inside a Natural Protected Area (FONAFIFO, 2012). Therefore, when monitoring, enforcement, and weak property rights exist, a PES scheme might provide some additionality to the community in which it is implemented, even in an NPA. In this sense, it is not an either/or policy design, but a hybridization process between a command and control, and a market-based instrument.

Unfortunately, thus far positive spillovers in the form of substantial "demonstration effects" for neighbor communities with similar characteristics haven't been clearly documented in any case. On the contrary, there's some evidence of "negative demonstration effects" in the Lacandon Forest in Chiapas, Mexico, where non-beneficiary neighbors have expressed their discomfort at being unfairly excluded, and perceive that the selection process hasn't been equal for all participants (Kosoy et al; 2007).

Finally, poverty alleviation seems to be the primary complementary goal for governments that run PES programs in Latin America. For the user-based schemes in South America, no income variables have been measured before and after the intervention of private and international funding that consider the opportunity cost of enrolling their land in the scheme. Another poverty correlated variable in which small-scale schemes have focused regarding side-goals has been in complementing weakly enforced forest rights or weak rules on deforestation. In short, there are three main issues that need to be addressed regarding the implementation of PES schemes in Latin America: the environmental behavioral change of former beneficiaries of PES programs; the feasibility of user-based PES schemes with government co-management; and the role of side goals on PES programs.

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SYSTEMS THINKING, SYSTEM DYNAMICS, AND ECOSYSTEM SERVICES EVALUATION

JOSÉ HÉCTOR CORTÉS FREGOSO◆

ABSTRACT

It has been a highly dedicated task to undertaking an academic effort so as to evaluate the services brought about by ecosystems. There are a very large specialized literature whose goal has developed methods both to explain and measure how to calculate those services in dollar terms taking into account not only certain small number of countries but almost all countries of the world, for example, all Latin American countries. Nevertheless, it seems there is something missing in that broad world-wide literature. The question has to do with policy implications, i.e., it is useful to get a very precise idea on those amounts of dollars produced by ecosystems of regions and countries, but what's next? How is it possible to usefully insert into the public policy objectives the calculations derived from such efforts?

For some systems analysts the answers to those questions have to do with the absence of a methodology that permits to solidly support all that intellectual structure implied by the ecosystems services evaluation. A methodological alternative is directed towards systems thinking, in the first place, and the application of system dynamics, in the second place.

This is precisely the objective looked for in this paper. The first section explores a little bit the most salient features of systems thinking or systems approach to support policy decisions; thereafter, the following discussion goes around an examination of the main characteristics of the system dynamics simulation methodology. Some related examples are briefly discussed in the third part of the research. Finally, some ideas are summed up as conclusions and certain references are given at the final part of the paper.

Key words: systems thinking, system dynamics, ecosystems services, evaluation of ecosystem services, policy making.

INTRODUCTION

For almost a century, the systems thinking, systems approach or systemics has been developing alternative methodologies so as to change the mechanistic viewpoint derived from physics and to adopt, as yet incompletely, a different and more realistic world vision, as proposed by the systems thinking. In fact, it is nowadays recognized by modern phylosophers, economists, and scientists in general that the complex problems of everyday circumstances require new solutions support-

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ed by new ontological, epistemological and methodological strategies.

Notwithstanding the complexity of contemporaneous ecological and social systems, the use and application of the systems approach has not reached the theoretical and empirical fundamentals of, for example, the effort undertaken by scholars and scientists bringing about new lights on the evaluation of ecosystem services. The relationship between both standpoints, i.e., between the systemic view and ecosystem services evaluation has becoming tighter, however, in the last decades, which is very welcome in terms of twenty-first century science development. Nevertheless, there is something more valuable worth of discussing from the ecosystem problems simulations, and that is the employment of systems dynamics,

Systems dynamics, initially developed by Jay W. Forrester to solve managerial problems, it was rapidly adapted to solving social complicated situations, like urban disarray and world growth. At the present time, system dynamics has been successfully applied so as to model complex real systems of any kind and, above all, simulate the time path of social, industrial, and world-wide pressing problems. It would be advisable to start simulating ecosystem services once evaluation models have been developed and applied in a wide range of regions, continents, and subcontinents, like those already available for the Latin American countries. As time goes on, it is expected ecosystem services researchers convincingly turn their heads towards the benefits offered by the system dynamics advantages.

In addition to this brief introduction, this essay pretends to explain some basic elements about certain principles governing how systems are expected to work out and, in this instance, how it is possible to take advantage of such principles. This is undertaken in the following section. The last part of the paper will try to delve a little bit into the dynamic meaning of system dynamics, its theoretical underpinnings and its useful simulation applications. A pair of conclusions are offered at the end of the paper. Some references end up the arguments found in the main discussion of the essay.

Systems thinking principles

In a recent paper, F. Capra, one of the most renowned names on systems thinking, offers “a conceptual framework for ecological economics based on systemic principles of life” (F. Capra, 2017). This is really the title of the paper. As can be seen, he centers his discussion around the interdisciplinary field of ecological economics, but nevertheless what is interesting goes directly to expound the systemic principles of life, i.e., those systemic principles that can help to approach and solve complex environmental and ecosystemic troubles. Many scholar investigators would agree with the following axiom: the more we know about how real systems work the easier will be to find more appropriate solutions to daily emergent complex problems. One example, although not so representative, are the so-called systemic archetypes, named so by P. Senge in his 1990 “classic” book, The Fifth Discipline.

After F. Capra discusses and explains the differences between the mechanistic approach, characteristic of the classical physics, and the systemic emphasis of a modern scientific systems view, Capra undertakes the effort to explaining the four systemic principles of life. It is true that Capra’s vision goes around the “systemic principles of life”, but we have to recognize the deep meaning of such four principles not only for ecological economics but for the rest of scientific interdisciplinary fields of contemporaneous science.

Capra asserts the economy does not dominate nature; it is the other way around for the economy is a subsystem of the natural system. The point here is the economy, say, the national economy, not economics as a science. Nevertheless, the study goal of the science of economics is the national economy with all its regional and urban subsystems. With this in mind, let's go on and try to understand the salient features of the four systemic principles of life.

The first principle approaches the economy from the idea of a nested system. Several decades ago, the institutional economist K. Boulding published a paper where he talks about the system thought as the skeleton of science; he develops a systems ranking and classifies the systemic approach into nine systems categories, from the simple and mechanic systems to the more complex and transcendental systems. The question is now open as to what is the relationship between the four principles of life and the nine Boulding's systems categories. Time has passed and recent systemic paradigms has emerged and developed. The personal standpoint of this author considers both approaches as complementary rather than adversary systemic categories.

The first principle takes into account a nested systemic standpoint in respect to the economy; Capra asserts the economy belongs to a nested system. According to him, "for economics, the systems view of life is revolutionary. It implies that nature is superior to the economy, not vice versa" (Capra, 2017). He considers the economic system "must be integrated into the organic network of reality". As an organic and living system, the economic system should be interconnected with other living systems: society, culture, politics, nature, and "ultimately Gaia, the living earth".

All systems analysts are convinced of the systemic nature the economy implies when considered as a nested system. It seems the relationships among the different subsystems make up the very nature of systems and that means the holistic view individuals should have in order to really change things happening in our world. This is, then, the essence of the first principle: the economy is a nested system and the meaning of this principles become the main support of the rest of systemic principles explained in the following sections.

It is not a big surprise to think about the structure of a system made up of relationships as a group of dynamic networks, and this is principle number two. For many systems researchers delving into the structure of a system helps to understand the system behavior. Such an understanding becomes the main focus in the sense of public policies, for once the system behavior is known, the decision making process can improve the efficiency of public policy consequences.

Most of system dynamics applied literature emphasizes, as step number one in order to fully recognize the salient features of the system under study, to develop a circular flow which presents the non linear causal relationships among the variables conforming the structure of the model, together with the feedback positive or negative loops brought about by those negative or positive polarities connecting the causal interconnectedness. According to Capra, "since a network is a particular pattern of connections and relationships, thinking in terms of patterns and relationships is the very essence of systems thinking."

Either from the system dynamics standpoint or the systems thinking approach there is no doubt of the methodological importance of knowing first the system structure. As was pointed before, to get familiar with the essentials of the system via its structure becomes indispensable to understanding its real behavior which derives "much of their character from the social and ecological networks" form living entities "interdependent both spatially and temporally".

Going a little bit further, Capra discusses the system's structure effect not only on the system behavior but he strongly pinpoints the interdependentness nature of whole systems and living organisms. To wit, ecosystem services are supposed to convey valuable information to public and private decision makers so as to embrace all the society members in a sense of a Pareto optimum. This is why Capra in talking about the economy as a living system shows a highly convincing attitude when suggests that "an economy based on local networks linked together globally provides the best basis for developing co-responsible human being".

As a consequence, we can say it is good to know and faithfully accept the full array of conclusions reached by the ecosystems services evaluation figures for the Latin American countries, but the simple questions are what's next? What are public and private decision makers are supposed to do so as to take advantage of those figures? Is it worthwhile to support economic and ecological policies based on very well done studies but lacking of a dynamic systems thinking methodological approach? After all, an "ecosystem", evaluated or not, brings about a highly complex systemic concept whose structure integrates both human and non-human nested subsystems, i.e., as Milsum (1967) states that, whether it is desirable to model and optimize systems, it is necessary to analyze those subsystems termed geosphere, biosphere, technosphere and sociosphere altogether or, as it is said today, both human systems and their place around the biodiversity and geodiversity from a sustainable vision of the world.

At the beginning of von Bertalanffy's general systems theory the closed system concept was a core feature of the historical development of a holistic standpoint. It was accepted and lots of investigators and researcher worked with it as an essential component of a "systemic" methodological tool. Notwithstanding the importance of von Bertalanfy's pioneering advance, critics of his scientific effort did not agree with the idea of a system being closed, and consequently proposed the concept of open system, a system with a given structure and behavior but also interconnected with its environment and, in a bilateral way of interrelationship, a social and natural environment flows influencing the dynamics of such an open system.

In Capra's words, "all living systems need to be open to continual flows of energy and matter, and all living systems produce wastes" and so, it is said that networks (second principle) and flows are relevant characteristics of the so called open system. This has to be kept in mind at the moment of evaluation ecosystem services, for all systems and subsystems being evaluated must reflect descriptive numbers and figures really picturing all the services they work out.

Any process has a dynamic nature and since the ecosystems services are those services offered by natural systems to socioeconomic systems, i.e., services coming from nature to improve human welfare, in a kind of circular flow, it is necessary following Capra's steps so as to consider the circular nature of social systems, from networks (open system) to flows (environment suprasystem) and vice versa, from flows to nature, from the suprasystem to the system.

According to Capa's paper, a living system should possess a nature whose "processes need to be circular in three dimensions, all of them related to the economy, nature, and culture, in a circular value chain as suggested before. Additionally, the dynamic circularity of open systems and living organisms "is the basis of the connection between the (socio) economic subsystem and nature. Sustainability depends on our ability to discover the connections between input and output of natural resources in the economic value chains. To develop a life-enhancing (socio) economic system it is necessary to cooperate with nature on both sides". Within a ecosystem services framework, it good to know the spatially distribution of different categories of ecosystemic services, however, the picture showed to decision makers should transmit a holistic image and, in addition, the possibility of simulating the ecosystem services throughout time.

Lastly, once he highlights the circular connection between the (socio) economic and the natural systems, Capra strongly asserts that "to understand how the economy works, contextual thinking, including nature and culture is a prerequisite". That means how strong must be the dynamic circular process connecting the whole range of nested systems as was discussed before.

Based on a frame of reference enforced by systems thinking, up to now three, out of four, systemic principles have been discussed so far, following Capra's suggestion and pushing such systemic principles into the problems brought about by the professional practice of ecosystem services evaluation . The last one, referred to a sense of ethics, has to do with the affirmative enunciation that "all living systems interact cognitively with their environment in ways that are determined by their own internal organization". This is a very important principle for the main interactions given by a socioeconomic system are the product of human interactions whose behavior comes up out of human decision made in order to solve problems and to satisfy reasonable objectives. This is the reason why Capra discusses systems as featured by "cognitive interactions".

Now the question arises with respect to the implications of public policy, concerned with the money-wise numerical evaluations of ecosystems services, and their impact on the economic and otherwise social benefits gained by people. Capra warns us about the absence of an ethical behavior, of not taking into consideration the spiritual consequences wrong policies undertaking by irresponsible decision makers. To reasonably highlight the ethical message, he states that "ethical behavior today should be based on the two fundamental values of human dignity and ecological sustainability. I we do not succeed in incorporating these ethical values into our personal lives, businesses, politics, and our economies, natural selection will see to it that humanity does not survive".

Yes, that is the way it is, human dignity and ecological sustainability are the two fundamental ethical, spiritual values all responsible decision makers must always keep in mind. Does ecosystem services evaluation serve both fundamental values? To know what the dollar amount of those services is can be used as benchmarkings to develop and practice good all-enhancing welfare public policies? It seems that is an alternative we can follow up so as to take advantage of the efforts undertaken by world researchers doing numerical evaluation of ecosystems services in favor of Latin American countries, as can be seen in some chapters of this book.

SYSTEM DYNAMICS: MODELING DYNAMIC SIMULATION PROCESSES

What is the advantage of using a systems thinking approach so as to derive more useful public policies from ecosystems services evaluation? Is it convenient to go from a static standpoint to a dynamic vision in considering pros and cons of ecosystem services evaluation? Is it worthwhile to look for a sustainable and practical support on the system dynamic tool? Four systemic principles were examined with a focus upon the relationship between systems thinking and ecosystem services evaluation in the preceding section.

A conclusion about the catch established a lack of methodological foundation of those ecosystem services and the systems approach. Now it is intended to spell out the salient features of system dynamics and its employment by ecosystem services evaluators so as to go a little further and try to simulate the possible behavior of the ecosystems evaluated in the future.

First of all, let us try to offer a "definition" of system dynamics. It was analyzed earlier in this paper the central role of the system structure as a pillar to wholly grasp the pattern of the system behavior. It is important to highlight both the structure and behavior of systems for these two elements ease off the study of lasting changes in the systems under consideration. Generally speaking, much of the research effort in scholastic institutions shows an emphasis on knowing the results, taking into account the events resulting from the systemic structural changes and, consequently, observing the pattern of behavior.

This is why linear regression analysis is so used, assuming an endogenous variable depends linearly on one or several exogenous variables. Our vision rests upon the events; this is pretty common among quantitatively biased academic researchers whose language presents interrelations in linear cause-and-effect chains instead of circular chains of cause-and-effect. It is not bad but can be substantially improved. An alternative has to do with system dynamics which is based on systems thinking.

In developing system dynamic models the first step goes to designing the so-called feedback and causal loop diagrams where it is possible to identify positive and negative feedback loops. In other words, and more formally, a feedback loop is a closed sequence of causes and effects, i.e., a closed path of action and information in relation to how the variables non-linearly considered cause the system's pattern of behavior. In Kirkwood's system dynamics introduction one can find a detail explanation of all aspects necessary to design a good causal diagram.

Moreover, after almost six decades J. W. Forrester created the system dynamics methodology by means of his works *Industrial Dynamics* and *Urban Dynamics*, it is not so useful trying a repetition of causal and Forrester diagrams. Kirkwood's book, among many available, deserves attention to get a good first start. In this vain, it is worthwhile to bring to mind Sterman's classical piece of science already whose subtitle offers a magnificent proposal to delve into the ecosystems services evaluation paradigm: *Systems Thinking and Modeling for a Complex World.* Ecosystems, by nature, are complex systems.

CONCLUSIONS

The intellectual exercise showed by the ecosystems services evaluation deserves a systems thinking foundation so as to visualize the effects of such assessments on people's welfare.

The ideas offered by the system dynamics tool might present an advantage in order to analyze changes brought about by ecosystem services intervened by government policies.

It is suggested, as discussed in the preceding paragraphs, a closer interrelationships among systemic researchers, system dynamic practitioners, and ecosystemic services evaluators.

The contents of this book related to ecosystems services evaluation for Latin American countries stands as a good example of the possibilities offered by the combination of systems thinking, system dynamics, and ecosystems services metrics.

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METHODS: ECOSYSTEM SERVICE VALUATION AND ECOLOGICAL FOOTPRINTS

PAUL C. SUTTON◆

INTRODUCTION

The idea of 'Natural Capital' and 'Ecosystem Services' is gaining increasing attention as a market failure of immense magnitude that warrants new institutional frameworks both to manage them and to insure the perpetuation of modern civilization. The neo-liberal economic world view that has historically dominated law, governance, and policy making is being increasingly recognized as grossly incapable of addressing questions of environmental management and sustainability. Some well-defined and acknowledged market failures are monopolies, common pool resources (e.g. tragedy of the commons), externalities (e.g. air pollution), and public goods (e.g. weather satellites, lighthouses etc.). Ecosystem services are a multi-faceted market failure in that they suffer from both positive but mostly negative externalities, they have complications related to property rights issues, are often common pool resources, and they are public goods in and of themselves.

Natural capital is the land air, water, and living organisms that generate myriad ecosystem functions which provide us with ecosystem goods and services that are the basis of all human economic activity. Ecosystem services are the various benefits that nature provides to humans. Classification of the variety of ecosystem services is an ongoing process but a consensus emerging is that in the aggregate there are provisioning services (food, fuel, timber), supporting services (nutrient cycling, water purification), regulating services (carbon sequestration, pest control), and cultural services (spiritual, recreational, educational). Historically we have discounted, undervalued, or simply ignored the incredibly large value of natural capital and the ecosystem services it provides. The consequences of this undervaluation are myriad, inexorable, and disturbing. These inter-related consequences include: loss of biodiversity (we are in the middle of the 6^{th} mass extinction in the history of planet earth and it is the only extinction attributed to a living species – *homo sapiens*), climate change (anthropogenic activity is increasing the concentration of greenhouse gases in the atmosphere causing numerous problems including impaired ecosystem function and global warming), depletion and corruption of freshwater supplies, loss of topsoil and soil degradation (e.g. soil salinization), deforestation, and loss of ecosystem services due to land cover change and land degradation. Ironically, economic valuation of ecosystem services is one way to get a sense of the magnitude and severity of the environmental challenges we face using the language and currency of the worldview that is a major cause of the problems we are experiencing.

Estimates of the value of ecosystem services are essentially an estimate of the annu-

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al value of the ecosystem functions provided by natural capital. Ecosystem services can be thought of as the 'annual interest' provided by natural capital. In 1997 an estimate of the global value of ecosystem services was made to be roughly $(US) 33 Trillion dollars per year. That estimate was roughly twice the size of global GDP at the time (which stood at roughly ~$18 Trillion). Some economists have critiqued this estimate as an '*underestimate of infinity*' which might be an interesting criticism if we truly valued nature at something akin to infinity. Unfortunately economists have historically valued ecosystem services at something closer to zero. The criticism does not hold water for other reasons also. It can easily be argued that water is 'infinitely valuable'; however, we don't pay anything near 'infinity' or even a very large fraction of our income for water. These estimates of the total value of the earth's ecosystem services are derived from literally thousands of peer-reviewed studies of economic valuations of ecosystem services based on pricing nature in ways we might price water (some approaches include avoided cost, hedonic pricing, contingent valuation, and replacement cost). A recent update of this work estimated that the earth provided roughly $145 Trillion dollars' worth of ecosystem services every year in 1997 which remains more than double the current global GDP (~$65 Trillion). Sadly, we have so damaged the earth's ecosystems (including a ~50% decline in the areal extent of functioning coral reefs) that we currently only receive $124 Trillion dollars of ecosystem services every year.

BACKGROUND – CASE STUDIES

The economic value of Green Infrastructure ($70 million/hectare/year !?)

Green infrastructure consists of natural areas within urban environments that provide extremely valuable ecosystem services to urban populations. Green infrastructure undoubtedly contributes substantially to human well-being in myriad ways including reducing urban heat islands, providing habitat for wildlife, reducing obesity, increasing non-motorized transport, increasing property values and tax revenues, and so on. One way to estimate the economic or dollar value of green infrastructure is to look at Central Park in New York City. Central Park consists of roughly 850 acres in central Manhattan. This is prime real estate that, if sold off for conversion to mixed use real estate, would be worth roughly $500 Billion dollars. That $500 Billion would likely yield a 5% annual return which amounts to $25 Billion dollars a year. Why don't the city fathers of New York City sell off central park and bank the money to produce $25 Billion dollars a year in annual revenue? Because it would be political suicide. What does that mean? Central Park's value as green infrastructure is worth more than $25 Billion dollars a year to the people of New York City. Nature's value is being preserved in Central Park but is that true elsewhere? Tony Hall has written extensively on the '*Death of the Australian Backyard*'. Private urban green spaces are getting paved over by lot splits and subdivisions for private gain while public costs in terms of storm water runoff, urban heat islands, and numerous other ecological consequences are externalized. Green infrastructure is an incredibly valuable asset that is only beginning to be recognized. How is Green Infrastructure so valuable? It is so valuable because it produces benefits that are a result of the *interaction* of natural, social, human, and built capital.

A modest proposal: Kill All The Bees!

Satire is a rough business as Johnathan Swift was probably well aware. This adaptation of Swift's 'modest proposal' is another way to explore the flawed logic of the neo-liberal economic world view. Causing the extinction of bees (which is a frightening possibility with dire consequences) can actually be seen to make economic sense if our objective is to increase economic activity. This has to do with the dollar value of the ecosystem services provided by bees. Many people have difficulty understanding how one might put a dollar value on an ecosystem service. Insect pollination is a standard example of an ecosystem service. Insects pollinate our crops for free. If honeybees were to go extinct we would need to find some other way to pollinate honeybee dependent crops – perhaps armies of people wandering from plant to plant with small pollen covered paintbrushes. Some basic questions can be very difficult to answer regarding the loss of pollination services. For example: *Can the value of the pollination services exceed the current value of the crops?* or *, How will the prices of the crops change as supplies dwindle and pollinators disappear?* The dynamics of these scenarios complicate estimating the value of these services and these estimates can consequently vary substantially. Nonetheless, one estimate is the labor costs to pay people to use pollen covered paintbrushes. Many estimates of the dollar value of the ecosystem service regarded as insect pollination exceed $200 billion annually. It is perhaps a tad facetious to suggest that current neo-liberal institutions (i.e. the economists) would endorse the modest proposal: "Kill all the bees". However, it should be noted that if bees were to go extinct and disappear it is very likely that many humans would be employed in the task of pollination. This would be a 'win-win-win' scenario from a strictly economic perspective: 1) it increases gross domestic product, 2) it creates jobs, and 3) it generates tax revenue. Whilst there may only be a few economists that would seriously argue for this policy it must be recognized that if bees truly did go extinct – *It would increase GDP, it would create jobs, and it would generate tax revenue.*

Swamps on the east coast of the United States worth $23 Billion a year?

Coastal wetlands (aka 'swamps') provide storm protection services in that they mitigate the damage to human made capital caused by hurricanes, typhoons and their storm surges. The dollar value of these services varies spatially as a function of many things including: frequency of storms, location of coastal wetlands relative to built infrastructure, and spatial variation in the intensity of economic activity. A statistical analysis of these kinds of data in combination with economic losses that resulted from storms and were reported to insurance companies determined that a loss of 1 hectare of wetland resulted in increased damage from storms per year of $33,000. This is an 'avoided cost' approach to estimating a single ecosystem service value (i.e. storm protection). Coastal wetlands actually provide many other valuable ecosystem services that are not included in the $33,000/ha/year number. In the aggregate the wetlands of the eastern seaboard of the United States provided an estimated $23 billion dollars a year worth of storm protection. This is more than three times the annual cost of the transportation securicty agency (TSA) of the United States. The TSA is the people and hardware that provide airport security and this cost in 2008 was roughly ~$7 billion / year. These numbers are not trivial and should not be dismissed as mere insignificant 'externalities'.

National Assessments of Ecosystem Service Value

There have literally been thousands of peer reviewed papers that provide estimates of a variety of ecosystem services. A consortium of academics and policy makers have established an initiative called TEEB (The economics of ecosystems and biodiversity) with the mission of making nature's values visible. One of the many ways nature can be valued is an economic valuation of the ecosystem services provided annually by functioning ecosystems using a variety of methods including avoided costs, hedonic pricing, shadow pricing, replacement cost, market value, and contingent valuation. A TEEB database of thousands of ecosystem service value studies has been developed (http://www.teebweb.org/). We used this database to develop national assessments of ecosystem service values. This TEEB data is used in conjunction with a global land cover database in which ecosystem service values associated with a variety of landcovers (Tropical forest, deciduous forest, grassland, cropland, shrubland, desert, urban, etc.) (See figure 1). This approach is often called 'benefits transfer'. This approach is much critiqued for a variety of reasons but is nonetheless recognized as a practical and cost-effective approach for making reasonable assessments of complex phenomena. The driving force for engaging in ecosystem service valuation is a belief that nature is not sufficiently valued by the prevailing economic system. And, when it is valued, its value is so large that it calls into question the viability and theoretical foundations of economics and the prevailing economic system.

ECOLOGICAL FOOTPRINT ANALYSIS

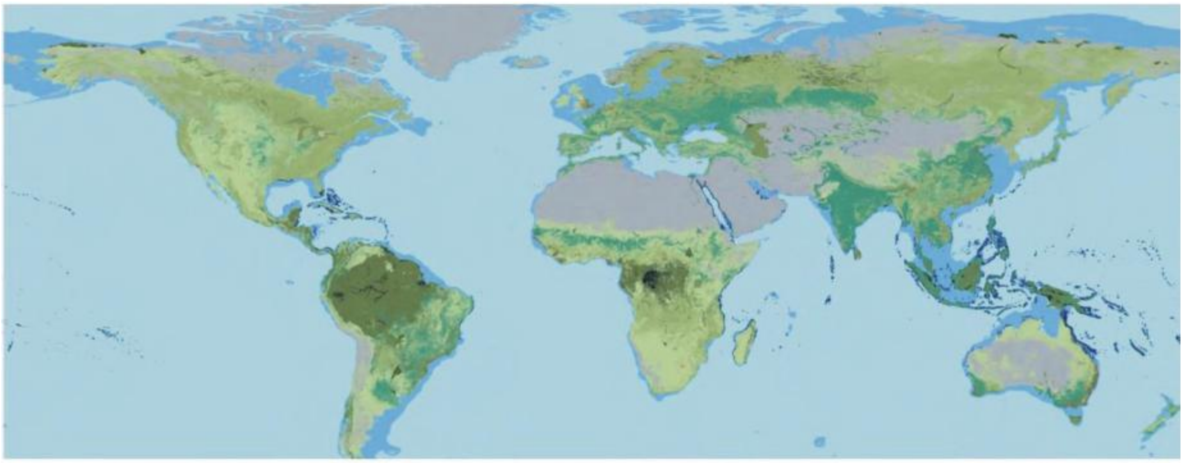
In addition to an economic valuation of ecosystem services we also produced a longitudinal assessment of national ecological footprints relative to national bio-capacity. This is particularly relevant to Latin American and African countries because these countries represent a large fraction of the world's nations that are not 'ecological debtors' - in other words they are living within the carrying capacity of their national endowment of ecosystem services. All of these figures were derived from the web service provided by the global footprint network (http://data.footprintnetwork.org/). The fact that so many Latin American countries are 'ecological creditor' nations is one of the reasons that many Latin American countries are victims of 'land grabbing' by nations that do not have an ecological surplus.

HOW DOES IT AFFECT YOU?

Global mismanagement of our natural capital has cost over $20 Trillion dollars a year in lost ecosystem services. This undoubtedly has multiplying effects with the market economy and is undoubtedly an underestimate. The overarching goal of improving the human condition is a laudable and appropriate purpose for government and society in general. Historically the prevailing guide for accomplishing this has been to maximize economic growth or GDP. There is increasing recognition that this is a flawed objective function. Establishing, implementing, and enforcing policy that alternatively aims to increase aggregate human well-being will prove to be far superior to policy aimed at maximizing economic growth or GDP exclusively. Human well-being results from an interaction of human, social, natural, and built capital (Figure 2). As some snippet of scripture suggests: '*man does not live by bread alone'* it can be analogously stated that '*human well-being does not result from money alone*'. Our well-being results from the interaction of natural, social, human, and built capital and it is really important to realize that they are not infinitely substitutable.

For example, the well-being that results from a tourist enjoying snorkelling along the great barrier reef involves all four capitals: 1) The social capital embedded in the interactions with the guides and travel agents, 2) The human capital embedded in the tourist

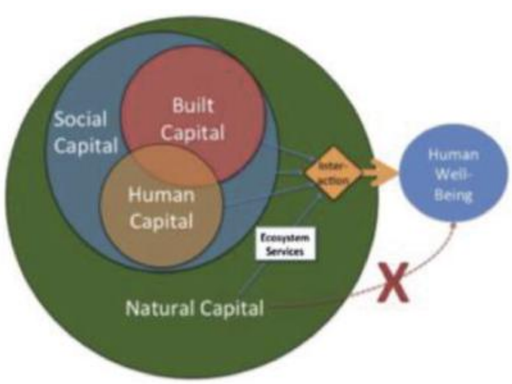
FIGURE 1. GLOBAL LAND COVER AND RELATED TABLE OF ECOSYSTEM SERVICE VALUES IN $ PER HECTARE PER YEAR



LandCover	Flow Value per Hectare per year	Legend	Area (millions of hectares)
Desert	$0		2159
Tundra	$0		433
Ice/Rock	$0		1640
Open Ocean	$491		33200
Marine Shelf	$2,222		2660
Grass/Rangelands	$2,871		4418
Temperate/Boreal Forest	$3,013		3003
Lakes/Rivers	$4,267		200
Tropical Forest	$5,264		1258
Cropland	$5,567		1672
Urban	$6,661		352
Swamps/Floodplains	$25,682		60
Tidal Marsh/Mangroves	$193,845		128
Coral Reefs	$352,249		28

Adapted from changes to the Global Value of Ecosystem Service (2014). Global Environmental Change vol. 26 constanza et al.

FIGURE 2. INTERACTION BETWEEN BUILT, SOCIAL, HUMAN, AND NATURAL CAPITAL REQUIRED TO PRODUCE HUMAN WELL-BEING



Built and human capital (the economy) are embedded in society which is embedded in the rest of nature. Ecosystem services are the relative contribution of natural capital to human well-being, they do not flow directly. It is therefore essential to adopt a broad, transdisciplinary perpective in order to address ecosystem services. (Adapted from Costanza et al. 2014) herself, 3) The built capital of snorkel, fins, boats, etc., and 4) The natural capital of the reef itself. The economic world view posits that if we 'run out' of one good we can substitute it with another (e.g. tea for coffee, tar sands for crude oil, etc.). The well-being that results from snorkelling along a coral reef can ONLY be achieved if there exist both snorkels AND coral reefs. Coral reefs cannot be substituted with more snorkels to achieve the same well-being. This ridiculously obvious flaw is embedded so deeply in economic thought that few of us recognize it for what it is. In myriad cases there are no efficient or effective substitutes for natural capital. This is a fundamental reason why environmental protection is such an important function of government. We treat the 'value' of nature as if it were free when it is actually more valuable than the entire market economy.

Clearly we have a serious problem with GDP as an indicator of progress. It is imperative that we understand how the dominant economic world view has corrupted our ability to see the world from an ecological perspective. *Failure to appreciate and incorporate a scientifically sound ecological perspective into our policy making will ultimately cause more human suffering in the long run.* For this reason alone an ecological perspective is morally and practically superior to a monetary economic perspective. The ecological perspective is also superior if we adopt the idea that maximizing human well-being is the greatest broad goal of society.

CONCLUSION

Ecosystem services are a market failure that is too big to ignore. Consequently we need to abandon magical thinking about invisible hands and free markets and develop appropriate world views that are broader than the narrow economic world view that we are currently trapped in. The question really is this: *Are ecosystem services so valuable (relative to the actual monetized economy) that, like the big banks, they should be considered "too big to fail"?* If our collective societal answer is 'yes' we need new institutions that adopt these world views to chart a path to a sustainable and desirable future. Producing an atlas that estimates 'the value of nature' for the countries of Latin America is our attempt to shed light on the undervalued natural capital in Latin America.

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ECOSYSTEM SERVICES MAPS
MEXICO, CENTRAL AMERICA, AND THE CARIBBEAN

This appendix contains thirteen ecosystem services value maps together with certain characteristics that explain social and natural features. Each one of the maps is divided into three parts (except for belize): the value of the ecosystem services in dollars with some more information on biomes, a graph on ecological footprint vs biocapacity, and a graph on ecological footprint by land type. The following table offers a synthesis of the map data.

SYNTHESIS OF INFORMATION ABOUT THIRTEEN MEXICO, CENTRAL AMERICA, AND THE CARIBBEAN MAPS

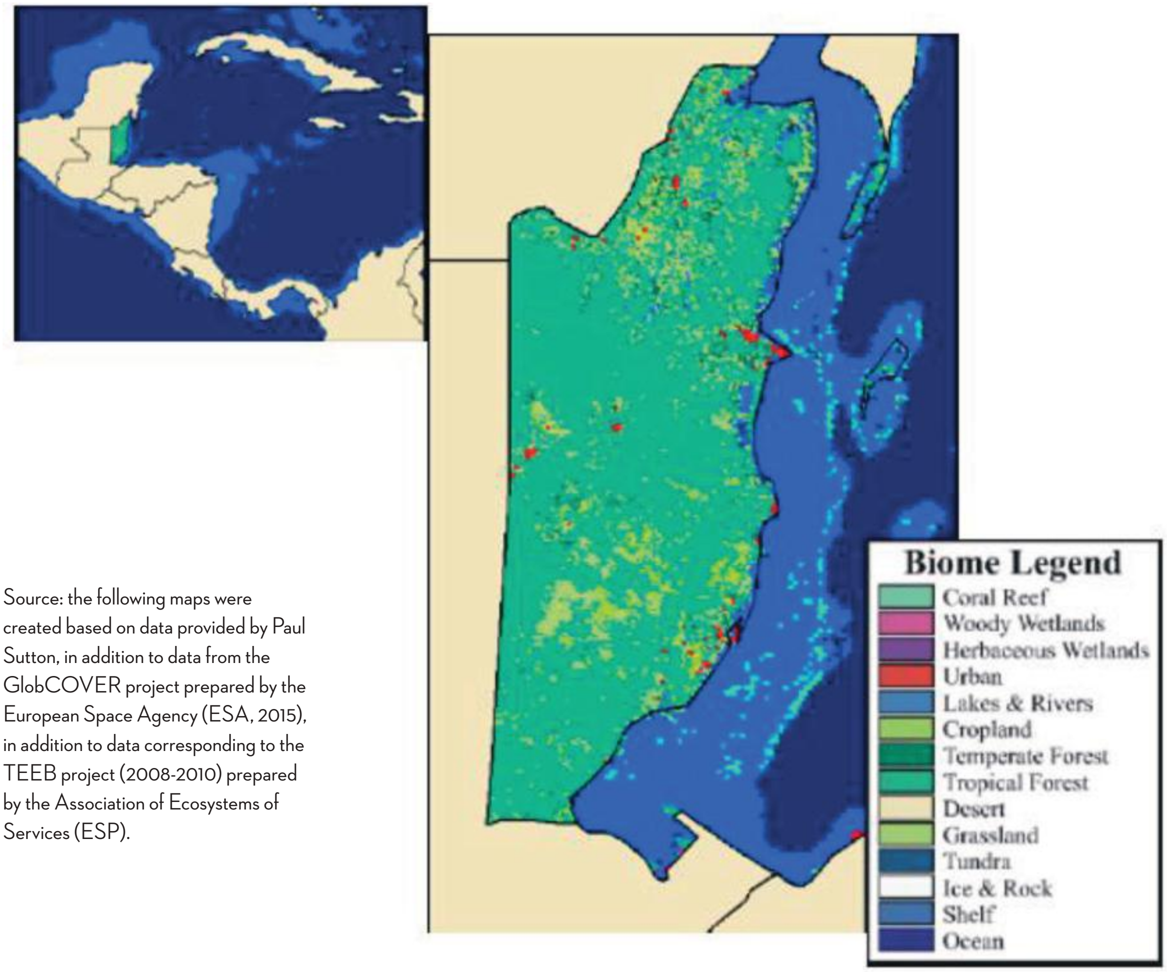
No.	COUNTRY	VALUE				
($ BILLION/YEAR)	BIOMES	AREA (KM2)	EF-B* (1961-2013)	EF-LT**		
1.	BELIZE	11.5	LEGEND & ITEMS	21,410	NO	NO
2.	COSTA RICA	42.3	LEGEND & ITEMS	50,921	YES	YES
3.	CUBA	68.1	LEGEND & ITEMS	106.561	YES	YES
4.	EL SALVADOR	14.9	LEGEND & ITEMS	20,600	YES	YES
5.	GUATEMALA	59.1	LEGEND & ITEMS	110,445	YES	YES
6.	HAITI	15.7	LEGEND & ITEMS	26,827	YES	YES
7.	HONDURAS	66.7	LEGEND & ITEMS	11,633	YES	YES
8.	JAMAICA	6	LEGEND & ITEMS	10,867	YES	YES
9.	MEXICO	846.4	LEGEND & ITEMS	1'953,505	YES	YES
10.	NICARAGUA	87	LEGEND & ITEMS	127,843	YES	YES
11.	PANAMA	51	LEGEND & ITEMS	73,152	YES	YES
12.	PUERTO RICO	5.5	LEGEND & ITEMS	8,903	YES	YES
13.	DOMINICAN REPUBLIC	26.2	LEGEND & ITEMS	47,648	YES	YES

* Ecological Footprint *vs* Biocapacity 1961-2013.
** Ecological Footprint by Land Type.

MAPS

BELIZE

THE VALUE OF ECOSYSTEM SERVICES FOR BELIZE. $11.5 BILLION/YEAR



Source: the following maps were created based on data provided by Paul Sutton, in addition to data from the GlobCOVER project prepared by the European Space Agency (ESA, 2015), in addition to data corresponding to the TEEB project (2008-2010) prepared by the Association of Ecosystems of Services (ESP).

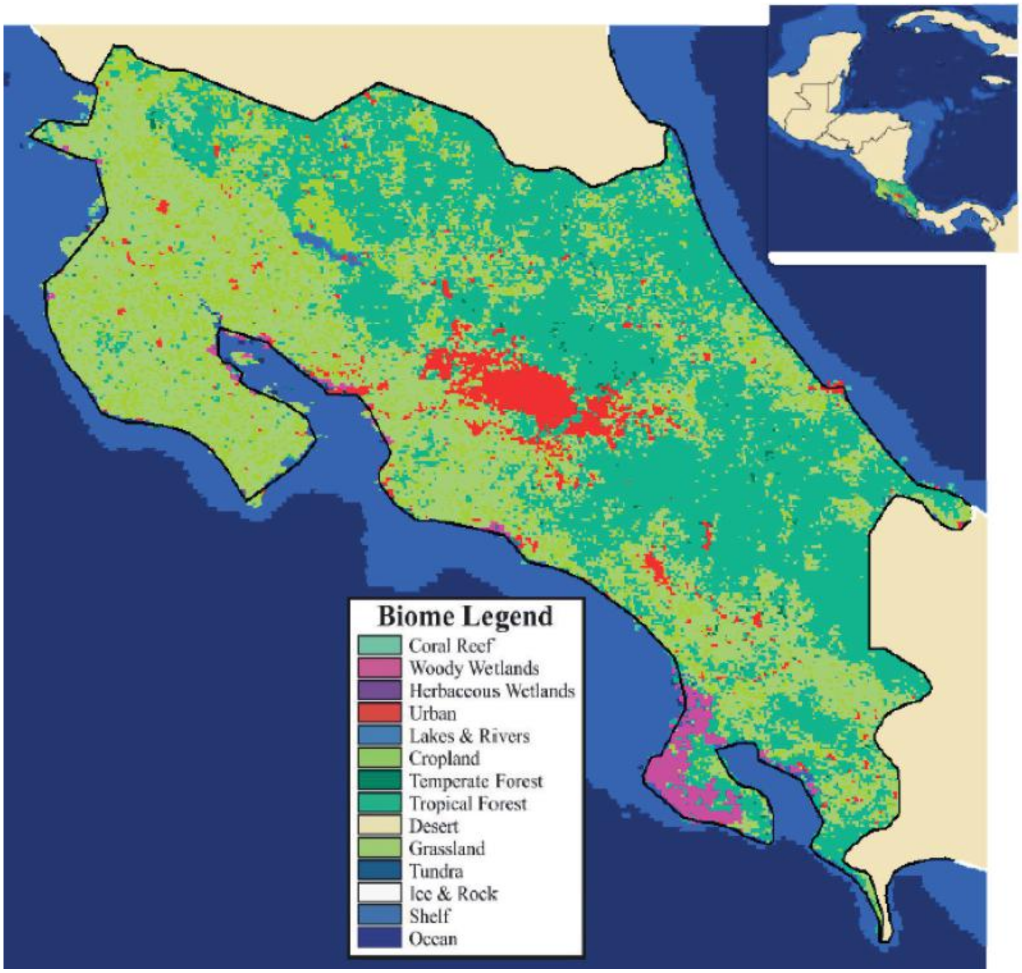
Biome	ES Value $/ha-yr	Area Km2	% Total Area	ES Value	% Total Value
Coral Reefs	$ 352,249.00	8	0.0%	281,799,200.00	2.5%
Woody Wetlands	$ 193,843.00	1	0.0%	19,384,300.00	0.2%
Herbaceous Wetlands	$ 25,681.00	-	0.0%	-	0.0%
Urban	$ 6,661.00	211	1.0%	140,547,100.00	1.2%
Lakes/Rivers	$ 12,512.00	117	0.5%	146,390,400.00	1.3%
Cropland	$ 5,567.00	634	3.0%	352,947,800.00	3.1%
Temperate Forest	$ 3,137.00	745	3.5%	233,706,500.00	2.0%
Tropical Forest	$ 5,382.00	17,343	81.0%	9,334,002,600.00	81.2%
Desert	*No Value*	-	0.0%	-	0.0%
Grasslands	$ 4,166.00	2,351	11.0%	979,426,600.00	8.5%
Tundra	*No Value*	-	0.0%	-	0.0%
Ice/Rock	*No Value*	-	0.0%	-	0.0%

Totals	Area Km2	21,410	ESV $/year	$11,488,204,500

Source: the following tables were created based on data provided by Paul Sutton, in addition to data from the GlobCOVER project prepared by the European Space Agency (ESA, 2015), in addition to data corresponding to the TEEB project (2008-2010) prepared by the Association of Ecosystems of Services (ESP).

COSTA RICA

THE VALUE OF ECOSYSTEM SERVICES FOR COSTA RICA: $42.3 BILLION/YEA

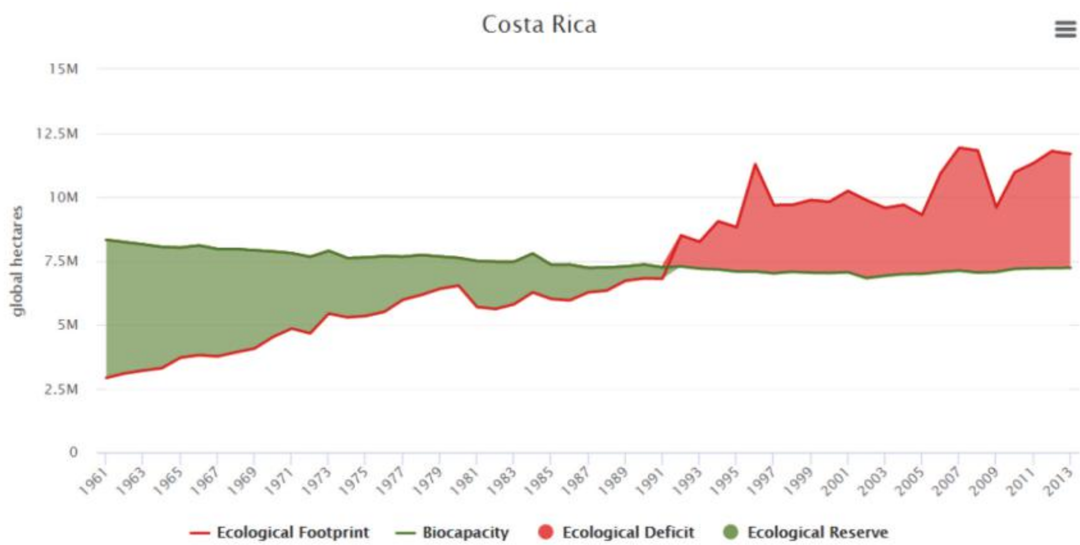


Biome	ES Value $/ha-yr	Area Km2	% Total Area	ES Value	% Total Value
Coral Reefs	$ 352,249.00	5	0.0%	176,124,500.00	0.4%
Woody Wetlands	$ 193,843.00	875	1.7%	16,961,262,500.00	40.1%
Herbaceous Wetlands	$ 25,681.00	-	0.0%	-	0.0%
Urban	$ 6,661.00	2,219	4.4%	1,478,075,900.00	3.5%
Lakes/Rivers	$ 12,512.00	156	0.3%	195,187,200.00	0.5%
Cropland	$ 5,567.00	7,257	14.3%	4,039,971,900.00	9.5%
Temperate Forest	$ 3,137.00	276	0.5%	86,581,200.00	0.2%
Tropical Forest	$ 5,382.00	22,074	43.3%	11,880,226,800.00	28.1%
Desert	*No Value*	-	0.0%	-	0.0%
Grasslands	$ 4,166.00	18,059	35.5%	7,523,379,400.00	17.8%
Tundra	*No Value*	-	0.0%	-	0.0%
Ice/Rock	*No Value*	-	0.0%	-	0.0%

Totals **Area Km2** **50,921** **ESV $/year** **$42,340,809,400**

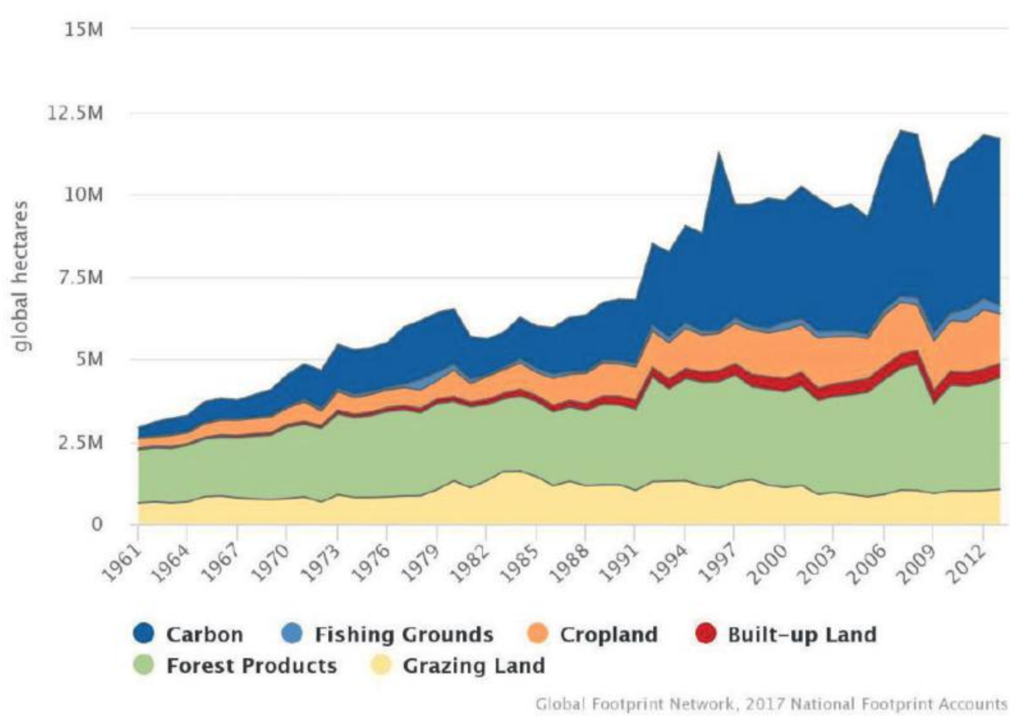
COSTA RICA

ECOLOGICAL FOOTPRINT VS. BIOCAPACITY 1961 - 2013



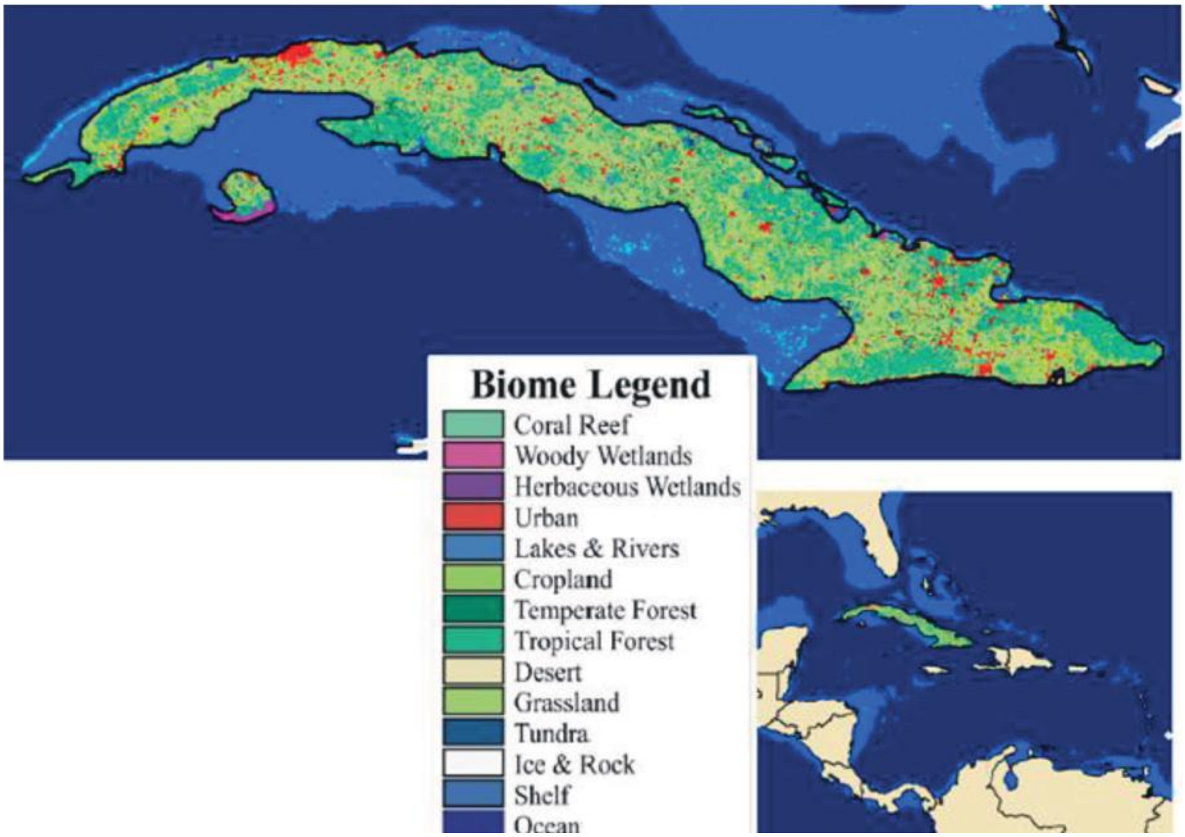
Source: the following tables were created based on data provided by Paul Sutton, in addition to data from the GlobCOVER project prepared by the European Space Agency (ESA, 2015), in addition to data corresponding to the TEEB project (2008-2010) prepared by the Association of Ecosystems of Services (ESP), plotted in the ecological footprint calculator (Global Footprint Network).

COSTA RICA ECOLOGICAL FOOTPRINT BY LAND TYPE



CUBA

THE VALUE OF ECOSYSTEM SERVICES FOR CUBA: $68.1 BILLION/YEAR

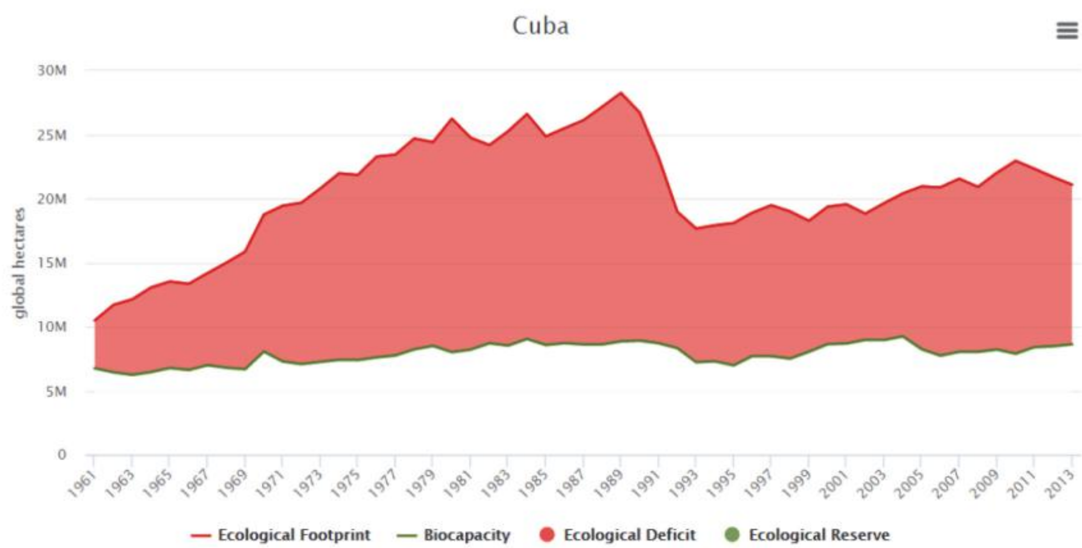


Biome	ES Value $/ha-yr	Area Km2	% Total Area	ES Value	% Total Value
Coral Reefs	$ 352,249.00	127	0.1%	4,473,562,300.00	6.6%
Woody Wetlands	$ 193,843.00	666	0.6%	12,909,943,800.00	18.9%
Herbaceous Wetlands	$ 25,681.00	-	0.0%	-	0.0%
Urban	$ 6,661.00	5,540	5.2%	3,690,194,000.00	5.4%
Lakes/Rivers	$ 12,512.00	1,115	1.0%	1,395,088,000.00	2.0%
Cropland	$ 5,567.00	7,633	7.2%	4,249,291,100.00	6.2%
Temperate Forest	$ 3,137.00	4,880	4.6%	1,530,856,000.00	2.2%
Tropical Forest	$ 5,382.00	31,387	29.5%	16,892,483,400.00	24.8%
Desert	*No Value*	-	0.0%	-	0.0%
Grasslands	$ 4,166.00	55,213	51.8%	23,001,735,800.00	33.8%
Tundra	*No Value*	-	0.0%	-	0.0%
Ice/Rock	*No Value*	-	0.0%	-	0.0%

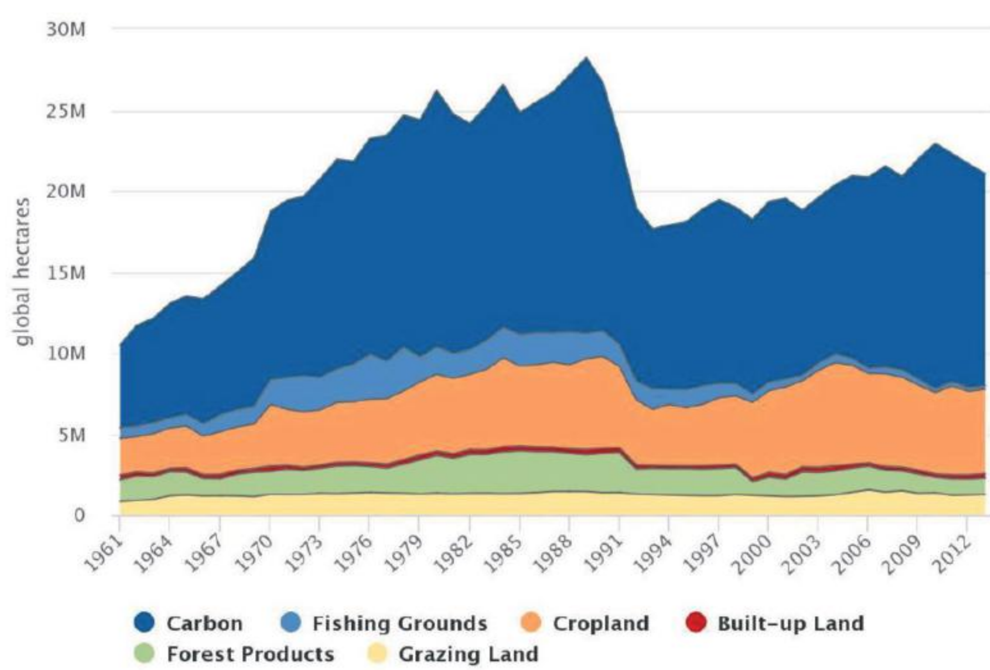
Totals Area Km2 106,561 ESV $/year $68,143,154,400

CUBA

ECOLOGICAL FOOTPRINT VS. BIOCAPACITY 1961 - 2013



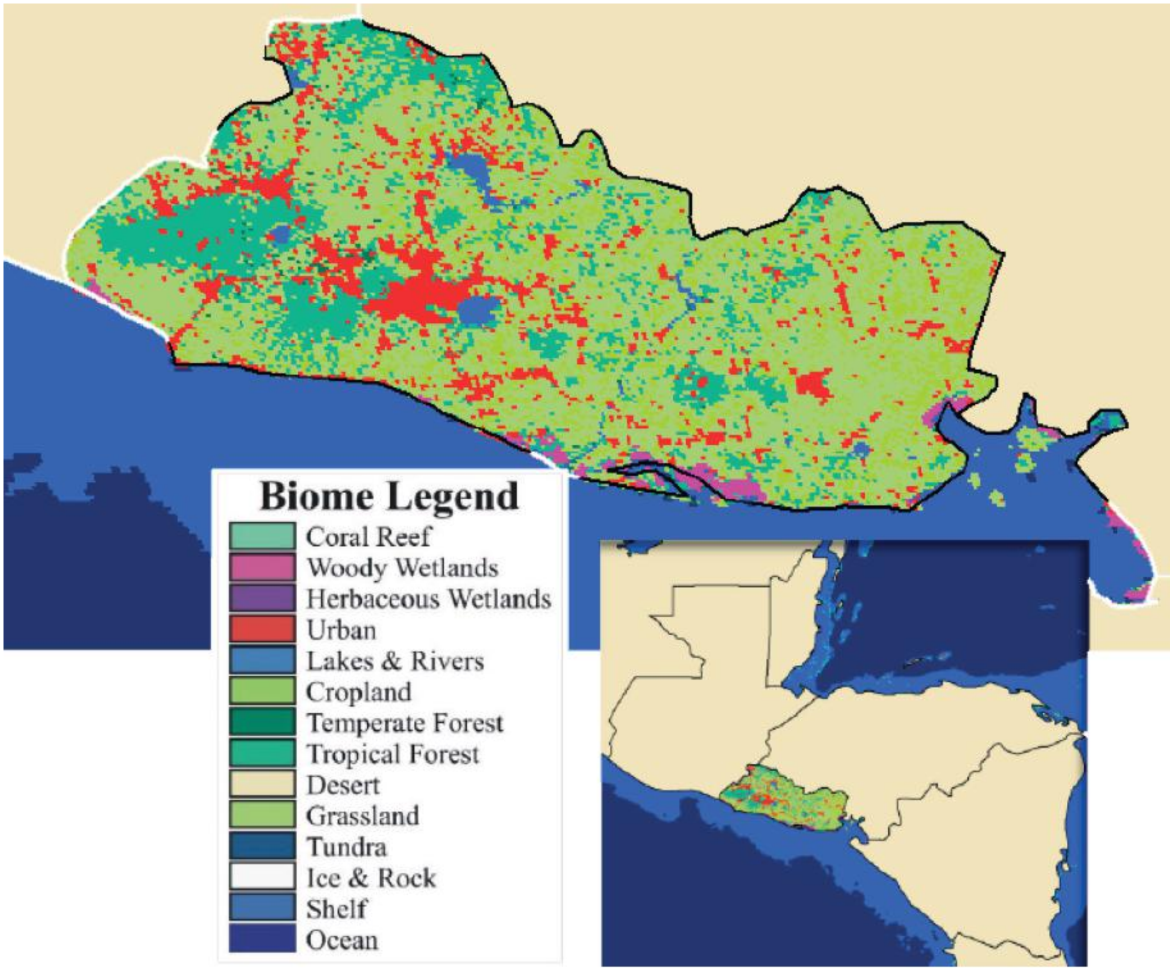
CUBA ECOLOGICAL FOOTPRINT BY LAND TYPE



Global Footprint Network, 2017 National Footprint Accounts

EL SALVADOR

THE VALUE OF ECOSYSTEM SERVICES FOR EL SALVADOR: $14.9 BILLION/YEAR

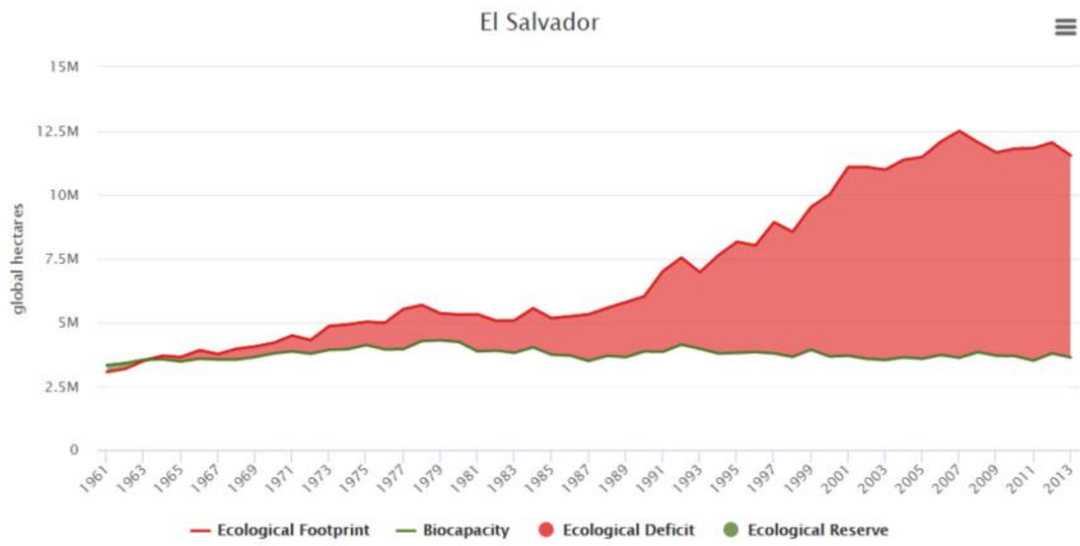


Biome	ES Value $/ha-yr	Area Km2	% Total Area	ES Value	% Total Value
Coral Reefs	$ 352,249.00	-	0.0%	-	0.0%
Woody Wetlands	$ 193,843.00	242	1.2%	4,691,000,600.00	31.4%
Herbaceous Wetlands	$ 25,681.00	-	0.0%	-	0.0%
Urban	$ 6,661.00	2,507	12.2%	1,669,912,700.00	11.2%
Lakes/Rivers	$ 12,512.00	288	1.4%	360,345,600.00	2.4%
Cropland	$ 5,567.00	3,330	16.2%	1,853,811,000.00	12.4%
Temperate Forest	$ 3,137.00	144	0.7%	45,172,800.00	0.3%
Tropical Forest	$ 5,382.00	3,672	17.8%	1,976,270,400.00	13.2%
Desert	*No Value*	-	0.0%	-	0.0%
Grasslands	$ 4,166.00	10,417	50.6%	4,339,722,200.00	29.1%
Tundra	*No Value*	-	0.0%	-	0.0%
Ice/Rock	*No Value*	-	0.0%	-	0.0%

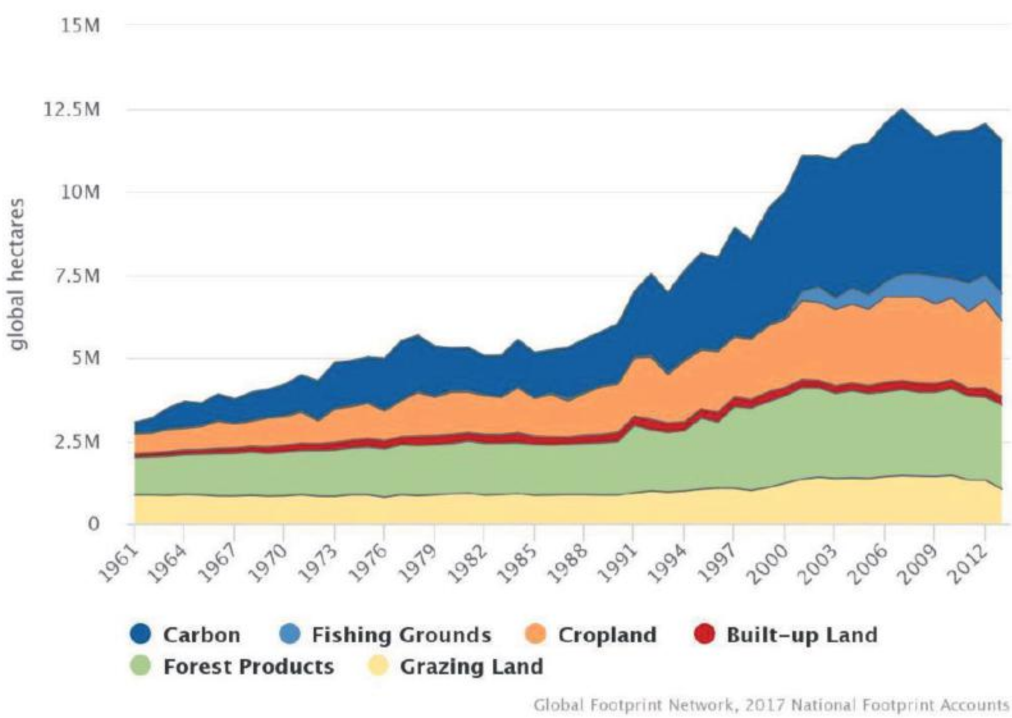
Totals	Area Km2	20,600	ESV $/year	$14,936,235,300

EL SAVALDOR

ECOLOGICAL FOOTPRINT VS. BIOCAPACITY 1961 - 2013

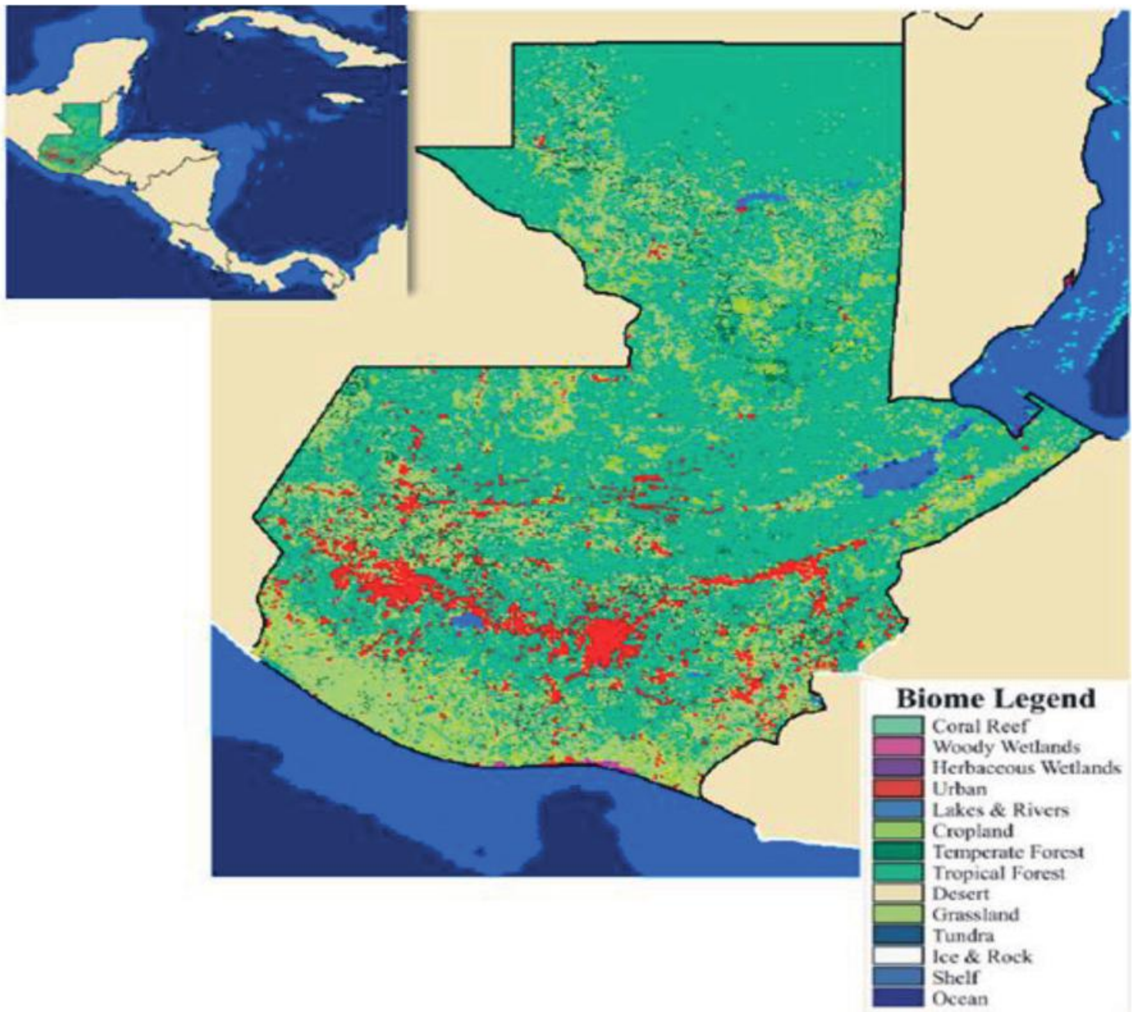


EL SALVADOR ECOLOGICAL FOOTPRINT BY LAND TYPE



GUATEMALA

THE VALUE OF ECOSYSTEM SERVICES FOR GUATEMALA: $59.1 BILLION/YEAR

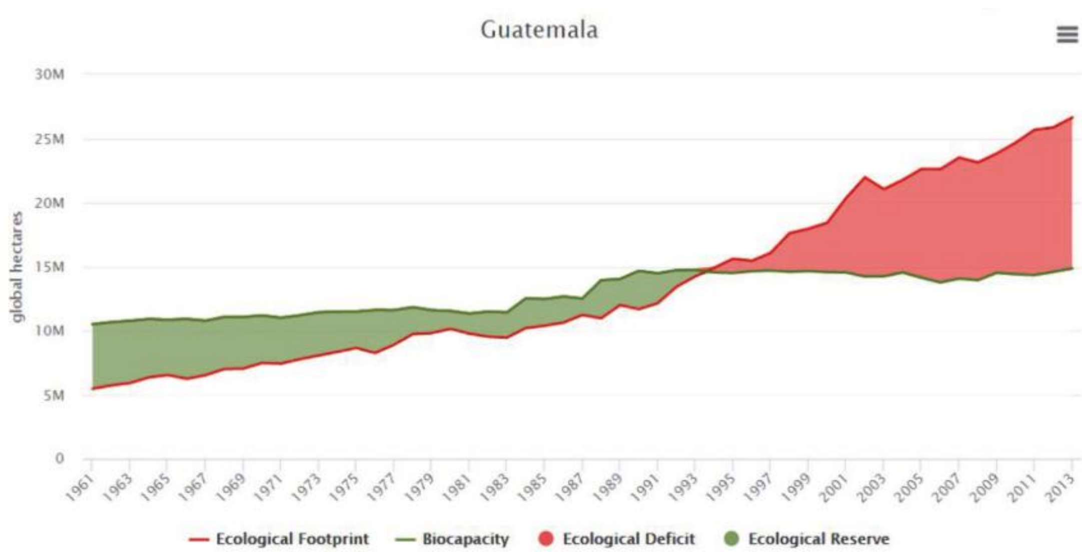


Biome	ES Value $/ha-yr	Area Km2	% Total Area	ES Value	% Total Value
Coral Reefs	$ 352,249.00	-	0.0%	-	0.0%
Woody Wetlands	$ 193,843.00	-	0.0%	-	0.0%
Herbaceous Wetlands	$ 25,681.00	1,013	0.9%	2,601,485,300.00	4.4%
Urban	$ 6,661.00	6,605	6.0%	4,399,590,500.00	7.4%
Lakes/Rivers	$ 12,512.00	1,143	1.0%	1,430,121,600.00	2.4%
Cropland	$ 5,567.00	4,584	4.2%	2,551,912,800.00	4.3%
Temperate Forest	$ 3,137.00	4,971	4.5%	1,559,402,700.00	2.6%
Tropical Forest	$ 5,382.00	67,375	61.0%	36,261,225,000.00	61.3%
Desert	*No Value*	-	0.0%	-	0.0%
Grasslands	$ 4,166.00	24,754	22.4%	10,312,516,400.00	17.4%
Tundra	*No Value*	-	0.0%	-	0.0%
Ice/Rock	*No Value*	-	0.0%	-	0.0%

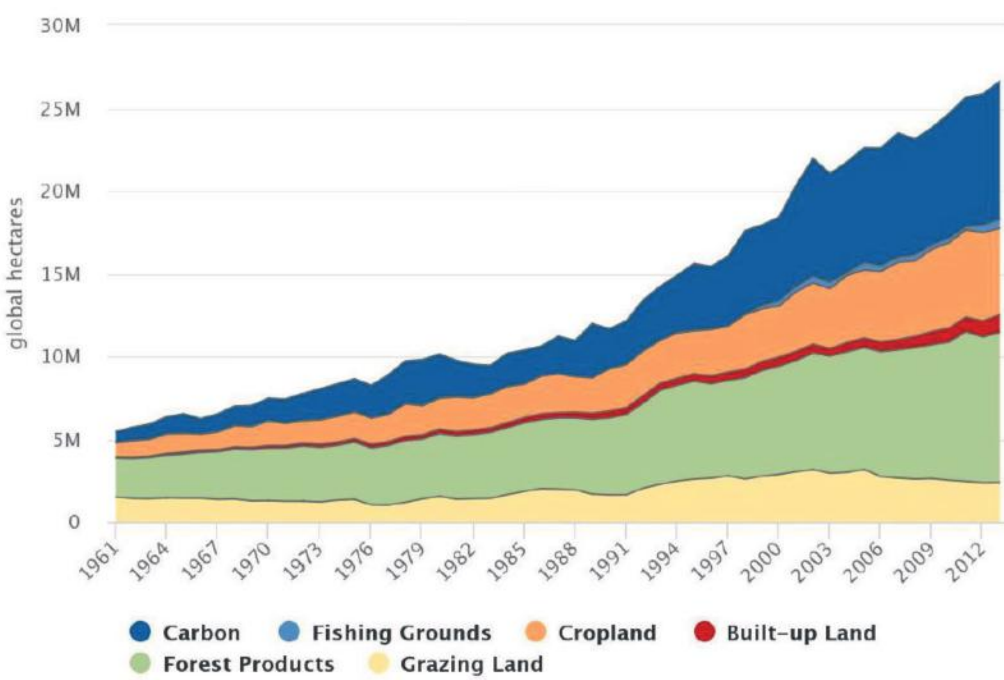
Totals **Area Km2 110,445** **ESV $/year** **$59,116,254,300**

GUATEMALA

ECOLOGICAL FOOTPRINT VS. BIOCAPACITY 1961 - 2013



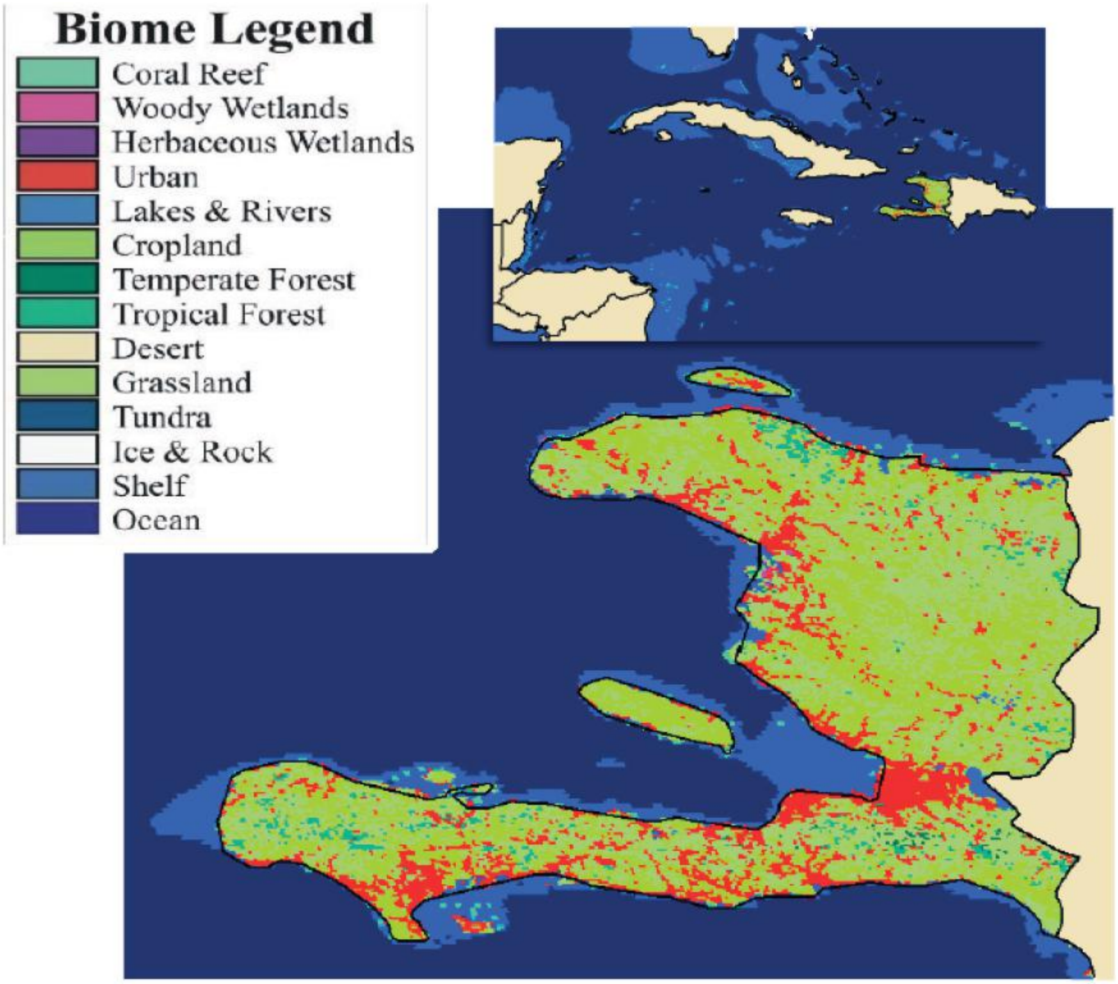
GUATEMALA ECOLOGICAL FOOTPRINT BY LAND TYPE



Global Footprint Network, 2017 National Footprint Accounts

HAITI

THE VALUE OF ECOSYSTEM SERVICES FOR HAITI: $15.7 BILLION/YEAR

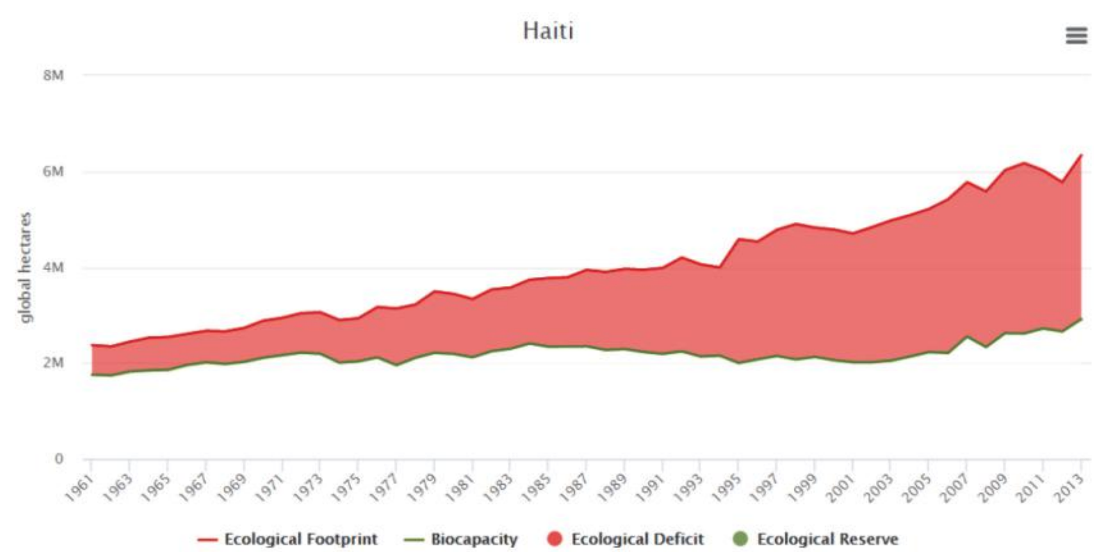


Biome	ES Value $/ha-yr	Area Km2	% Total Area	ES Value	% Total Value
Coral Reefs	$ 352,249.00	40	0.1%	1,408,996,000.00	9.0%
Woody Wetlands	$ 193,843.00	25	0.1%	484,607,500.00	3.1%
Herbaceous Wetlands	$ 25,681.00	-	0.0%	-	0.0%
Urban	$ 6,661.00	4,326	16.1%	2,881,548,600.00	18.3%
Lakes/Rivers	$ 12,512.00	143	0.5%	178,921,600.00	1.1%
Cropland	$ 5,567.00	10,088	37.6%	5,615,989,600.00	35.7%
Temperate Forest	$ 3,137.00	135	0.5%	42,349,500.00	0.3%
Tropical Forest	$ 5,382.00	781	2.9%	420,334,200.00	2.7%
Desert	*No Value*	-	0.0%	-	0.0%
Grasslands	$ 4,166.00	11,289	42.1%	4,702,997,400.00	29.9%
Tundra	*No Value*	-	0.0%	-	0.0%
Ice/Rock	*No Value*	-	0.0%	-	0.0%

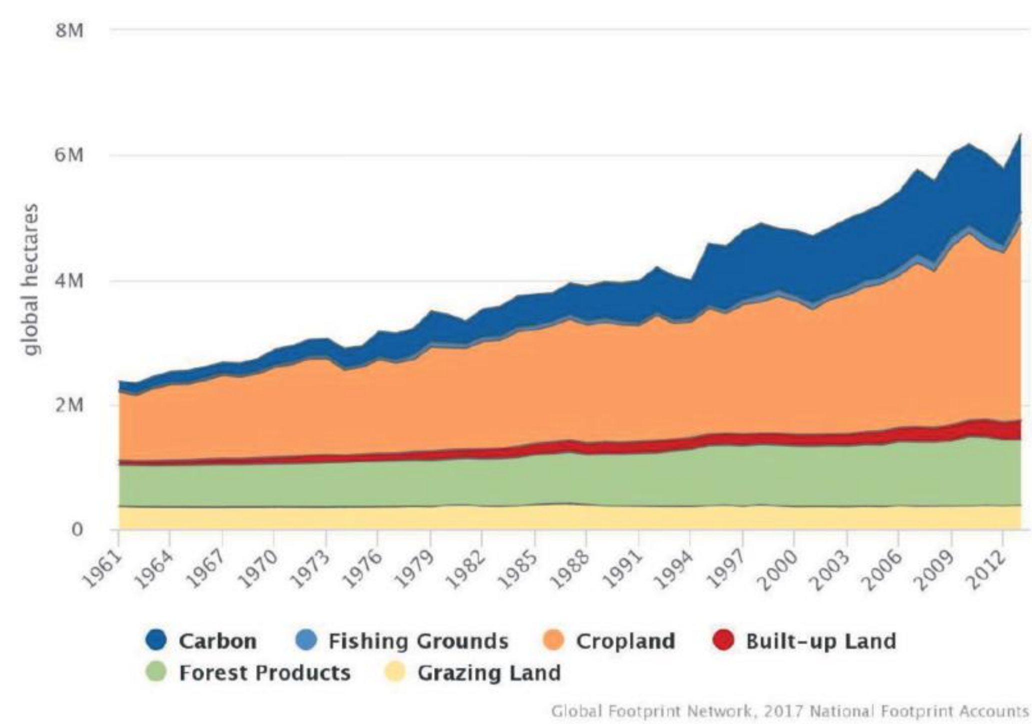
Totals **Area Km2** **26,827** **ESV $/year** **$15,735,744,400**

HAITI

ECOLOGICAL FOOTPRINT VS. BIOCAPACITY 1961 - 2013

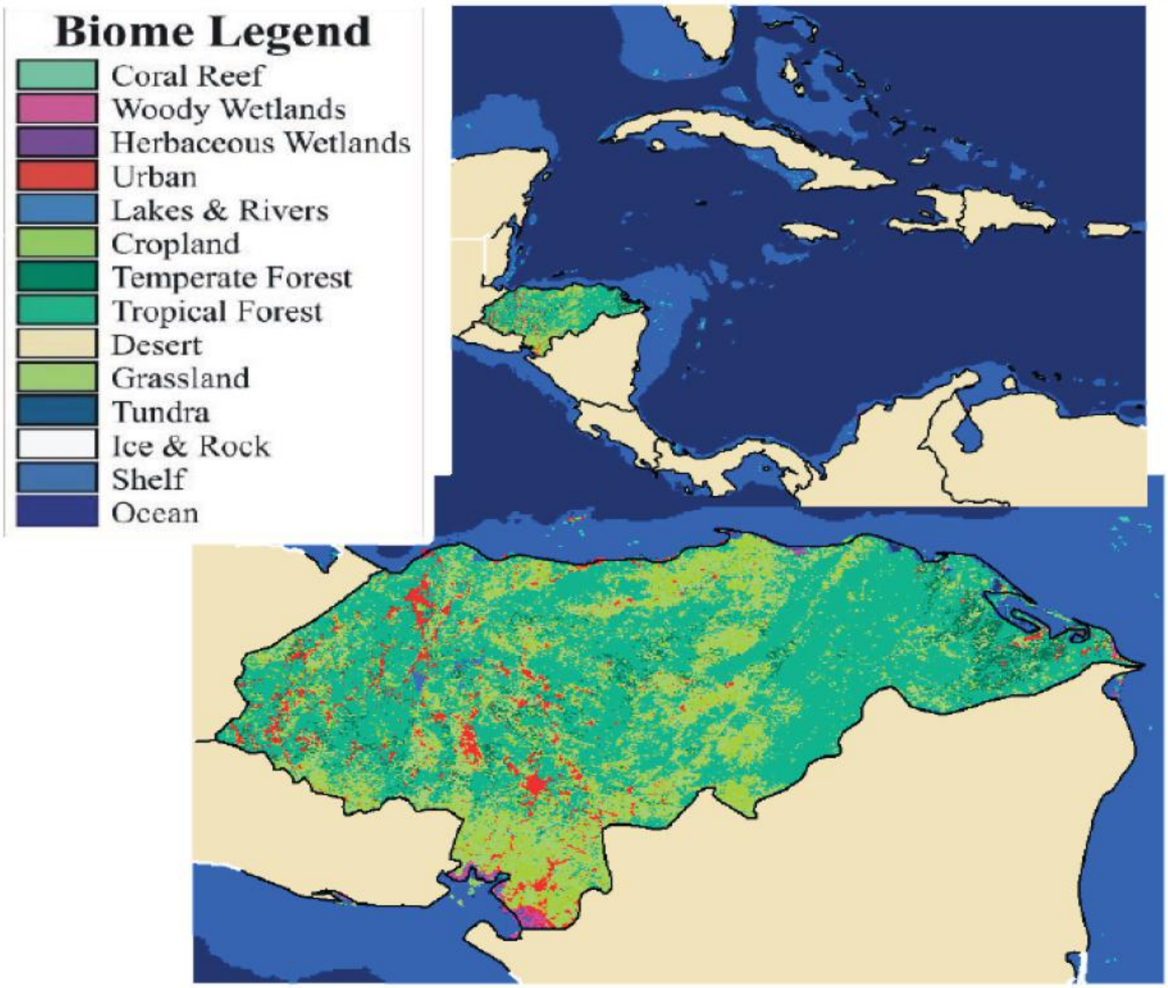


HAITI ECOLOGICAL FOOTPRINT BY LAND TYPE



HONDURAS

THE VALUE OF ECOSYSTEM SERVICES FOR HONDURAS: $66.7 BILLION/YEAR

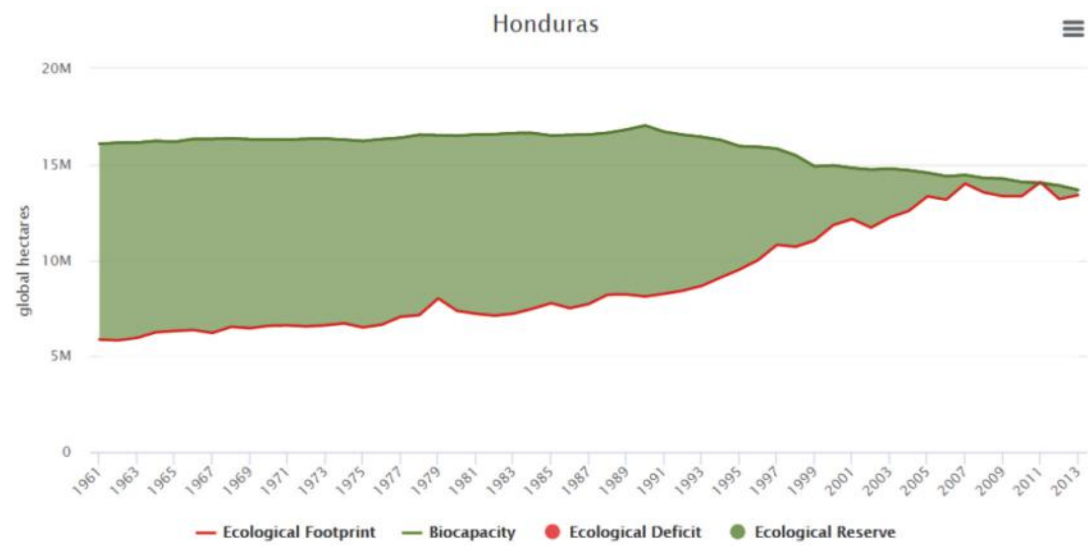


Biome	ES Value $/ha-yr	Area Km2	% Total Area	ES Value	% Total Value
Coral Reefs	$ 352,249.00	13	0.0%	457,923,700.00	0.7%
Woody Wetlands	$ 193,843.00	496	0.4%	9,614,612,800.00	14.4%
Herbaceous Wetlands	$ 25,681.00	-	0.0%	-	0.0%
Urban	$ 6,661.00	4,942	4.4%	3,291,866,200.00	4.9%
Lakes/Rivers	$ 12,512.00	400	0.4%	500,480,000.00	0.8%
Cropland	$ 5,567.00	13,848	12.4%	7,709,181,600.00	11.6%
Temperate Forest	$ 3,137.00	5,134	4.6%	1,610,535,800.00	2.4%
Tropical Forest	$ 5,382.00	60,566	54.3%	32,596,621,200.00	48.9%
Desert	*No Value*	-	0.0%	-	0.0%
Grasslands	$ 4,166.00	26,234	23.5%	10,929,084,400.00	16.4%
Tundra	*No Value*	-	0.0%	-	0.0%
Ice/Rock	*No Value*	-	0.0%	-	0.0%

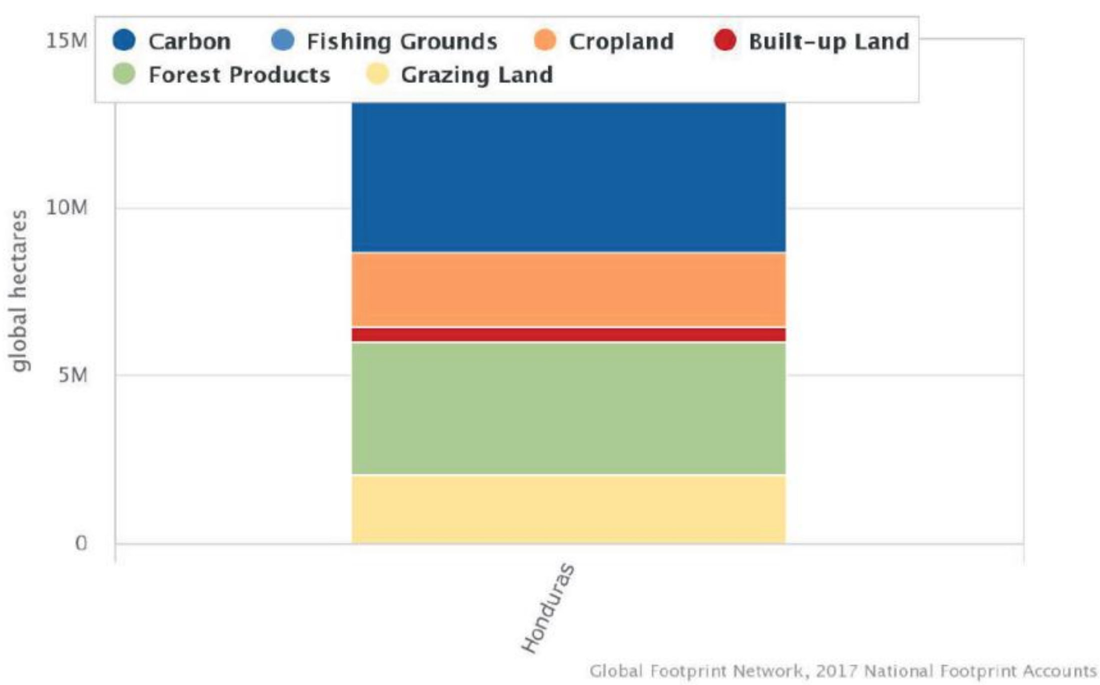
Totals **Area Km2** **111,633** **ESV $/year** **$66,710,305,700**

HONDURAS

ECOLOGICAL FOOTPRINT VS. BIOCAPACITY 1961 - 2013

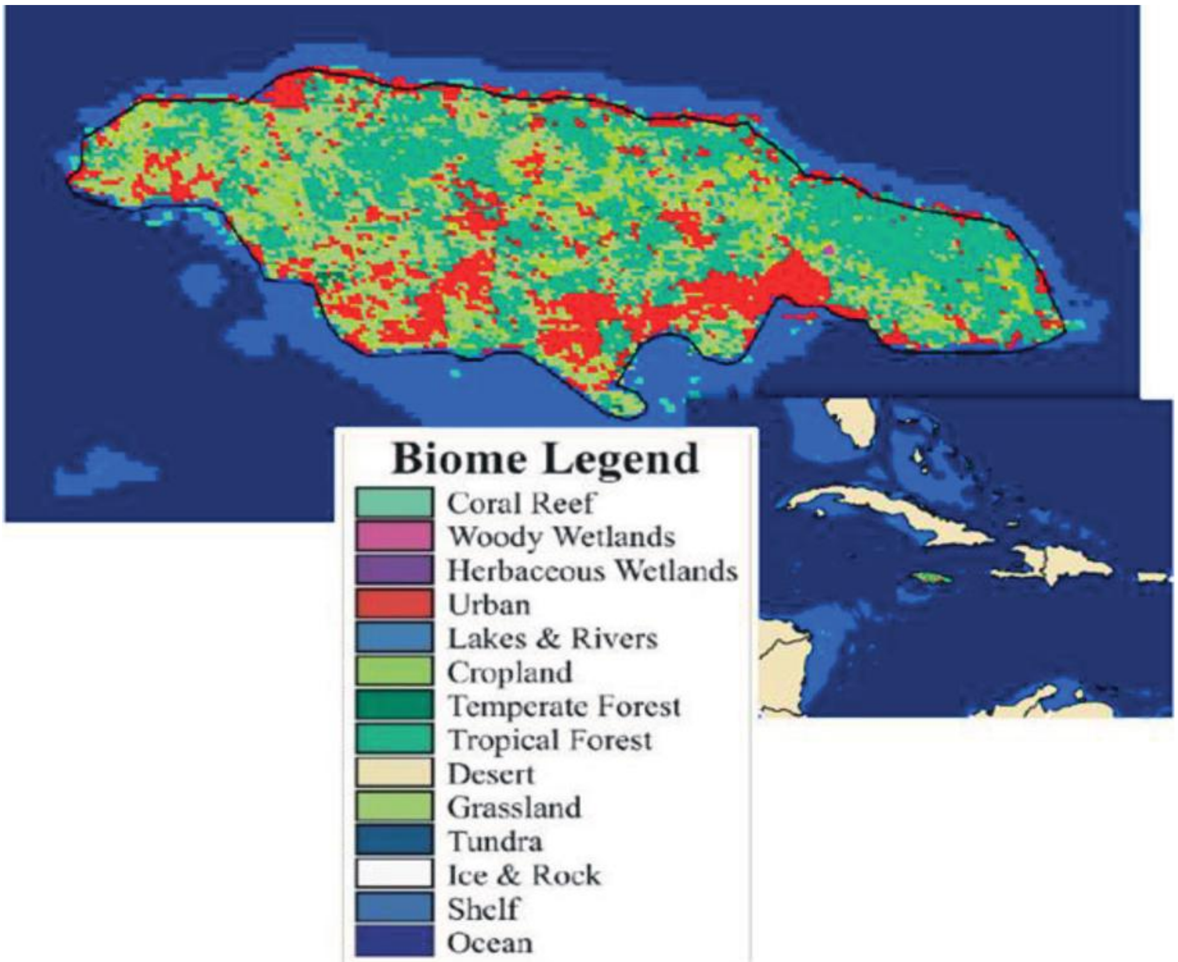


HONDURAS ECOLOGICAL FOOTPRINT BY LAND TYPE 2013



JAMAICA

THE VALUE OF ECOSYSTEM SERVICES FOR JAMAICA: $6 BILLION/YEAR

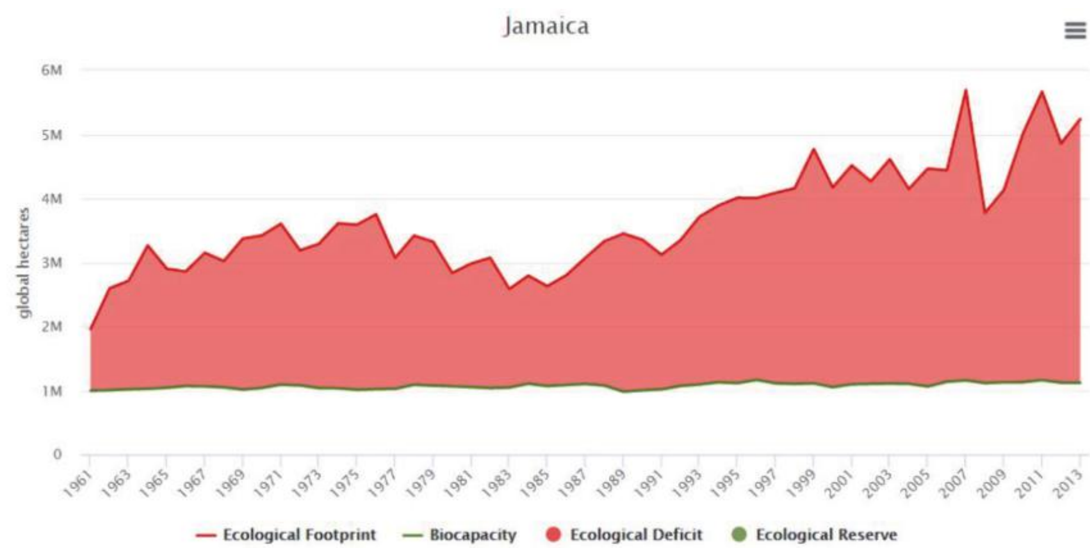


Biome	ES Value $/ha-yr	Area Km2	% Total Area	ES Value	% Total Value
Coral Reefs	$ 352,249.00	8	0.1%	281,799,200.00	4.7%
Woody Wetlands	$ 193,843.00	-	0.0%	-	0.0%
Herbaceous Wetlands	$ 25,681.00	5	0.0%	12,840,500.00	0.2%
Urban	$ 6,661.00	2,164	19.9%	1,441,440,400.00	23.9%
Lakes/Rivers	$ 12,512.00	1	0.0%	1,251,200.00	0.0%
Cropland	$ 5,567.00	1,062	9.8%	591,215,400.00	9.8%
Temperate Forest	$ 3,137.00	52	0.5%	16,312,400.00	0.3%
Tropical Forest	$ 5,382.00	4,307	39.6%	2,318,027,400.00	38.5%
Desert	*No Value*	-	0.0%	-	0.0%
Grasslands	$ 4,166.00	3,268	30.1%	1,361,448,800.00	22.6%
Tundra	*No Value*	-	0.0%	-	0.0%
Ice/Rock	*No Value*	-	0.0%	-	0.0%

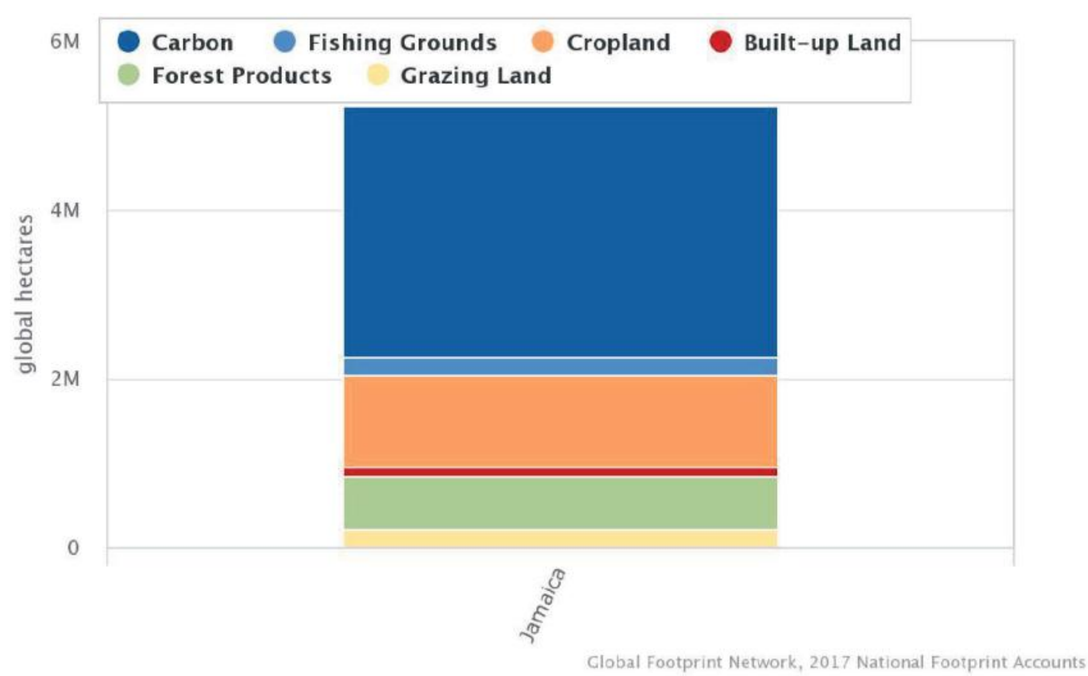
Totals **Area Km2** **10,867** **ESV $/year** **$6,024,335,300**

JAMAICA

ECOLOGICAL FOOTPRINT VS. BIOCAPACITY 1961 - 2013

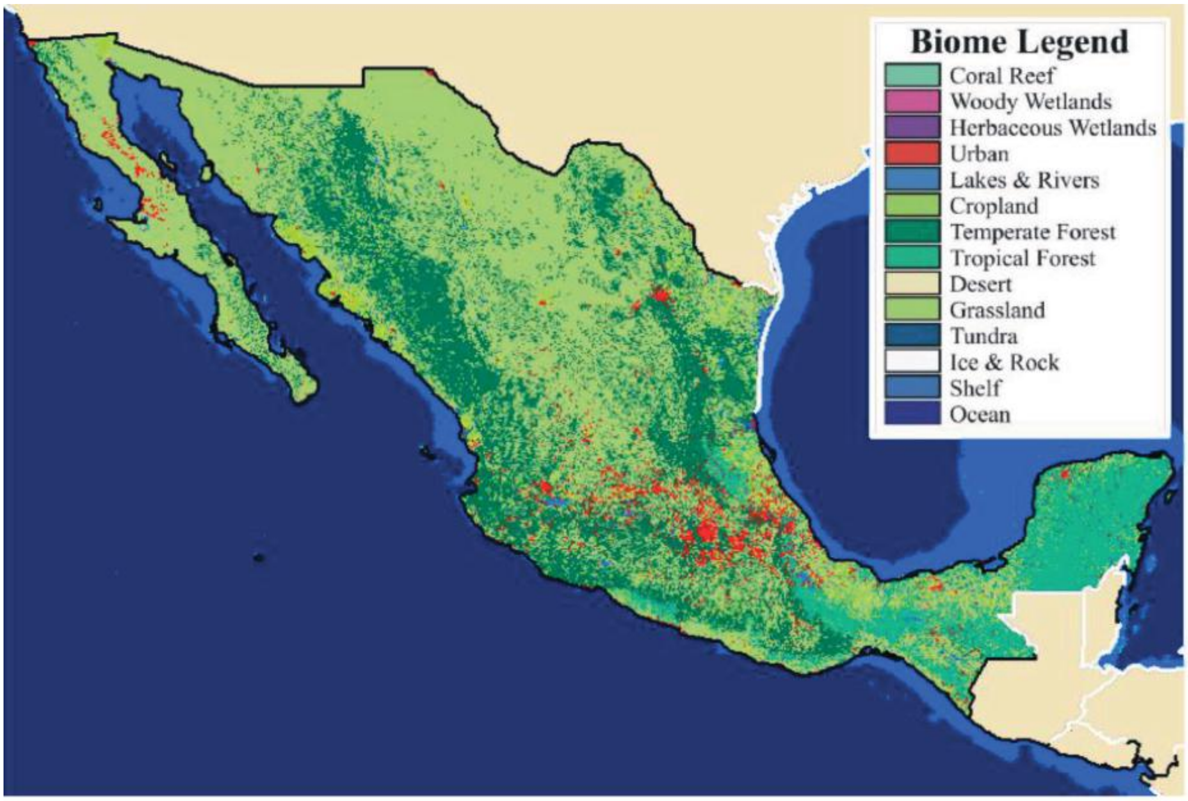


JAMAICA ECOLOGICAL FOOTPRINT BY LAND TYPE 2013



MEXICO

THE VALUE OF ECOSYSTEM SERVICES FOR MEXICO: $846.4 BILLION/YEAR

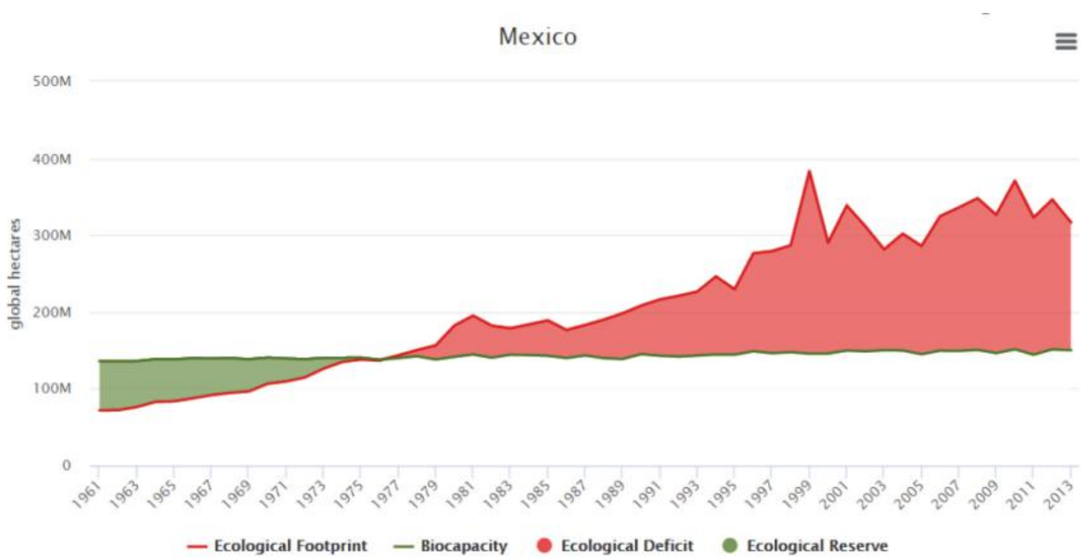


Biome	ES Value $/ha-yr	Area Km2	% Total Area	ES Value	% Total Value
Coral Reefs	$ 352,249.00	42	0.0%	1,479,445,800.00	0.2%
Woody Wetlands	$ 193,843.00	1,612	0.1%	31,247,491,600.00	3.7%
Herbaceous Wetlands	$ 25,681.00	1	0.0%	2,568,100.00	0.0%
Urban	$ 6,661.00	66,976	3.4%	44,612,713,600.00	5.3%
Lakes/Rivers	$ 12,512.00	10,075	0.5%	12,605,840,000.00	1.5%
Cropland	$ 5,567.00	59,278	3.0%	33,000,062,600.00	3.9%
Temperate Forest	$ 3,137.00	571,381	29.2%	179,242,219,700.00	21.2%
Tropical Forest	$ 5,382.00	213,375	10.9%	114,838,425,000.00	13.6%
Desert	*No Value*	-	0.0%	-	0.0%
Grasslands	$ 4,166.00	1,030,755	52.8%	429,412,533,000.00	50.7%
Tundra	*No Value*	-	0.0%	-	0.0%
Ice/Rock	*No Value*	10	0.0%	-	0.0%

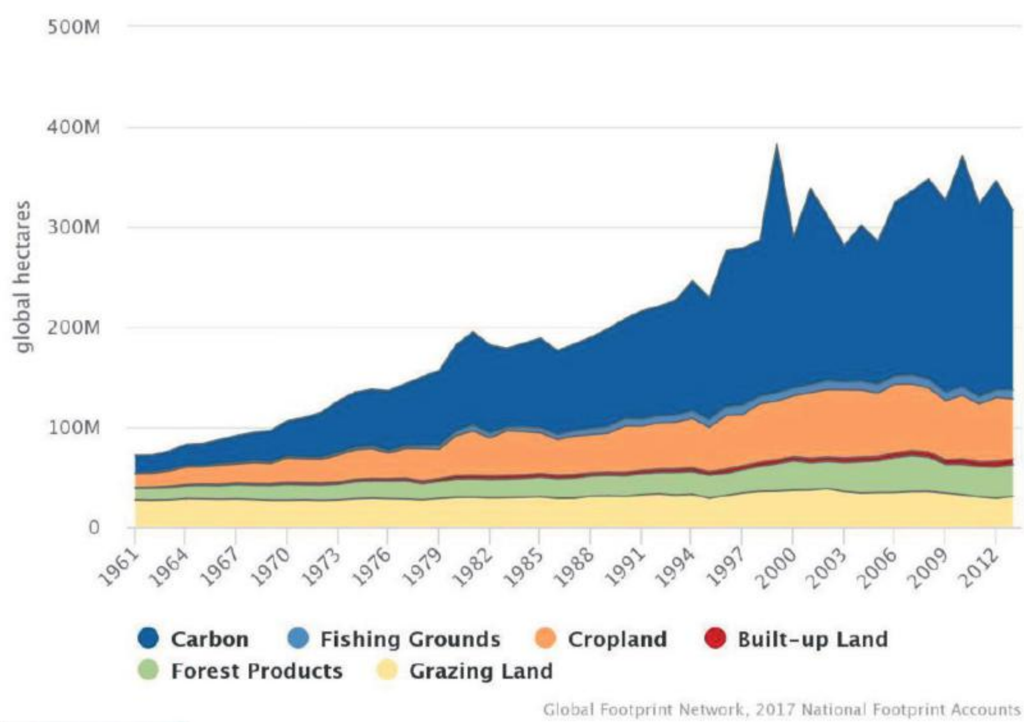
Totals	**Area Km2**	**1,953,505.0**	**ESV $/year**	**$846,441,299,400**

MEXICO

ECOLOGICAL FOOTPRINT VS. BIOCAPACITY 1961 - 2013

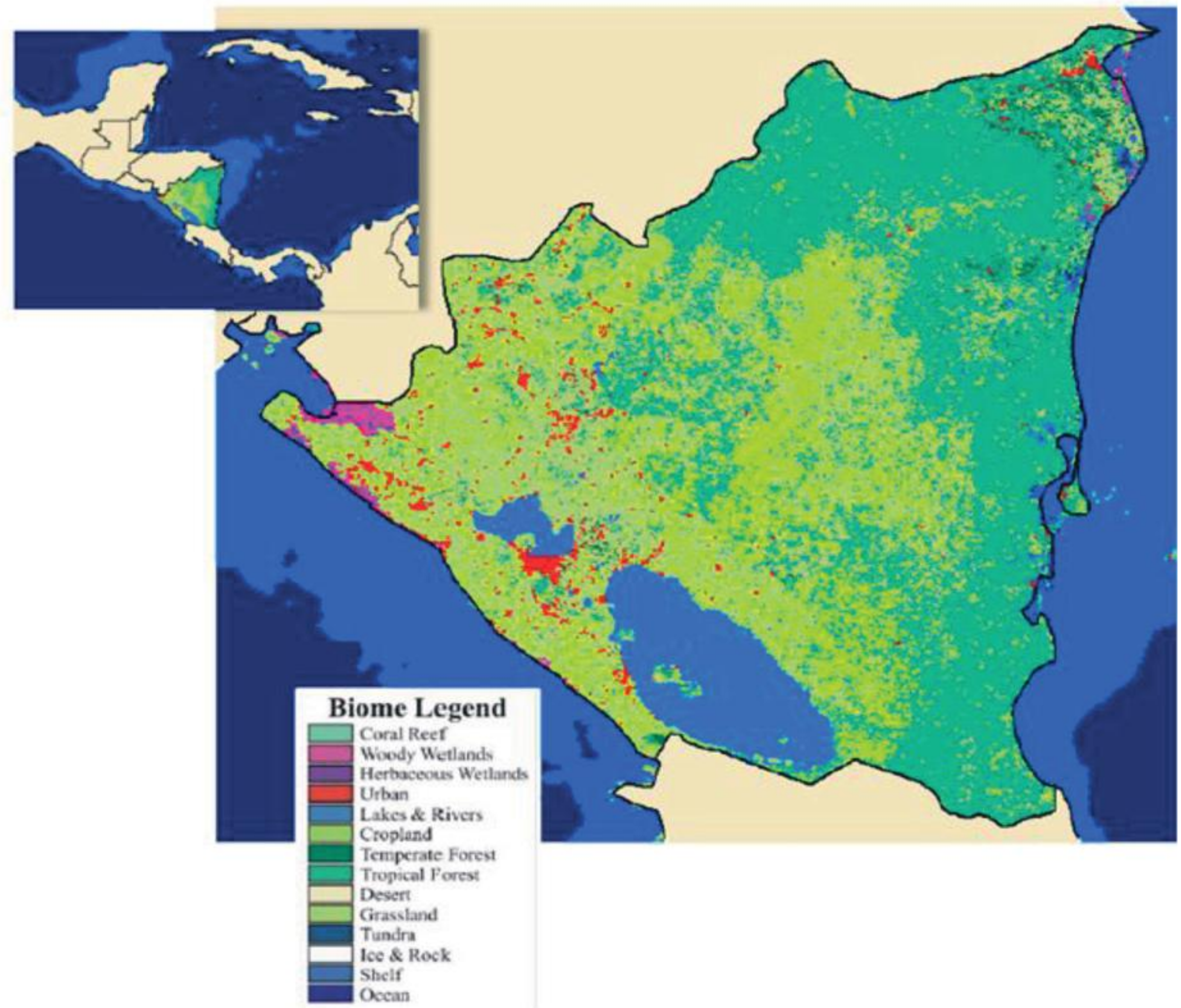


MEXICO ECOLOGICAL FOOTPRINT BY LAND TYPE



NICARAGUA

THE VALUE OF ECOSYSTEM SERVICES FOR NICARAGUA: $87 BILLION/YEAR

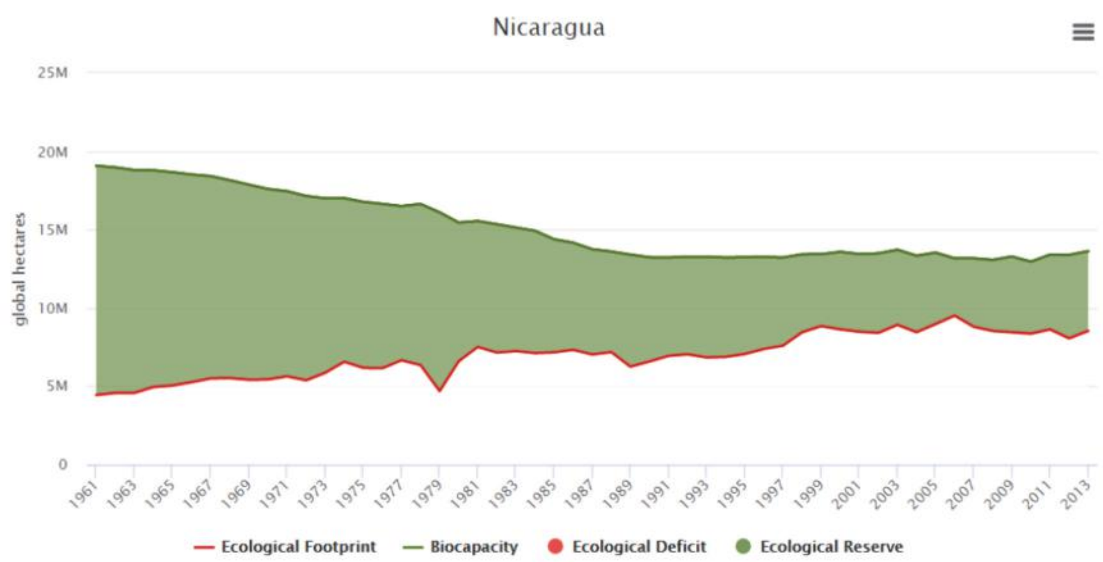


Biome	ES Value $/ha-yr	Area Km2	% Total Area	ES Value	% Total Value
Coral Reefs	$ 352,249.00	-	0.0%	-	0.0%
Woody Wetlands	$ 193,843.00	813	0.6%	15,759,435,900.00	18.1%
Herbaceous Wetlands	$ 25,681.00	-	0.0%	-	0.0%
Urban	$ 6,661.00	2,652	2.1%	1,766,497,200.00	2.0%
Lakes/Rivers	$ 12,512.00	9,675	7.6%	12,105,360,000.00	13.9%
Cropland	$ 5,567.00	25,837	20.2%	14,383,457,900.00	16.5%
Temperate Forest	$ 3,137.00	2,316	1.8%	726,529,200.00	0.8%
Tropical Forest	$ 5,382.00	51,951	40.6%	27,960,028,200.00	32.1%
Desert	*No Value*	-	0.0%	-	0.0%
Grasslands	$ 4,166.00	34,599	27.1%	14,413,943,400.00	16.5%
Tundra	*No Value*	-	0.0%	-	0.0%
Ice/Rock	*No Value*	-	0.0%	-	0.0%

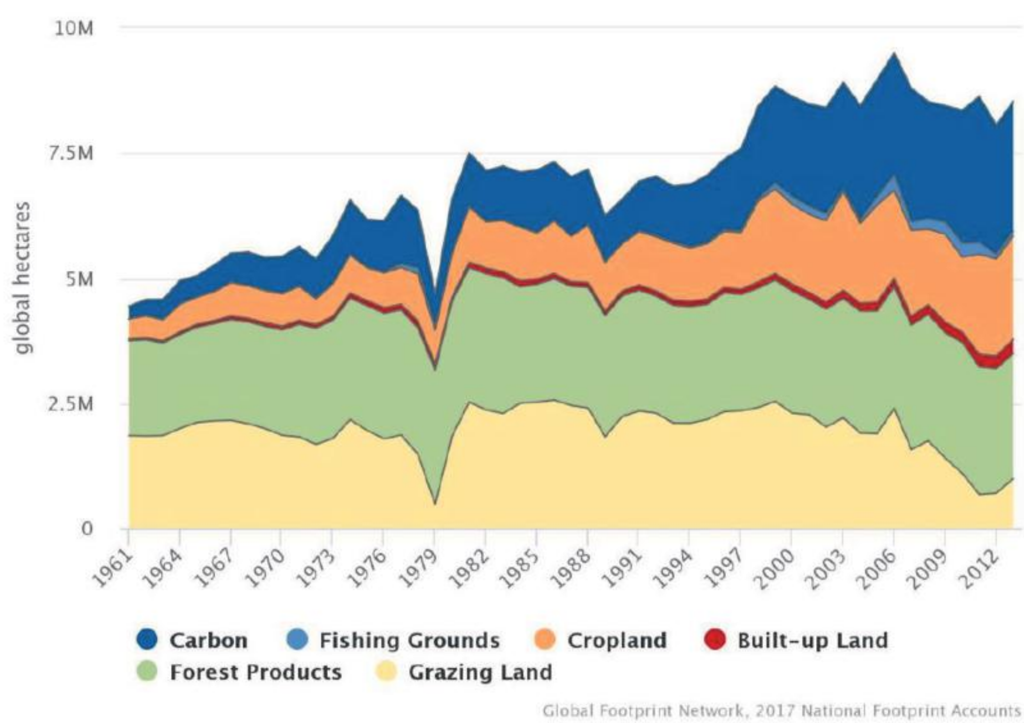
Totals	**Area Km2**	**127,843**	**ESV $/year**	**$87,115,251,800**

NICARAGUA

ECOLOGICAL FOOTPRINT VS. BIOCAPACITY 1961 - 2013

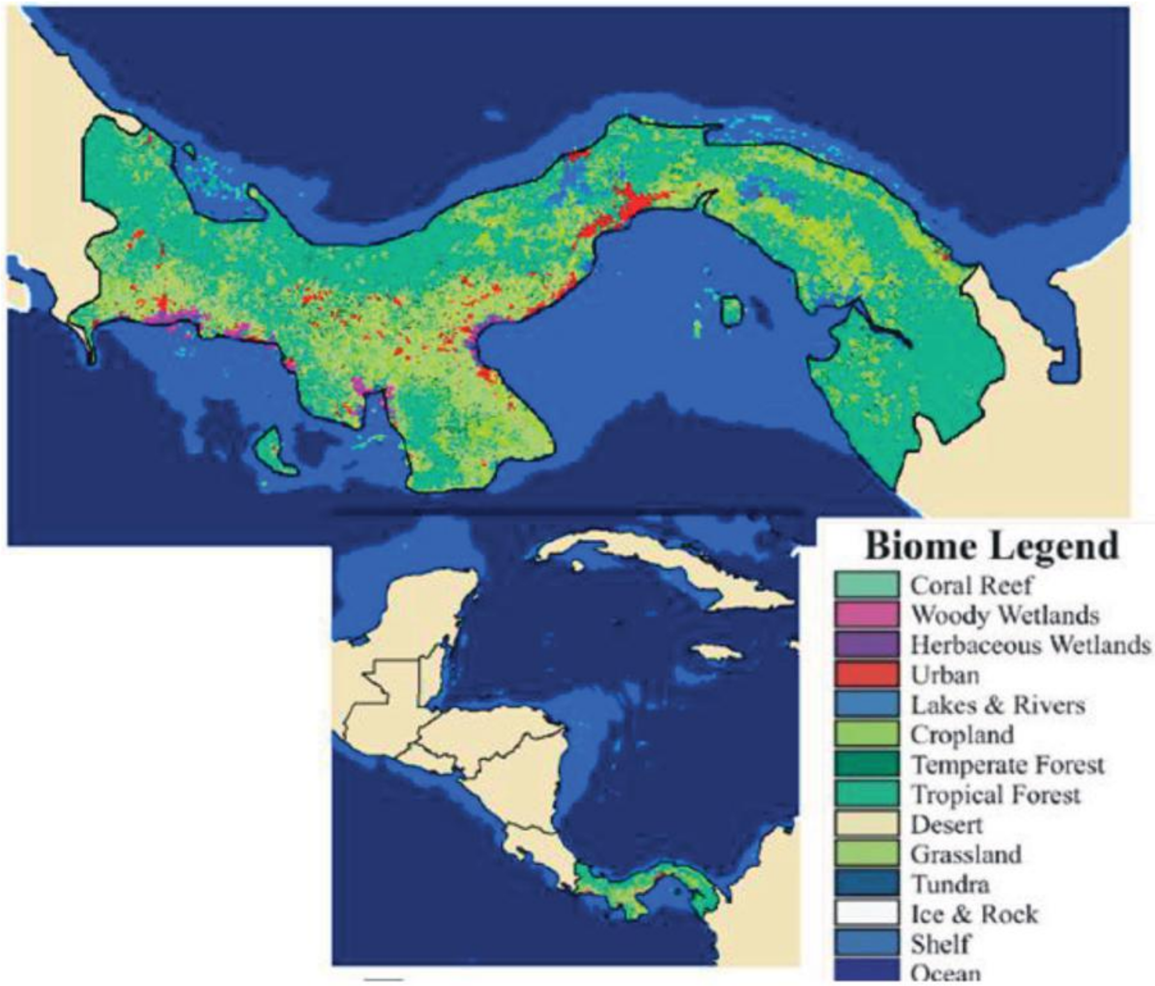


NICARAGUA ECOLOGICAL FOOTPRINT BY LAND TYPE



PANAMA

THE VALUE OF ECOSYSTEM SERVICES FOR PANAMA: $51 BILLION/YEAR

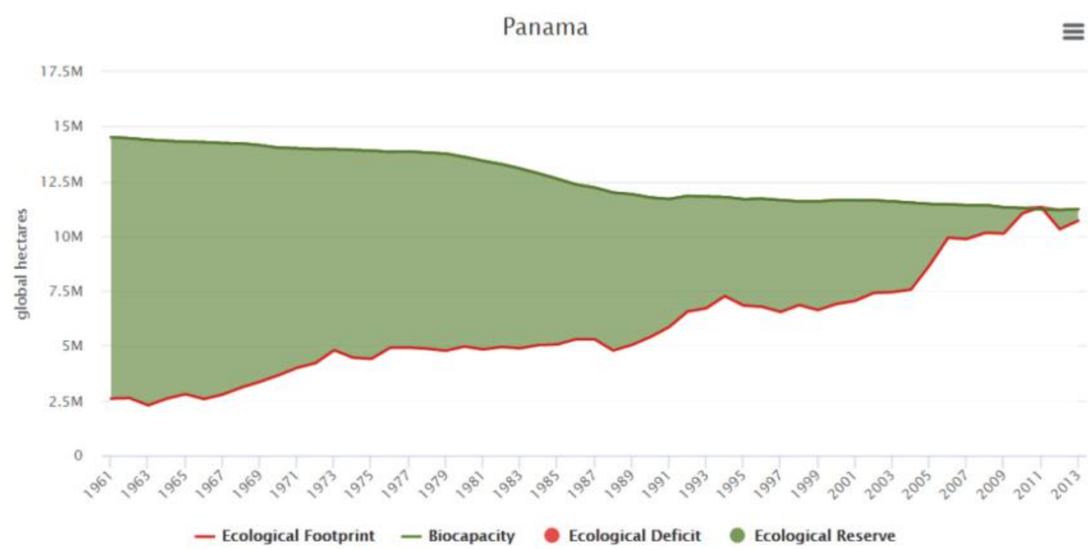


Biome	ES Value $/ha-yr	Area Km2	% Total Area	ES Value	% Total Value
Coral Reefs	$ 352,249.00	50	0.1%	1,761,245,000.00	3.4%
Woody Wetlands	$ 193,843.00	625	0.9%	12,115,187,500.00	23.6%
Herbaceous Wetlands	$ 25,681.00	-	0.0%	-	0.0%
Urban	$ 6,661.00	2,015	2.8%	1,342,191,500.00	2.6%
Lakes/Rivers	$ 12,512.00	933	1.3%	1,167,369,600.00	2.3%
Cropland	$ 5,567.00	8,373	11.4%	4,661,249,100.00	9.1%
Temperate Forest	$ 3,137.00	2,042	2.8%	640,575,400.00	1.2%
Tropical Forest	$ 5,382.00	41,139	56.2%	22,141,009,800.00	43.1%
Desert	*No Value*	2	0.0%	-	0.0%
Grasslands	$ 4,166.00	17,973	24.6%	7,487,551,800.00	14.6%
Tundra	*No Value*	-	0.0%	-	0.0%
Ice/Rock	*No Value*	-	0.0%	-	0.0%

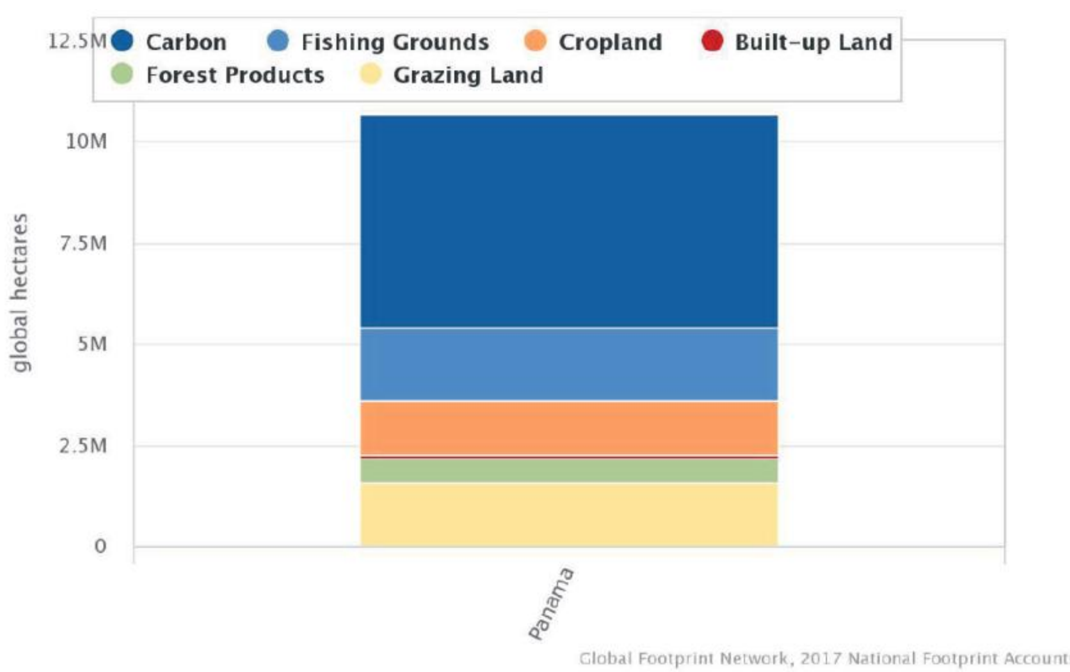
Totals		Area Km2	73,152	ESV $/year	$51,316,379,700

PANAMA

ECOLOGICAL FOOTPRINT VS. BIOCAPACITY 1961 - 2013

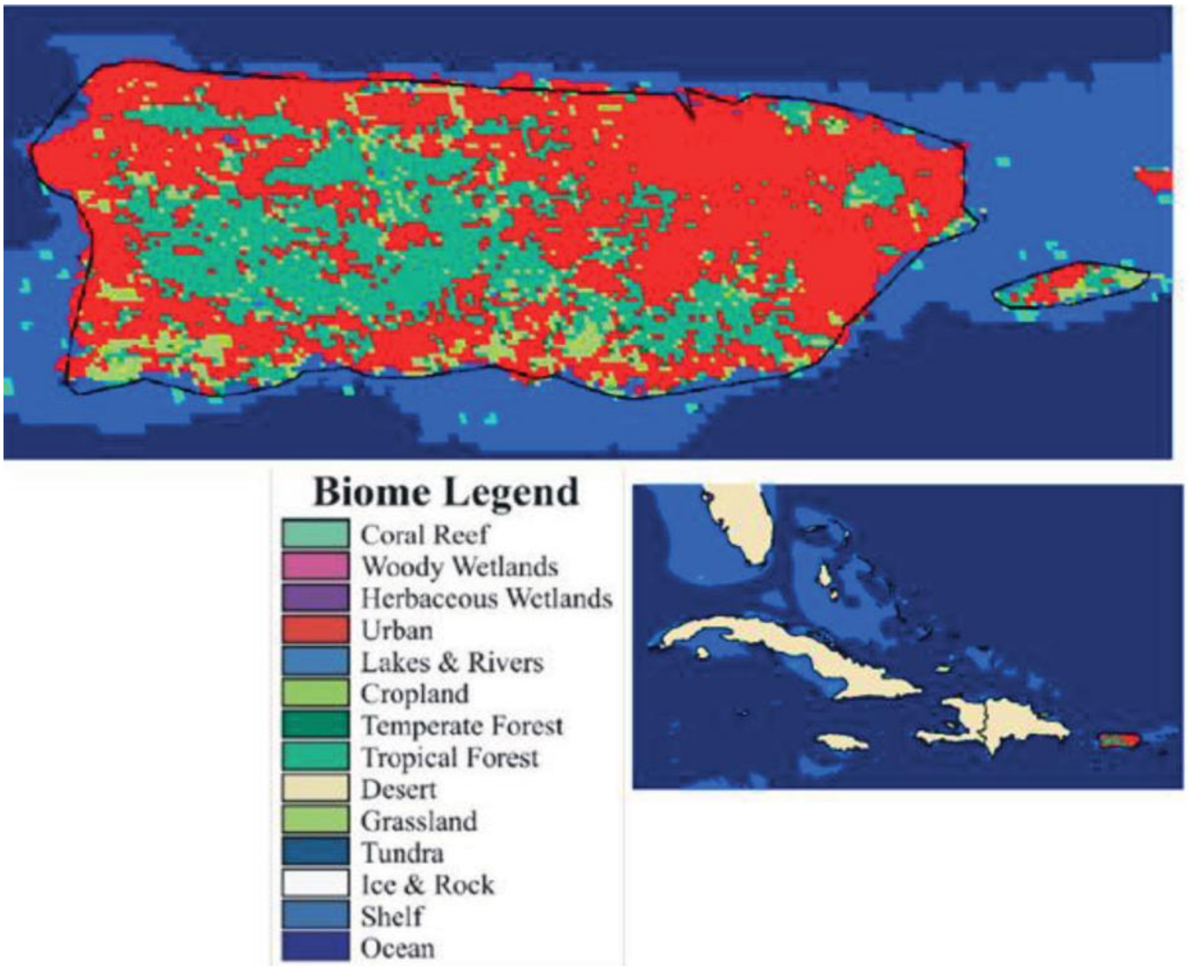


PANAMA ECOLOGICAL FOOTPRINT BY LAND TYPE 2013



PUERTO RICO

THE VALUE OF ECOSYSTEM SERVICES FOR PUERTO RICO: $5.5 BILLION/YEAR

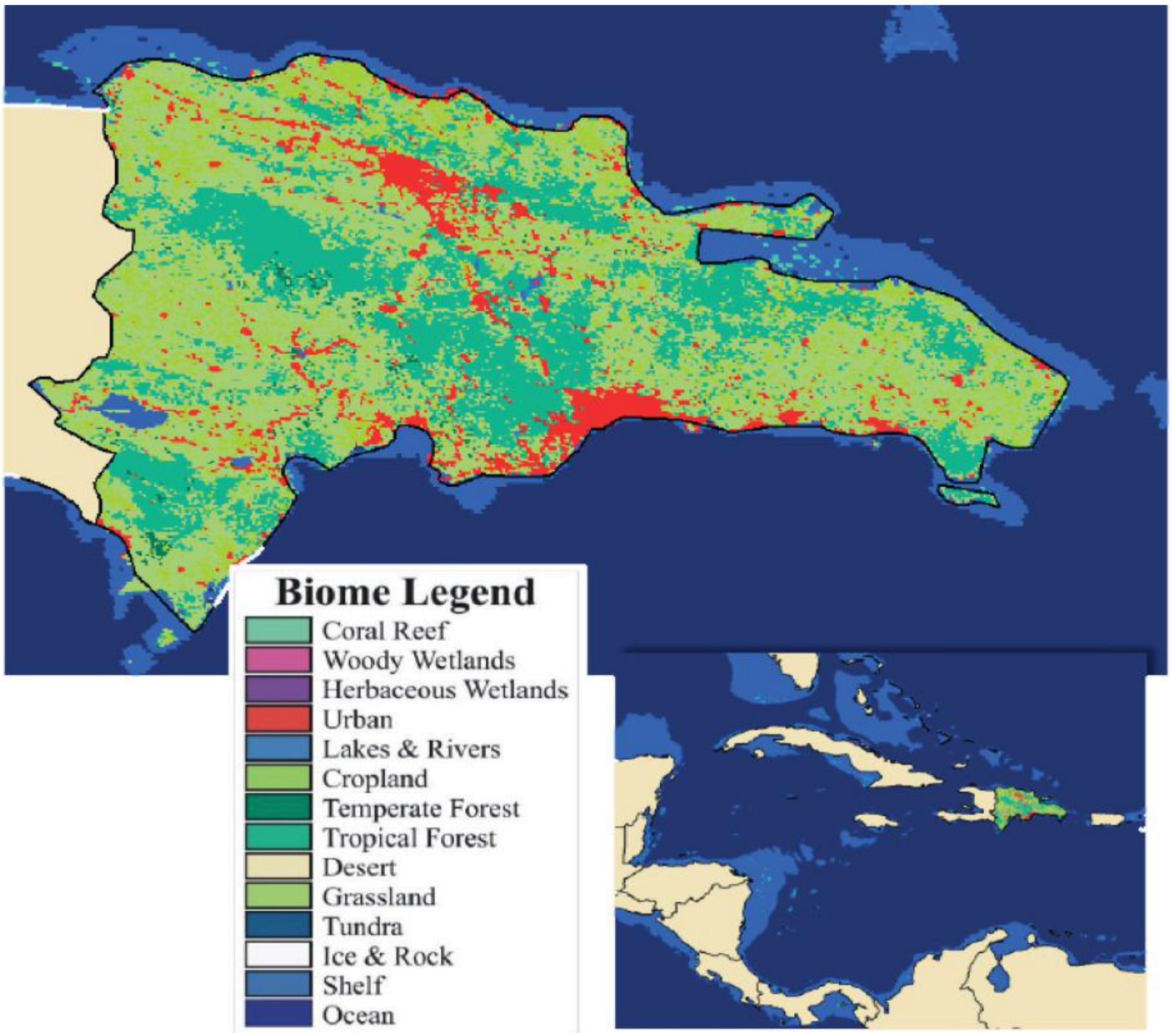


Biome	ES Value $/ha-yr	Area Km2	% Total Area	ES Value	% Total Value
Coral Reefs	$ 352,249.00	4	0.0%	140,899,600.00	2.6%
Woody Wetlands	$ 193,843.00	1	0.0%	19,384,300.00	0.4%
Herbaceous Wetlands	$ 25,681.00	-	0.0%	-	0.0%
Urban	$ 6,661.00	5,229	58.7%	3,483,036,900.00	63.2%
Lakes/Rivers	$ 12,512.00	9	0.1%	11,260,800.00	0.2%
Cropland	$ 5,567.00	99	1.1%	55,113,300.00	1.0%
Temperate Forest	$ 3,137.00	41	0.5%	12,861,700.00	0.2%
Tropical Forest	$ 5,382.00	2,653	29.8%	1,427,844,600.00	25.9%
Desert	*No Value*	-	0.0%	-	0.0%
Grasslands	$ 4,166.00	867	9.7%	361,192,200.00	6.6%
Tundra	*No Value*	-	0.0%	-	0.0%
Ice/Rock	*No Value*	-	0.0%	-	0.0%

Totals Area Km2 **8,903** ESV $/year **$5,511,593,400**

DOMINICAN REPUBLIC

THE VALUE OF ECOSYSTEM SERVICES FOR DOMINICAN REPUBLIC: $26.2 BILLION/YEAR

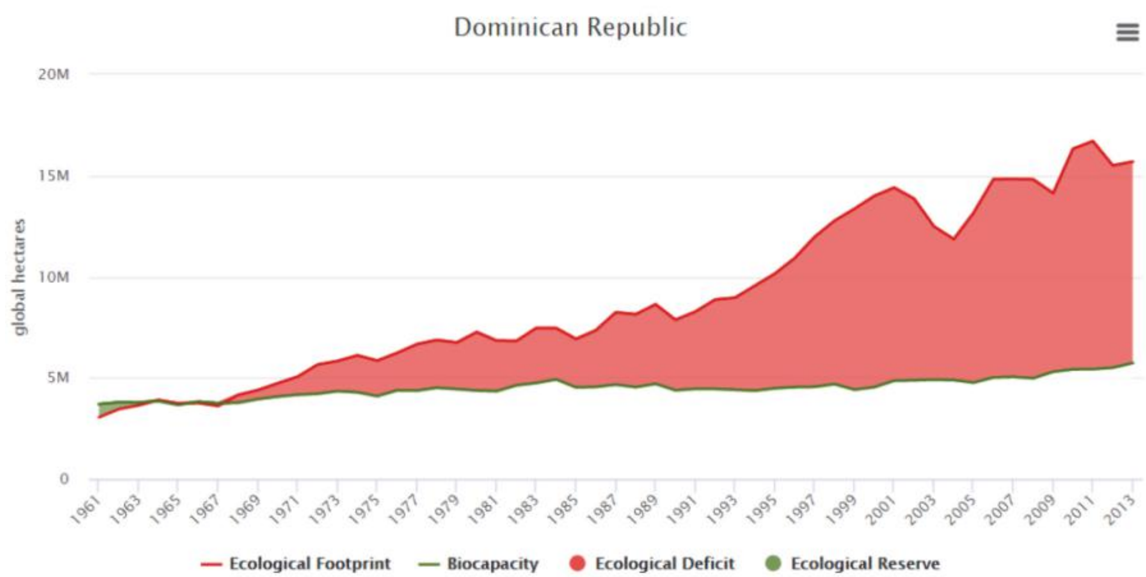


Biome	ES Value $/ha-yr	Area Km2	% Total Area	ES Value	% Total Value
Coral Reefs	$ 352,249.00	76	0.2%	2,677,092,400.00	10.2%
Woody Wetlands	$ 193,843.00	4	0.0%	77,537,200.00	0.3%
Herbaceous Wetlands	$ 25,681.00	-	0.0%	-	0.0%
Urban	$ 6,661.00	4,136	8.7%	2,754,989,600.00	10.5%
Lakes/Rivers	$ 12,512.00	131	0.3%	163,907,200.00	0.6%
Cropland	$ 5,567.00	6,927	14.5%	3,856,260,900.00	14.7%
Temperate Forest	$ 3,137.00	548	1.2%	171,907,600.00	0.7%
Tropical Forest	$ 5,382.00	13,266	27.8%	7,139,761,200.00	27.2%
Desert	*No Value*	-	0.0%	-	0.0%
Grasslands	$ 4,166.00	22,560	47.3%	9,398,496,000.00	35.8%
Tundra	*No Value*	-	0.0%	-	0.0%
Ice/Rock	*No Value*	-	0.0%	-	0.0%

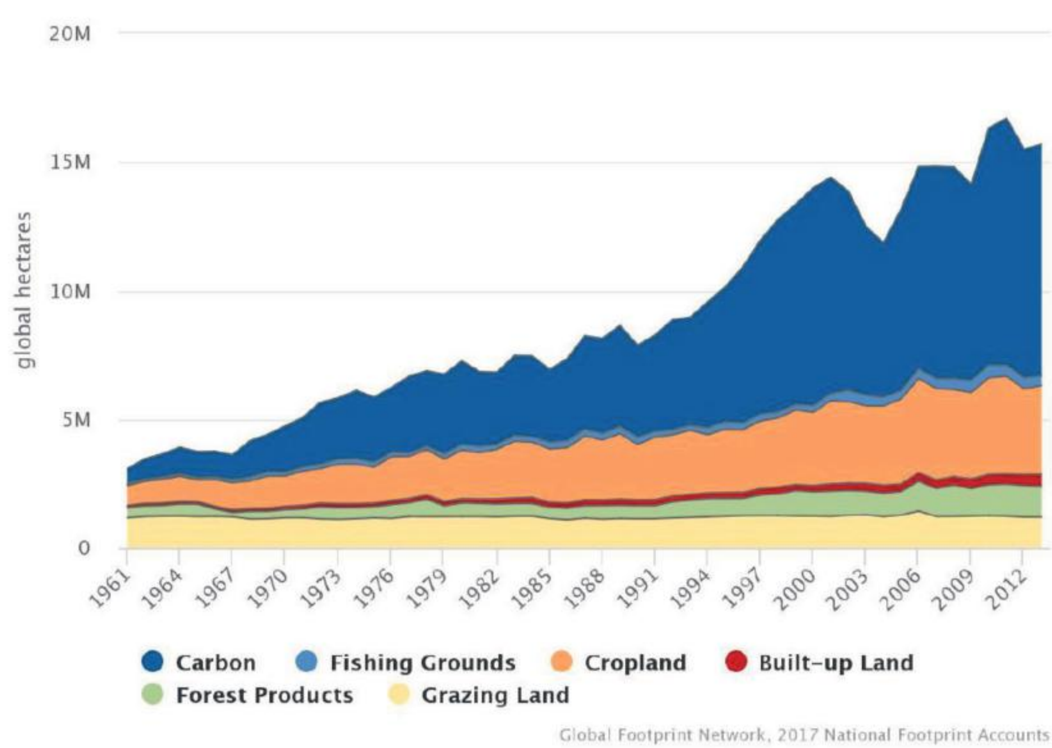
Totals **Area Km2** **47,648** **ESV $/year** **$26,239,952,100**

DOMINICAN REPUBLIC

ECOLOGICAL FOOTPRINT VS. BIOCAPACITY 1961 - 2013



DOMINICAN REPUBLIC ECOLOGICAL FOOTPRINT BY LAND TYPE



Ecosystem Services Valuation of Mesoamerica and the Caribbean
se terminó de imprimir en mayo de 2019
en los talleres de Ediciones de la Noche
Madero #687, Zona Centro
Guadalajara, Jalisco

El tiraje fue de 500 ejemplares

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Ecosystem services are nature's gifts to society, services that do not appear in the market's price structures but that are indispensable for the very survival of any society. As Costanza et al stated in their seminal paper on valuation of the world's ecosystem services, "The economies of the Earth would grind to a halt without the services of eco-logical life support systems, so in one sense their total value to the economy is infinie".

University of Denver

de Economía Ecológica

Universidad de Guadalajara

ECOSYSTEM SERVICES VALUATION OF MESOAMERICA AND THE CARIBBEAN

PAUL C. SUTTON · SALVADOR PENICHE
COORDINATORS