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Future scenarios for the value of ecosystem services in Latin America and the Caribbean to 2050

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ABSTRACT

We explore the implications of four scenarios for the value of ecosystem services provided by terrestrial ecosystems to the year 2050 for Latin America and the Caribbean, based on the Great Transition Initiative scenarios and previous studies at a global scale. We estimated the current ecosystem services value (ESV) of the 33 countries that make up this region to be $US15.3 trillion/year. By modelling the four future scenarios, we estimated that there is a potential for ESV to decrease to $8 trillion/year (for the "Fortress World" scenario) or an increase to $19 trillion/year (for the "Great Transition" scenario), a difference of a 47% decrease or a 25% increase. Our results indicate that adopting appropriate policies could greatly enhance human well-being and sustainability in the region and help to achieve the UN Sustainable Development Goals (SDGs).

1. Introduction

The value of natural capital becomes evident in a region such as Latin America and the Caribbean (LAC)[1], which holds sixty per cent of global terrestrial biodiversity as well as a diverse marine and freshwater flora and fauna. Six of the most biodiverse countries in the planet are in this region (Brazil, Colombia, Ecuador, Mexico, Peru and Venezuela), including the most biodiverse habitat on Earth, the Amazon rainforest (UNEP-WCMC, 2016). Due to the extension of its area and the historical context of LAC, it is also highly diverse in terms of economy, geography, and policy, which determines the route of development that the region has followed over the last decades.

Data from Steffen, Broadgate, Deutsch, Gaffney, and Ludwig (2015), provides a general picture of this development path. In the period from 1750 to 2010, Mesoamerica's population increased 2,157%, with Costa Rica having the highest increase, 13,659%. In the Caribbean, population increased by 4,134%, with Dominican Republic having the highest increase with 8,070%. The population of South America increased by 5,008%, with Argentina being the country with the highest increase, 1,3455%.

Understanding the population's migration to urban settlements is critical as the associated land-cover change has one of the most significant impacts on natural capital. In the same period, 1750 to 2010, Mesoamerica increased its urban population by 51,097%, Costa Rica again with the highest increase, 162,828%. The Caribbean increased by 70,838%, with the greatest change in Dominica, 429,794%. South America shows an increase of urban population of 68,785%, with the highest increase in Brazil, 155,516%.

The same data set describes the increase of economic activity of LAC and its sub-regions, for the period of 1969 to 2010. Mesoamerica increased its GDP by 310% in these five decades, Belize with the highest increase, 833%; the Caribbean increased by 250% its GDP with the highest amount in Dominican Republic, 797%; and South America increased the same indicator by 314% with the highest increase in Chile, 431%.

These indicators show the development path that LAC has followed, which is characterized by examples of success in sustainability, as well as by social and economic challenges. For example, in the period between 1990 and 2014, the total terrestrial area of LAC under protection increased from 8.8% to 23%, a 266% increase (UNEP, 2016). On the other hand, urban areas have been growing in LAC, increasing the urban population by more than 35 million people in five years (2010-2015 period), with a projected increase by 2025 to a total of 597 million persons (UNEP, 2016). This urban development, combined with economic growth and inequity, is one of the most significant threats to biodiversity in many areas of the region (Pauchard & Barbosa, 2013).

Having broadly described the region's past development and its environmental and social implications, this paper explores through a scenario

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[1] Includes 33 countries as defined by the United Nations Environment Programme (UNEP)

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Table 1
Social-economic indicators of the four scenarios of the Great Transition Initiative.

Indicator	Market forces	Policy reform	Great transition	Fortress world
Population (10ˆ6 people)	778	739	692	817
Total GDP (10ˆ9 $PPP)	16,539	18,056	18,844	15,630
Income ($PPP per capita)	21,259	24,429	27,215	19,133
Hunger (millions of people)	55	26	1	81
Energy Demand (EJ)	91.31	50.31	38.37	92.60
Crop Output (million kt)	3.17	2.77	2.58	3.04
Livestock Output (million t)	204.59	200.35	159.14	168.36
Forest Area (kha)	574,218	690,607	798,790	581,282
Water Use (10ˆ12 mˆ3)	0.50	0.24	0.23	0.48
CO2 Emissions (GtC)	1.70	0.41	0.04	1.63
Quality of Development Index	0.44	0.55	0.68	0.38

Source: Great Transition Initiative, 2018

planning approach, how the economic value of natural capital in LAC might change in the future. We estimate the change of the value of ecosystem services by 2050 under different development scenarios for the region, with the main goal to inform policymakers the consequences that land cover change decisions have on natural capital. This paper is based on the global study on the future value of ecosystem services conducted by Kubiszewski, Costanza, Anderson, and Sutton (2017), who estimated that global value of ecosystem services can decline by $51 trillion/year or increase by $30 trillion/year, depending on the development scenario. Other studies have also used data from this global one to produce regional estimates, such as the case of Asia and the Pacific (Kubiszewski, Anderson, Costanza, & Sutton, 2016).

1.1. Scenario planning

Scenario planning or analysis is a structured process of generating future possibilities which have social-economic and environmental implications (Bohensky et al., 2011). Scenarios are narratives that consider how alternate futures may unfold from combinations of highly influential and uncertain drivers, and their interaction with more certain driving forces (O'Brien, 2000). Furthermore, scenarios are not predictive models, forecasts or predictions, rather explorations of *plausible* (not probable) futures (Peterson, Cumming, & Carpenter, 2003).

Scenario planning is based on four assumptions: 1) the future is unlike the past, and is significantly shaped by human choice and action, 2) the future cannot be foreseen, but exploring possible futures can inform present decisions, 3) there are many possible futures, scenarios therefore map within a "possibility space", and 4) scenario development involves both rational analysis and creative thinking (Costanza, 2014).

Although some aspects from the future world created in each scenario can potentially occur, these "fictional" worlds are best viewed as caricatures of reality that allow the public to learn and take better decisions regarding the factors that are being evaluated (Costanza et al., 2015). The majority of scenarios developed around the world for multiple purposes, fall into a small number of types or "archetypes", which cover topics such as growth, transformation, collapse, and discipline/restraint narratives (Bohensky et al., 2011).

In this study, the four scenarios that we used are a synthesis of prior scenario studies and based around the four "Great Transition Initiative" (GTI) archetypes (Hunt et al., 2012) created by an international network of scientists, using models and regional analyses (McGrail, 2011; Raskin et al., 2002). In general, the driving forces of these scenarios are demographics, considering population growth and urbanization; economics, specially growing markets, regulation and people's preferences; social issues such as inequality and poverty; culture in a globalized world; technological advance; environment, through a global and interconnected vision; and governance, considering a trend towards democratization and decentralization of authority (Raskin et al., 2002).

These are the four scenarios from GTI, as describe in its website (http://www.tellus.org/results/scenarios.html):

- **Market Forces (MF)**: The Market Forces scenario is a story of a market-driven world in the 21st century in which demographic, economic, environmental, and technological trends unfold without major surprises. Continuity, globalization and convergence are key characteristics of world development – institutions gradually adjust without major ruptures, international economic integration proceeds apace and the socioeconomic patterns of poor regions converge slowly toward the development model of the rich regions. Despite economic growth, extreme income disparity between rich and poor countries, and between the rich and poor within countries, remains a critical social trend. Environmental transformation and degradation are a progressively more significant factor in global affairs.
- **Policy Reform (PR)**: The Policy Reform scenario envisions the emergence of strong political will for taking harmonized and rapid action to ensure a successful transition to a more equitable and environmentally resilient future. Rather than a projection into the future, the Policy Reform scenario is a normative scenario constructed as a backcast from the future. It is designed to achieve a set of future sustainability goals. The analytical task is to identify plausible development pathways for reaching that end-point. Thus, the Policy Reform scenario explores the requirements for simultaneously achieving social and environmental sustainability goals under high economic growth conditions similar to those of Market Forces.
- **Fortress World (FW)**: The Fortress World scenario is a variant of a broader class of Barbarization scenarios, in the hierarchy of the Global Scenario Group (Gallopín et al. 1997). Barbarization scenarios envision the grim possibility that the social, economic and moral underpinnings of civilization deteriorate, as emerging problems overwhelm the coping capacity of both markets and policy reforms. The Fortress World variant of the Barbarization story features an authoritarian response to the threat of breakdown. Ensconced in protected enclaves, elites safeguard their privilege by controlling an impoverished majority and managing critical natural resources, while outside the fortress there is repression, environmental destruction and misery.
- **Great Transition (GT)**: The Great Transition scenario explores visionary solutions to the sustainability challenge, including new socioeconomic arrangements and fundamental changes in values. This scenario depicts a transition to a society that preserves natural systems, provides high levels of welfare through material sufficiency and equitable distribution, and enjoys a strong sense of local solidarity.

The future by 2050 of LAC under these scenarios poses great challenges and opportunities for sustainable development in the region. Taking a more in-depth look at the data on the scenarios from the Great Transition Initiative for Latin America (See Table 1), it shows that population could increase the most, under the Fortress World scenario, going from 557 million people in 2005 to 817 million; and it could increase the least under the Great Transition scenario, reaching 692 million people by 2050. More people in the future can also have a significant impact on poverty, with the most populated scenario (Fortress World) also having the most people with hunger, 81 million, while the Great Transition could have 1 million people under this condition.

These two variables, population and hunger, can be also reflected in the future economic conditions of the region, which present its extremes again under the Fortress World and the Great Transition scenarios. The Fortress World would produce the lowest economic activity, with a GDP of 15 trillion and a per capita income of $19,000, while the Great Transition scenario presents the highest GDP of all scenarios, 18 trillion, as well as the highest income per capita, $27,000. These figures show some of the socio-economic factors that make LAC under the Great Transition scenario a region with high levels of welfare through material sufficiency and equitable distribution.

The Market Forces scenario would have the highest values of those variables related more to commercial activity (although we can argue that all

Table 2
Terrestrial values of ecosystem services in Latin America and the Caribbean for 2011 and for 2050 under 4 scenarios.

Country	Area (km2)	GDP, PPP (2011 Million$)	ESV_2011 (Million$/yr)	S1_MF (Million $/yr)	MF % change from 2011	S2_FW (Million $/yr)	FW % change from 2011	S3_PR (Million $/yr)	PR % change from 2011	S4_GT (Million$/yr)	GT % change from 2011
Mesoamerica											
Belize	22,211	2,587	11,647	10,352	−11%	9,268	−20%	11,618	0%	13,840	19%
Costa Rica	51,410	60,138	42,444	30,740	−28%	22,144	−48%	42,672	1%	51,343	21%
El Salvador	20,680	45,998	14,953	11,058	−26%	8,850	−41%	15,061	1%	18,217	22%
Guatemala	109,691	102,318	58,364	51,519	−12%	45,974	−21%	58,853	1%	70,241	20%
Honduras	112,866	33,791	66,954	54,006	−19%	46,800	−30%	66,974	0%	80,364	20%
Mexico	1,965,721	1,893,303	848,935	763,625	−10%	676,614	−20%	859,273	1%	1,019,572	20%
Nicaragua	128,867	24,529	87,309	71,065	−19%	59,578	−32%	87,279	0%	104,884	20%
Panama	74,595	60,793	51,622	38,148	−26%	31,843	−38%	51,673	0%	62,196	20%
Total Mesoamerica	2,486,041	2,223,457	1,182,228	1,030,513	−13%	901,071	−24%	1,193,404	1%	1,420,657	20%
South America											
Argentina	2,787,501		2,212,877	1,418,025	−36%	935,071	−58%	2,194,339	−1%	2,698,339	22%
Bolivia	1,092,700	56,424	1,294,751	652,015	−50%	405,007	−69%	1,310,242	1%	1,639,570	27%
Brazil	8,523,524	2,973,856	6,768,369	4,726,633	−30%	3,717,035	−45%	6,868,298	1%	8,461,479	25%
Chile	745,770	348,602	298,938	177,484	−41%	158,005	−47%	284,881	−5%	390,255	31%
Colombia	1,142,733	533,513	717,015	538,452	−25%	468,230	−35%	740,988	3%	934,161	30%
Ecuador	257,031	150,664	160,915	120,877	−25%	105,843	−34%	163,455	2%	201,541	25%
Guyana	211,967	4,594	182,562	110,337	−40%	88,824	−51%	191,707	5%	250,956	37%
Paraguay	400,675	47,233	496,869	380,381	−23%	251,496	−49%	497,670	0%	599,140	21%
Peru	1,299,044	308,865	922,717	556,076	−40%	448,138	−51%	942,175	2%	1,202,038	30%
Suriname	145,973	7,914	141,562	83,839	−41%	64,152	−55%	145,858	3%	185,120	31%
Uruguay	178,378	60,619	125,929	88,071	−30%	67,292	−47%	126,284	0%	152,939	21%
Venezuela	916,774	500,326	691,372	460,285	−33%	371,038	−46%	715,163	3%	902,459	31%
Total South America	17,702,070	4,992,610	14,013,876.8	9,312,476	−34%	7,080,130	−49%	14,181,059	1%	17,617,998	26%
Caribbean											
Antigua and Barbuda	537	1,762	984.6	810.7	−18%	669.9	−32%	990.6	1%	1,144	16%
Bahamas, The	12,204	8,312	28,623	13,698	−52%	10,216	−64%	28,647	0%	35,302	23%
Barbados	448	4,322	322	298.7	−7%	216	−33%	329	2%	389	21%
Cuba	109,710	214,296	68,757	55,242	−20%	46,182	−33%	69,358	1%	82,987	21%
Dominica	778	728	586	428	−27%	357	−39%	563	−4%	717	22%
Dominican Republic	48,634	114,065	26,451	23,842	−10%	21,450	−19%	26,686	1%	31,803	20%
Grenada	349	1,179	288.8	264	−9%	237	−18%	293	2%	348	20%
Haiti	27,322	15,849	15,837	14,189	−10%	12,662	−20%	16,025	1%	19,111	21%
Jamaica	11,094	22,898	6,156	5,498	−11%	4,989	−19%	6,247	1%	7,396	20%
Saint Kitts and Nevis	198	1,090	201	153	−24%	138	−31%	170	−16%	243	21%
Saint Lucia	637	1,889	537	486	−10%	438	−19%	543	1%	606	13%
Saint Vincent and the Grenadines	343	1,079	692	197	−72%	148	−79%	678	−2%	852	23%
Trinidad and Tobago	5,038	39,730	6,016	3,377	−44%	2,286	−62%	6,246	4%	7,995	33%
Total Caribbean	217,292	427,199	155,453	118,485	−24%	99,988	−36%	156,775	1%	188,893	22%
Total Latin America & The Caribbean	20,405,403	7,643,266	15,351,558	10,461,474	−32%	8,081,190	−47%	15,531,239	1%	$ 19,227,547	25%

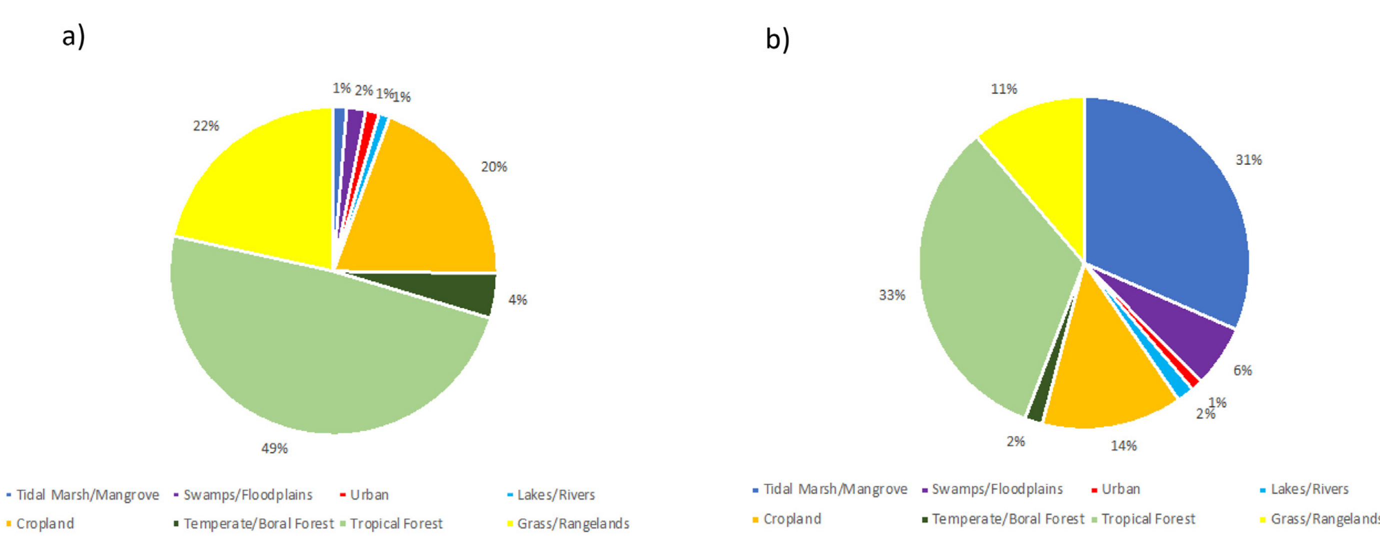

Fig. 1. a) Land-cover distribution of Brazil in 2011. b) Value of ecosystem services for each land-cover in Brazil in 2011.

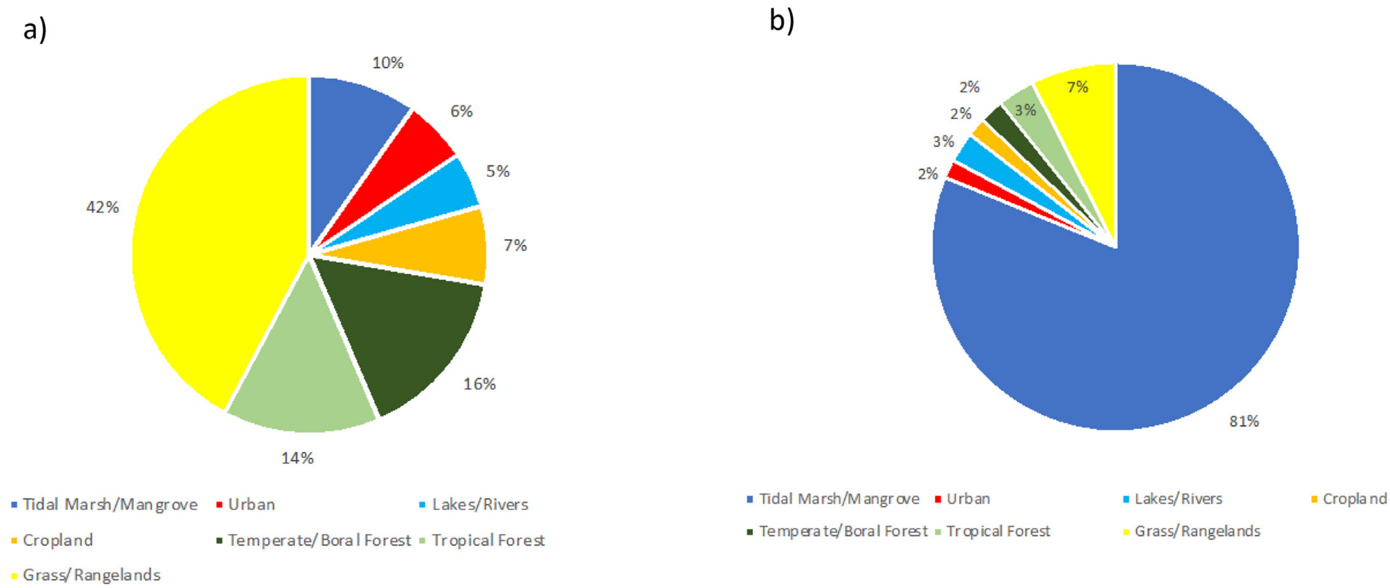

Fig. 2. a) Land-cover distribution of Bahamas in 2011. b) Value of ecosystem services for each land-cover in Bahamas in 2011.

variables interact with each other in some way), which is the core narrative of this scenario. Agriculture under this scenario has the highest production, with crop outputs and livestock outputs of 2 kilo tonnes and 204 million tonnes respectively. The impact of the high levels of production of these two economic activities, plus other ones in the Market Forces scenario, is reflected in the use of natural resources, which under this scenario are the highest. For example, water use could reach 0.5 trillion cubic meters, the highest of all the four scenarios, and energy demand is the second highest with 91 EJ. A fully market-oriented LAC would also experience the highest CO_2 emissions and the lowest forest cover, which are in part a product of the high agricultural activity.

On the other hand, the Great Transition scenario depicts a LAC with the lowest crop output (2.6 million kt and livestock output (159 million t) which are possible related with this scenario having the lowest population of all four, and the lowest consumption of meat. This as well is reflected in the Great Transition scenario having the lowest water footprint (0.2 trillion m^3) and carbon footprint (0.04 GtC), along with the highest forest cover (798 billions of ha). These environmental indicators show that the Great Transition scenario would represent a true green economy, one in which the levels of GDP and income per capita are the highest, while natural resources are consumed at the lowest level.

2. Methods

2.1. Land-cover change scenarios

Using the interactive web tool from the GIT website, Futures in Motion (www.tellus.org/results/results_World.html), we estimated land use change (urban, cropland, forest, grassland, desert), population, economic activity (GDP), and inequality, among other variables for the four scenarios described in the previous section to the year 2050.

Because wetlands are not included in the GTI scenarios, we estimated its cover based on past trends loss seen between 1997 and 2011 for the MF and FW scenarios (Costanza et al., 1997; Costanza et al., 2014; Millennium Ecosystem Assessment, 2005), a policy of "no net loss" for the PR scenario, and a wetland restoration policy for the GT scenario based on achieving wetland areas similar to those in 2000 (Costanza et al., 2014; Gascoigne et al., 2011; Mitsch & Day Jr, 2006).

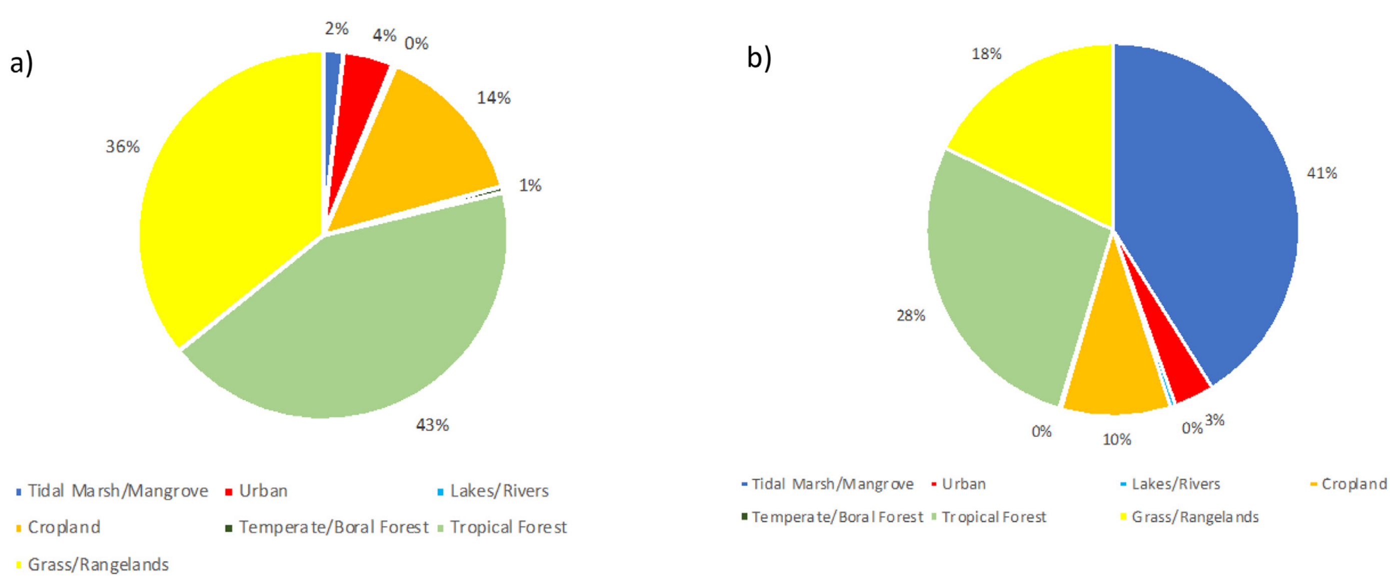

Fig. 3. a) Land-cover distribution of Costa Rica in 2011. b) Value of ecosystem services for each land-cover in Costa Rica in 2011.

Fig. 4. Land-cover map of Latin America and the Caribbean in 2010

2.2. Unit value change scenarios

The change in value of ecosystem services from each land-cover in the four scenarios respectively, was calculated in relation with two factors: 1) change in area covered by each ecosystem type, and 2) change in the "unit value" of each ecosystem (i.e. aggregate value of all the marketed and non-marketed ecosystem services per hectare per year) due to degradation or restoration. Management policies of land and water in each country determine the change of unit values of ecosystem services. These changes were separated out by evaluating the scenarios in two ways: a) using the 2011 unit values estimated by Costanza et al. (2014) and only changing land use, and b) changing both unit values and land use. Moreover, the 2011 unit values of each ecosystem are averages of values found in studies on natural capital valuation, and they were carefully evaluated by the TEEB initiative (de Groot et al, 2012). Due to the scale of the study, our estimates are a simplification of the reality, but they were sufficient for the purposes of this exploratory exercise.

The unit value changes in each scenario were calculated based on management and policy assumptions in each one of them. Furthermore, these changes also take into account the change in preferences of the people living in each scenario. For example, in the Fortress World scenario, it is assumed that society will follow a development path based on inequality and unsustainable use of natural resources, and therefore, unit values of ecosystems would decrease by 20%, and in the opposite case, in the Great Transition scenario, in which society achieve sustainable development, unit values would increase by 20%. These assumed percentages were based in a general way on the estimates from the Bateman et al. (2013) study of six future scenarios for the United Kingdom; they were used here as an illustration on how each development path described in each scenario have plausible changes on the value of natural capital, and therefore, can be

Fig. 5. Land-cover map of Latin America and the Caribbean in 2050 under the MF scenario.

applied in any region of the world. The following assumptions were made for each scenario:

- **Market Forces:** decrease in consideration of the environmental and non-market factors resulting in an average *10 per cent reduction in unit values* from their 2011 levels. In this scenario, climate change has not been dealt with.
- **Fortress World**: *significant* decrease in consideration of environmental and non-market factors resulting in an average *20 per cent reduction in unit values* from their 2011 levels. In this scenario, climate change has accelerated.
- **Policy Reform**: slight improvement from 2011 policies and management leading to *no significant change in unit values* from their 2011 estimates. In this scenario, climate change has been moderated.
- **Great Transition**: *significant* increase in consideration of environmental and non-market factors resulting in an average *20 per cent increase in unit values* from their 2011 levels. In this scenario, climate change has been addressed.

2.3. Mapping land-cover change

The spatial data of the change of land-cover for each scenario was created via a loose coupling with the scenario projection modelling. Each scenario was modelled to generate a change in land-cover at a 1 km^2 resolution for the following types: urban, wetland, cropland, forest, grassland, and desert. The value of ecosystem services attributed to land cover types does vary as a function of spatial scale of resolution (Konarska, Sutton, & Castellon, 2002). A modified version of the GlobCov (Global Land Cover map) from the European Space Agency was used as the original base data which is consistent across Latin America which insures comparability and also suggests our estimates are underestimates because the areal extent of high value land covers (e.g. rivers, wetlands, etc.) are often lost in coarse

Fig. 6. Land-cover map of Latin America and the Caribbean in 2050 under the FW scenario.

resolution data. In each scenario, land-cover increased or decreased according to the percentage change indicated in the previous sub-section, and these changes were adjacent to the existing original extent of that land-cover. Precedence for these land-cover changes occurred in the following order: urban, wetland, cropland, forest, rangeland/grassland, and desert. This precedence worked in such a way that all previous land-cover transitions are excluded from subsequent conversion (e.g. cropland cannot replace urban or wetlands).

3. Results

3.1. Values in 2011

The total terrestrial ecosystem service value (ESV) in 2011 of Latin America and the Caribbean is USD $15.3 trillion/year (Table 2). As expected, Brazil had the largest ESV, USD $6.8 trillion/year, due to its size and extensive rain forest cover. Argentina and Bolivia, although following Brazil in ESV in the region, have less than a third of the value with USD $2.2 and $1.3 trillion/year, respectively. Mexico is the country with the highest ESV in Mesoamerica, with a value of USD $849 billion/year, accounting for 72% of the ESV of this sub-region; while in the Caribbean Cuba has the highest, USD $68 billion/year.

Looking at the region through a lens of ecosystem services value per area per year, South America has the highest ESV of the three regions, USD $7900/ha/year. Nevertheless, at a country level, the Caribbean have the top 3 countries with the highest ESV per area per year of the region, The Bahamas ($23 thousand/ha/year), Saint Vincent and the Grenadines ($20 thousand/ha/year) and Antigua and Barbuda ($18 thousand/ha/year). In Mesoamerica, Costa Rica has the highest ESV per hectare at USD $8 thousand/ha/year.

Differences in values of ecosystem services per hectare are due to varying land-use management practices and policies in the countries and

Fig. 7. Land-cover map of Latin America and the Caribbean in 2050 under the PR scenario.

heterogeneity distribution of ecosystem services across the region. For example, the “weight" that certain land-covers or ecosystems have on the ESV is evident in countries such as Brazil, in which forest accounts for half of the land-cover of the country (Fig. 1a), but they provide a third of the ESV. Furthermore, while tidal marshes and mangroves cover only 1% of the territory, they provide 31% of the countries ESV (Fig. 1b), this is because these ecosystems are the most valuable of all assessed, USD $194000/ha, a very high value compared to ecosystems such as tropical forests that are valued in USD $5400/ha (Costanza et al., 2014). In Brazil, out of the 7408km of its coastline, 6786km contain mangrove forests (Schaeffer-Novelli, Cintrón-Molero, Soares, & De-Rosa, 2000), which provide a wide arrange of ecosystem services (Estrada, Soares, Fernadez, & de Almeida, 2015).

In the Bahamas, forests cover 30% of the territory, but account for only 5% of its ESV. This is also another clear example on how tidal marshes and mangroves play a key role in the provision of ecosystem services in the country. Here, these ecosystems cover 10% of the territory (Fig. 2a), but they constitute 81% of the ESV of the Bahamas (Fig. 2b). Despite the high contribution of mangroves to the country’s ESV, they are currently threated by several stressors such as coastal development, mainly in New Providence and Grand Bahama (Buchan, 2000).

A similar case happens with Costa Rica, where tidal marshes and mangroves cover 2% of the country (Fig. 3a) but are 41% of its ESV (Fig. 3b). Forest also provide a significant portion of the ESV of the country, 28%, with a forest cover of 43%. Costa Rica is known for his pioneering Payment for Ecosystem Services scheme that has played a key role in stopping deforestation by paying private land owners for the services that these ecosystems provide to society (Farley & Costanza, 2010; Pagiola, 2008; Porras, Barton, Miranda, & Chacón-Cascante, 2013); our results show that PES programs have a high potential on other ecosystems such as coastal ones.

These three countries provide a sound justification for ecosystems that provide highly valuable goods and services to society and therefore, the

Fig. 8. Land-cover map of Latin America and the Caribbean in 2050 under the GT scenario.

necessity to its conservation and promotion of financial mechanisms that are based in cost-benefit analysis.

3.2. Future values of ecosystem services

After 100 years from the Great Acceleration, in a world fully embedded in the Anthropocene, land-cover in Latin America and the Caribbean could change substantially under the four development scenarios that we assessed (Figs. Fig. 4–8). With land-cover change, values on ecosystem services of the region will decline the most under the Fortress World scenario with a 47% decrease. The Market Forces scenario also results in a significant decline of ESV in the region with a 32% decrease. The Policy Reform scenario would result in almost the same ESV as it is in the present, with only a 1% increase, while under the Great Transition scenario the ESV of the region would increase in 25% (Table 2).

At the sub-regional level, despite having the smallest area of the sub-regions analyzed, the Caribbean will experience the most change in ESV in the future under three of the four scenarios, decreasing 35% under the FW scenario, and increasing 3% and 30% under the PR and GT scenarios respectively. Furthermore, South America can experience a decrease of 49% of its ESV under the FW scenario, the highest decrease of all sub-regions.

At the country level, Saint Vincent and the Grenadines show the greatest potential ESV loss among the countries in the FW scenario with a decrease of 79%. This is a decrease of USD $545 million/year since the 2011 base value, which is equal to losing approximately half of the country's GDP (USD $1 billion in 2011). Saint Vincent and the Grenadines has already the challenge of forest management in the face of increasing demands for land intended for housing and agriculture; in addition to the threats that climate change poses on Small Islands Developing Stats like this, such as coastal erosion, droughts, floods and forest fires (Ministry of Health Wellness, 2013; UNEP, 2010).

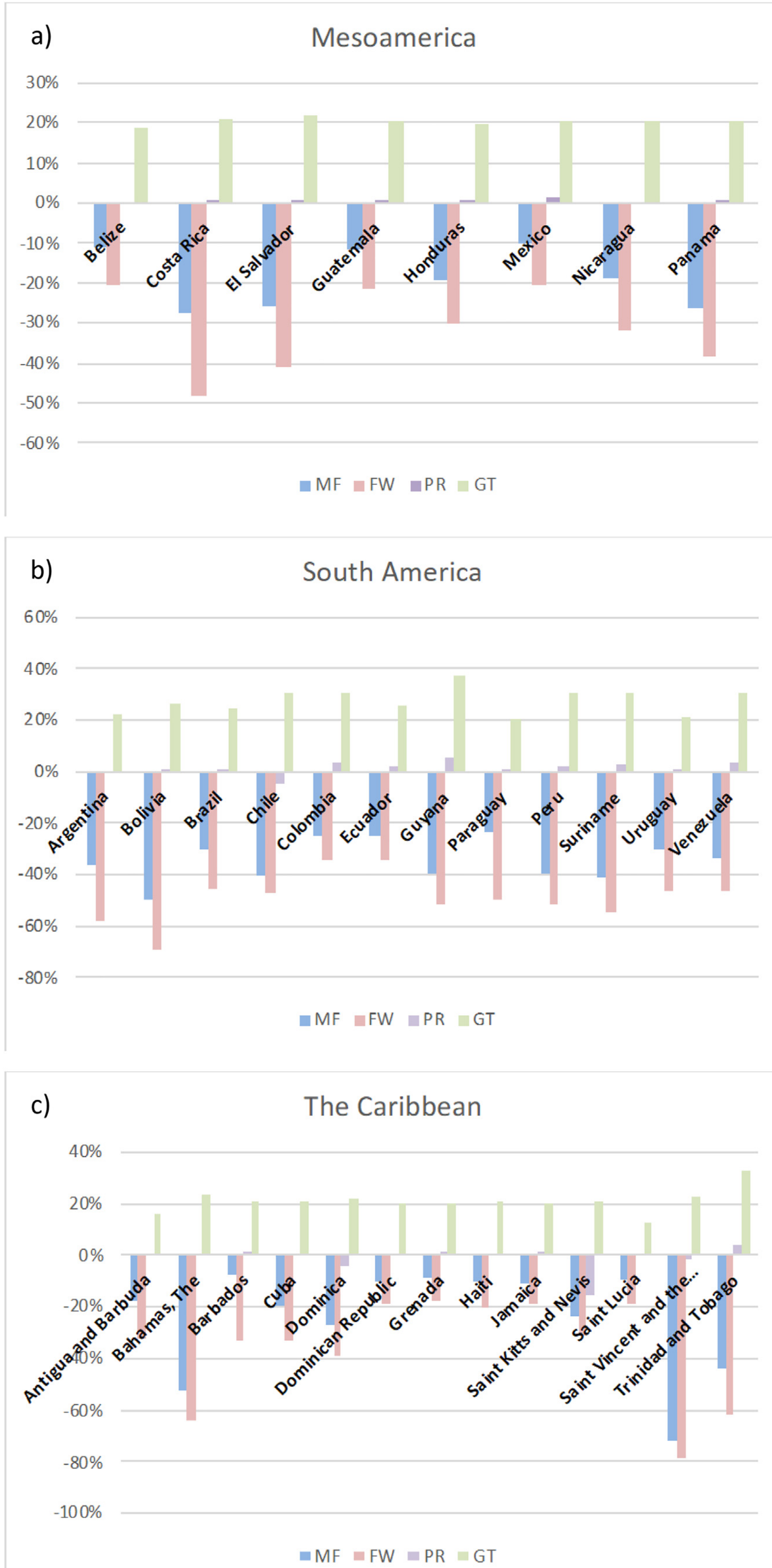

Fig. 9. Percentage of change of the total ecosystem services value in each scenario for Mesoamerica (a), South America (b) and the Caribbean (c).

In Mesoamerica, Costa Rica is the most affected under the MF and FW scenarios with a decrease in the ESV of 28% and 48% respectively, and in South America, Bolivia is the country with the highest decrease of ESV, also under these two scenarios, with a loss of 50% and 69% respectively. Under the PR scenario, the majority of the countries show little change in their ESV except for Saint Kitts and Nevis which experiences a 16% decline. The GT scenario shows a similar increase of ESV among Mesoamerican countries (between 19% and 22%), and the highest increase occurs in the Caribbean with an improvement of 37% in Guyana. The Caribbean is the region that will experience the greatest volatility (Fig. 9).

These results should be interpreted considering the following limitations and caveats. First, as in any other study on scenario analysis, scenarios are a simplification of plausible complex futures, and therefore, they are not predictions. Second, the value of ecosystem services for each biome is assumed to be constant over space, it is the potential supply of services from an ecosystem, but it is not related to the location and intensity of the demand from beneficiaries. This can be addressed in future studies by assessing specific services from which their beneficiaries are known or modelled.

Furthermore, the valuation method applied in Costanza et al., 2014 (i.e. value transfer) has some limitations of its own, such as the quantity of primary studies available for each targeted ecosystem service, difference in social, economic and ecological conditions between the study site (i.e. where the primary study was conducted) and the policy site (where the results of the primary studies are going to be applied/transferred). The potential errors that can occurred due to these limitations have been extensively studied (Bergstrom & Taylor, 2006; Brouwer, 2000; Johnston & Rosenberger, 2010); and several protocols has been put in place to reduce these errors (Colombo & Hanley, 2008; Richardson, Loomis, Kroeger, & Casey, 2015), which were considered in this study.

Finally, in our analysis and results of the change of land-cover and its ESV, some could argue the role that scarcity plays on their value, meaning that a loss of ecosystem services could raise their value since they would be scarcer, as in the case with marketed goods. Nevertheless, the majority of ecosystem services that we evaluated are non-rival, non-excludable, and non-marketed public or common property goods and services, which means that their unit values may not be affected significantly by relative scarcity from reduced area as much as by population demand. We assumed here that changes in supply are the major factor and the unit values will change mainly as a function of management policies and ecosystem health and condition that these imply (Kubiszewski et al., 2017).

4. Discussion

As described before, LAC is one of the most biodiverse regions of the world, but also struggles with high rates of poverty (Wodon & Ayres, 2000) and other social challenges. This makes both the environment and the communities that depend on it for their livelihoods very vulnerable to changes as the plausible ones calculated in this study, under different development scenarios. Moreover, it seems that in the current development path, the region is following similarly to MF, with a population and economic activity growing but at the expense of significant social and environmental impacts.

This tendency is shown in reports such as the GEO-6 Regional Assessment for Latin America and the Caribbean, which found that the region has a strong reliance on primary products and natural resources, both accounting for 50% of all good exports, and in the case of South America this is even more prominent due to extra-regional demands for agricultural (e.g. coffee, soybean and meat) and mineral (e.g. ores and metals) resources. Furthermore, international tourism receipts in the Caribbean were 45% of total exports, more than twice the amount earned by Mesoamerica, and 9 times greater than South America. The report concludes that although the rate of conversion of natural systems has begun to slow, the overall rate of loss of ecosystems remains high (UNEP, 2016).

Reaching a development as the one described in the GT scenario will require an integral and perhaps escalated approach, finding solutions for the most urgent social problems (e.g. extreme poverty and inequality) that constitutes the bases to address the economic challenges, both being the pillars towards environmental sustainability. The GT scenario, and to some extent the PR scenario, take into consideration many of the 17 Sustainable Development Goals agreed by all the UN member states in 2015 as part of the 2030 Agenda for Sustainable Development (United Nations, 2015).

The key challenge on maintaining and enhancing ecosystem services is the development of strategies that reduce the negative environmental impacts of land use across multiple services and scales while maintaining social and economic benefits, balancing short-term and long-term needs (Foley et al., 2005), at the same time that “tipping points” are considered (Galaz, 2014). A well-known example that this is possible is the case of Costa Rica, a country with no army, with 5% of the planet’s biodiversity, electricity produced by more than 95% renewable energy, and that has not only stopped deforestation rates, but it has also reverted it, having more forest every year at the same time its GDP is growing, with incomes per capita that are double than what they used to be three decades ago, and providing universal access to health care and education (Stiglitz, 2018).

Bold development decisions in Costa Rica, such as eliminating the army, or switching to an economy based more on nature conservation rather than the former economic strategy based on agriculture, required decision makers to imagine a future that, a few decades ago, seemed not plausible or too different from the development path other countries were following. Nevertheless, current policy in the great majority of countries around the world, is based on the wrong assumption that the future will be similar to the present, making policies obsolete and unadaptable to unforeseeable surprises.

Scenario planning exercises on natural capital as the one presented here, help decision makers to develop policies under a shared goal of environmental sustainability, making evident the intrinsic relation between economic development and nature conservation, enhancement and restoration. Conducting this type of studies will provide policy makers a clear picture of plausible changes in economic benefits from healthy ecosystems according to different development paths, as well as to identify which land covers could be protected or restored in order to get the highest economic gains (which should be done in combination with ecological and biophysical assessments), representing a unique opportunity to produce cost-benefit analysis in the present and future.

5. Conclusion

This study is the first of its kind for Latin America and the Caribbean, providing values of the ecosystem services for all 33 countries of the region for the present and the future. Our estimates show how different management options, and development priorities, can have a significant impact on land-cover and its ecosystem services. The ecosystem service value of Latin America and the Caribbean range from USD $19 trillion under the GT scenario to USD $8 trillion under the FW, a difference equivalent to a 145% of the region’s GDP in 2011.

The change in ecosystem services values under plausible scenarios highlight the fundamental role that healthy ecosystems have in achieving global objectives such as the Aichi Targets (specially target 14) of the Convention of Biological Diversity, the Sustainable Development Goals, in which natural capital (goals 6, 13, 14 and 15) is the cornerstone that sustains the rest of the goals, and the 1.5°C temperature increase limit of Paris Agreement of the United Nations Framework Convention on Climate Change. The economic value of the services that we assessed here is a clear message for policy makers of the importance that nature based solutions have on the sustainable development, both through its conservation and its restoration.

The process of scenario planning can be applied in the development of new policies as well as in the assessment of current policies to determine how vulnerable they are under plausible futures as the ones we used here. This tool provides a vision on how a development based on ecological economics, in which the issue of scale is consider as the main component of economic development, can yield a myriad of benefits to people, that expands beyond economic benefits, including cultural and spiritual ones that are intricately linked to nature conservation.

We suggest applying this approach at national level through a participatory process in order to include the interests of many stakeholders from different sectors, this can be done through workshops on participatory planning and narrative development for each scenario. This process by itself represents a good opportunity for different sectors of society to become aware of development issues beyond their domain, understanding the needs of the other sectors and hence improving their strategic planning towards a more integral one.

The results of this study are a first approximation to the present and future value of natural capital. Further research on this should take into consideration key factors such as the non-linear behavior of drivers of change and its associated tipping points, the participation of different sectors of society at local scale that can provide new visions of plausible futures that were not taken in consideration at the global and regional scale, and the role of communication using novel approaches such as visual arts and science fiction narratives in order to engage a wider public.

Declaration of Competing Interest

None.

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