CHAPTER **5**

CURRENT AND FUTURE INTERACTIONS BETWEEN NATURE AND SOCIETY

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5.1 EXECUTIVE SUMMARY

1 **One hundred per cent of the natural units of analysis will continue to be negatively affected, with a concomitant decrease in nature's contributions to people, given current trends (business as usual), though the magnitude and exact mechanism of the individual drivers will vary by driver and unit of analysis (*established but incomplete*) {5.4}.** For example, tropical moist and dry forest and coastal mangroves will continue to exhibit a decline due to land use change regardless of the scenarios considered, but different local factors (agriculturalization and urbanization, respectively) will be involved (*well established*) {5.4.1, 5.4.11}. Additionally, some drivers will affect units of analysis differently. Empirical evidence indicates differential effects of climate change: boreal forest is extending northward {5.4.2}, while tundra is diminishing in land area (*established but incomplete*) {5.4.3}. Thus, some drivers, and their relative roles, will need to be further refined on a local scale and with respect to their proximate factors.

2 **Multiple drivers will act in synergy and further produce biodiversity loss and impact nature's contributions to people in most of the units of analysis for the Americas (*established but incomplete*) {5.4}.** Climate change, combined with other drivers, is predicted to account for an increasingly larger proportion of biodiversity loss in the future, in both terrestrial and aquatic ecosystems {5.3}. Forest fragmentation, climate change and industrial development increase risk of biodiversity and nature's contributions to people loss i.e. dry forest unit of analysis {5.4.1.2}. Predictions on invasive species and climate change indicates an increase in habitable areas and their potential impacts on different units of analysis {5.3}.

3 **Changes in temperature, precipitation regime and extreme climate events are predicted to impact all units of analysis in the Americas (*well established*) {5.4}.** Climate change and the potential impacts on tropical dry forests by changing the frequency of wildfires; change in forest structure and functional composition in the Amazon tropical moist forest; extreme drought events changing nature's contributions to people in the Amazon region; insect outbreaks and changes in albedo are predicted to significantly impact temperate, boreal and tundra units of analysis, affecting society and indigenous communities and well-being {5.4}.

4 **Thresholds, or tipping points (conditions resulting in rapid and potentially irreversible changes) may have already been exceeded for some ecosystems and are likely for others (*established but incomplete*).** For instance, it is considered more likely than not that such a threshold has already been passed in the cryosphere with respect to summer sea ice (*established but incomplete*) {5.4.12}. Model simulations indicate changes in forest structure and species distribution in the Amazon forest in response to global warming and change in precipitation patterns (forest die-back) (*established but incomplete*) {5.4.1}. So too, a 4oC increase in global temperatures is predicted to likely cause widespread die off of boreal forest due to greater susceptibility to disease {5.4.2} and global temperature increases may have already started persistent thawing of the permafrost {5.4.3}. Under 4°C warming, widespread coral reef mortality is expected with significant impacts on coral reef ecosystems {5.4.11}. Sea surface water temperature increase will cause a reduction of sea grass climatic niche: those populations under seawater surface temperature thresholds higher than the temperature ranges required by the species could become extinct by 2100 with concomitant loss of ecosystem services.

5 **Changes in nature and nature's contributions to people in most units of analysis are increasingly driven by causal interactions between distant places (i.e. telecouplings) (*well established*) {5.6.3}, thus scenarios and models that incorporate telecouplings will better inform future policy decisions.** Nature and nature's contributions to people in telecoupled systems can be affected negatively or positively by distant causal interactions. Provision of food and medicine from wild organisms in temperate and tropical grasslands, savannas and forests of South America is being dramatically reduced due to land-use changes driven by the demand of agricultural commodities (e.g. soybeans) mainly from Europe and China. Conservation of insectivorous migratory bats in Mexico benefits pest control in agroecosystems of North America, resulting in increased yields and reduced pesticide

costs. Trade policies and international agreements will thus have an increasingly strong effect on environmental outcomes in telecoupled systems.

6 Policy interventions have resulted in significant land use changes at the local and regional scales and will continue to do so through 2050. These policies have affected nature's contributions to people both positively and negatively, and provide an opportunity to manage trade-offs among nature's contributions to people (*well established*) {5.4}. Land use changes are now mainly driven by high crop demand, big hydropower plans, rapid urban growth and result in a continued loss of grasslands {5.4.4, 5.4.5}. However, strategies for establishing conservation units have helped in reducing deforestation in the Brazilian Amazon from the period of 2004 to 2011 (*well established*) {5.4.1}. Similarly, wetland protection policies and regulation have helped reduce the conversion of wetlands in North America {5.4.7}. Policies based on command and control measures may be limited in providing effective reduction in ecosystem loss and should be complemented with policies acknowledging multiple values {5.6.3}.

7 Policy interventions at vastly differing scales (from national to local) lead to successful outcomes in mitigating impacts to biodiversity (*established but incomplete*) {5.4}. For instance, long-established governmental protections of wetlands in North America have significantly slowed and may have stopped wetland loss based on acreage {5.4.7}. In South America, where mangrove loss continues at a rate of one to two per cent, different stakeholders such as local communities and/or governments have been successful in protecting mangroves based on empowerment and shared interests in their preservation {5.4.11}.

8 Pressures to nature are projected to increase by 2050, negatively affecting biodiversity as indicated by a potential reduction of the mean species abundance index. However, the magnitude of the pressures by 2050 are expected to be less under transition pathways to sustainability in comparison to the business as usual scenario (*established but incomplete*), {5.5}. The Global Biodiversity model projected that under the business as usual scenario mean species abundance had decreased in the Americas by approximately 30 per cent by 2010 compared to its values prior to European settlement of the New World, with historical losses primarily attributed to land transformation to agricultural uses. Using the Global Biodiversity model, there is an additional projected loss of 9.6 per cent by 2050, primarily attributed to some additional land use changes , and especially to climate change, which will steadily increase relative to other drivers considered in the model. However, under the transition pathways to sustainability of global technologies, decentralised solutions, and consumption change pathways, the projected losses are 6 per cent, 5 per cent, and 5 per cent, respectively, achieving a relative improvement of approximately 30 per cent to 50 per cent compared to the business as usual scenario. Under these pathways, climate change mitigation, the expansion of protected areas and the recovery of abandoned lands would significantly contribute to reducing biodiversity loss.

9 Participative scenarios have proven to be a successful tool for envisioning potential futures and pathways and to embrace and integrate multiple and sometime conflicting values and their role in promoting bottom-up decision making in the face of future's uncertainties (*well established*) {5.3}. The use of participative approaches to develop scenarios has increased during recent years in the Americas. The inclusion of different stakeholders and their knowledges in the process of constructing potential futures has promoted a better understanding of the complexity of the social-ecological systems in which they are embedded. This has enhanced co-learning processes between all actors involved, even those normally under-represented in decision-making activities. As a result, several participative scenario exercises have motivated community-based solutions and local governance initiatives all pointing towards the development of adaptive management strategies {5.3}.

10 Pathways that consider changes in societal options will lead to less pressure to nature (*established but incomplete*) {5.6.3}. An example is the indirect impact that shifts in urban dietary preferences have on agricultural production and expansion, and food options that are expected to continue growing into the future. Therefore, not only is there a strong connection between urbanization and economic growth, but also between affluence (and urban preferences) and the global displacement of land use particularly from high-income to low-income countries.

11 Available local studies informing regional futures of nature and nature's benefit to people do not allow scalability as of yet (*well established*) {5.3}. The challenge in expanding the findings from local studies resides in the fact that a number of comparable local studies are still not available. Information is scattered throughout the region by the use of different units, methods and scales, which prevents a local-to-regional generalization. The list of "nature" indicators used in studies at local scales is large and heterogeneous (*well established*). Even for the same indicator (e.g. biodiversity), different metrics are used (e.g. species-area curve, mean species abundance) {5.5}. In other cases, multiple indicators are used to describe different aspects of biodiversity and ecosystem services. In this latter case, synergies and trade-offs are explicitly mentioned with a clear pattern in which increasing the provision of some indicators result in the detriment of others {5.3}. For example, agriculture expansion leading to loss in biodiversity illustrates a common trend from local studies expected to continue into the future.

12 **There is a significant research gap in the development of models and scenarios that integrate drivers, nature, nature's contributions to people and good quality of life (*well established*) {5.3}.** Models and scenarios can be powerful tools to integrate and synthesize the complex dynamics of coupled human and nature systems, and to project their plausible behaviors into the future. Most existing models and scenarios focus on the link between drivers and its impacts on nature. Few cases exist in which models or scenarios integrate the relationships between changes in nature and changes in nature's contributions to people and good quality of life {5.3}. Inter-and trans-disciplinary modeling efforts will be required to address this research gap {5.3}.

5.2 INTRODUCTION

The IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) conceptual framework illustrates the complex relationships between natural systems and human well-being and how these relationships are determined through the interdependence of the various components. These components include the specific biological system, Nature's Contributions to People (NCP, which includes both ecosystem goods and services and natures' gifts), direct and indirect drivers affecting the system, and the perceived value of the NCP. Previous chapters considered the breadth of NCP, the status and trends of biodiversity, and the major direct and indirect drivers affecting NCP. This chapter aims to: 1) integrate these components by examining what is known with respect to the relationships between them in the Americas; 2) examine what the future state of biodiversity and NCP may be under different plausible future conditions (i.e. "scenarios"); and 3) discuss the establishment of a framework, or pathway, to inform the policy process to attain a sustainable future.

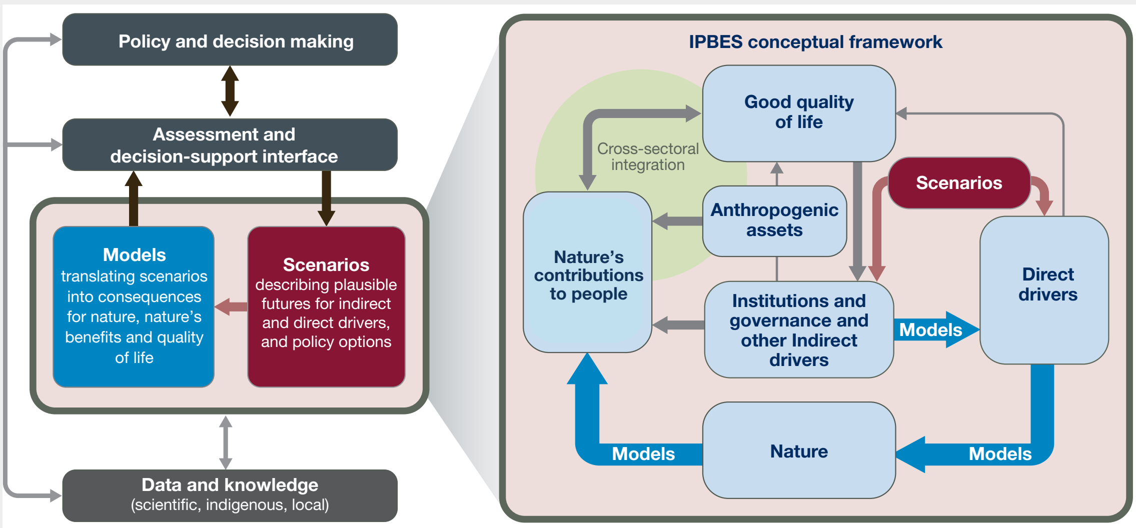
To achieve integration of the framework components we relied on two sources of information: 1) the empirical information presented in earlier chapters of this assessment; and 2) modeling studies. As described in 1.2.6, (IPBES, 2016), and as depicted in **Figure 5.1**, models are "qualitative or quantitative descriptions of key components of a system and of the relationships between those components", which can be used to assess how systems function or how changes in a system may result in altered outcomes. In the case of this chapter, models involving the components of the IPBES framework can inform us as to likely future conditions, the possible result of policy interventions, or help us define pathways to a more sustainable future and more equitable distribution of NCP among sectors of society or regions. However, it should be noted that even the best models are only approximations of reality and they all have some degree of uncertainty associated with them (Maier *et al.,* 2016). We then evaluated this information through the lens of four major classes of scenarios.

Due to the complexity of the issue of biodiversity and NCP, as well as the universe of possible policy interventions, there are an almost infinite number of scenarios that can be constructed and on which models can be based; Hunt *et al.* (2012) report that over 450 scenarios relating to NCP have been developed. However, as compellingly argued by Hunt *et al.* (2012), van Vuuren *et al.* (2012), IPBES (2016) and Kubiszewski *et al.* (2017), scenarios can be grouped according to a limited number of "archetypes" or families, originally identified by the Global Scenario Group (Gallopin & Rijsberman, 1997). The archetypes encompass four main themes: 1) Market Forces; 2) Fortress World; 3) Policy Reform; and 4) Great Transition.

- **Market Forces:** This 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.

- **Policy Reform:** This 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.

Figure 5 1 **IPBES Conceptual framework and high-level roles of scenarios and models in assessment and decision support. Source: IPBES (2016).**



- **Fortress World:** This scenario is a variant of a broader class of Barbarization scenarios in the hierarchy of the Global Scenario Group. 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.

- **Great Transition:** This scenario explores visionary solutions to the sustainability challenge, including new socioeconomic arrangements and fundamental changes in values.

Comparison of future conditions among the archetypes can be informative as they present a continuum of possible future conditions and can highlight the implications to NCP of continuing on the world's current path, or veering to better or worse paths with respect to biodiversity conservation. Consistent with the basic uses of modeling, they can also be used to develop more detailed pathways to different possible futures.

This chapter follows a logical progression, starting from a synthesis of the modeling literature at local scales, to consideration of the empirical evidence of chapters 2, 3 and 4, to consideration of global modeling efforts and their applicability to the Americas. Thus, in section 5.3, literature involving local scales is reviewed and synthesized into the larger context of the regional scale. In section 5.4, we elaborate narratives for the units of analysis based on focal issues of importance to the Americas Region drawn from the information contained in chapters 2, 3 and 4. section 5.5 examines the results of global-level modeling, and how global databases and models can be used in the America's context. Section 5.6 examines present thoughts on particularly important considerations in the development of pathways to a sustainable future. Throughout development of this chapter, we were able to identify clear limits to the modeling approach imposed by lack of data or simply the fact that the modeling has not been done. These "data gaps" provide guidance as to future areas in need of research to generate data for more in-depth and expansive analyses with respect to geography, status and trends of biodiversity and its indicators, and direct and indirect drivers; we consider these, along with our conclusions section 5.7.

A separate IPBES effort is focusing on the concept of sustainable use of biodiversity, and hence, sustainability is not the focus of this assessment specifically. However, when we consider the integration of NCP, trends in biodiversity, drivers, and policy in this chapter, we are doing so with the ultimate purpose of informing not only policy makers, but other IPBES teams with respect to issues related to sustainability. Thus, discussions related to resource exploitation, pollution, and land use change are intimately related to sustainability and will be considered, as appropriate, throughout this chapter.

5.3 INFORMING THE FUTURE FROM LOCAL STUDIES

Given the regional diversity of ecosystems, the heterogeneity of social groups, different types of local knowledge and country-based environmental decisions and policies, transformation processes are expected to occur at different magnitudes and in response to the influence of distinct drivers of change throughout the region. Arguably, a precise understanding of future trends of biodiversity and nature's contribution to people for the Americas, the role that different drivers, models and scenarios play in this understanding, and the amount of synergies and trade-offs between them requires the analysis and synthesis of studies developed at local scales.

In an attempt to elucidate what is known concerning the relationships between indirect and direct drivers, direct drivers and nature, and nature and nature's contribution to people, a literature search was conducted to identify studies with a local scope that used a prognostic approach through "modeling" to determine the nature, form and future projections of those relationships. Within this context, models are seen as "qualitative or quantitative descriptions of key components of a system and of the relationships between those components" (IPBES, 2016). We conducted an initial literature review based on Thompson Reuters Web of Science database using an open search approach in which different combination of search terms were used (e.g. scenarios, ecosystem services, biodiversity, participative scenarios, nature's futures, visions, land use change scenarios, climate change scenarios). The search lasted until September 2016. From each document, the abstract was evaluated for its suitability for the chapter where the main criterion was that analyses use projections, trends or narratives into the future. Subsequently other documents were identified through the list of references as well as recommendations by third parties. This led to a selection of 36 local case studies published between 2001 and 2017 **(Figure 5.2)**.

The consulted literature could be categorized into 3 groups: studies mainly with a social science perspective (accounting for 25% of the total), those with an economic focus (17% of the total) and predominantly ecological studies (58% of the total), aiming at understanding current drivers, indicators and trends in the use of ecosystem services. These groups, however, are not mutually exclusive as some of the studies do apply to more than one category.

The first group, with a predominantly social sciences approach, focused mostly on stakeholders' perceptions and dependence on ecosystem services (Cárcamo *et al.,* 2014; Riensche *et al.,* 2015), community adaptation

Figure 5 2 **Geographic distribution of the 36 local studies used for the analysis.**

Yellow: social studies; Purple: ecological studies; Blue: economic studies. Source: own representation visualized in google maps.

ECONOMIC STUDIES

- Willamette Valley
- Suriname
- Belize
- Glacier National Park
- Peoria
- Región de los Lagos

SOCIAL STUDIES

- Rio Xingu
- Departamento Santa Cruz
- La Huerta
- Araucanía
- Tom Yawkey Wildlife Center
- Sierra Juarez
- Coquimbo
- Bahía Blanca
- Utria National Park

ECOLOGICAL STUDIES

- Cabo Pulmo
- Sierra Divisor
- Provincia Gran Chaco
- Carmo de Minas
- Rocky Mountain National Park
- Minas Gerais
- Mato Grosso
- Manuripi Heath National Amazon Reserve
- Santa Cruz de la Sierra
- Amazonas
- Southern Nebraska
- Eastern Norther American forests
- Atlantic Forest
- Michigan
- Contiguous United States
- Washington State
- The Americas
- Brazil
- USA & Canada
- Colombia
- North America

responses (Brown *et al.,* 2016), the political process in nature conservation (Manuschevich & Beier, 2016), effects of natural phenomena on people and property (Arkema *et al.,* 2013) and social implications of land use change (Evans *et al.,* 2001; Mastrangelo & Laterra, 2015; Tejada *et al.,* 2016).

A commonality in this type of studies is the use of participative approaches for scenario development. In a recent review and analysis of several participative scenario exercises, Oteros-Rozas *et al.* (2015) grouped different studies according to their application and utility. Studies were placed in each of the four identified clusters as follows:

- **Cluster 1:** studies that performed desirability and vulnerability analysis. These studies broaden the thinking of social actors about social-ecological systems and also identified the stimulation of creative and complex thinking as a strength (Beach & Clark, 2015; Quinlan, 2012; Ruiz-Mallén *et al.,* 2015).

- **Cluster 2:** studies that identified stakeholders and drivers of change before workshops, and developed backcasting during the participatory process. They aimed to understand the social and institutional mechanisms behind management decisions and they recognized insights for landscape management as a positive outcome (Vilardy-Quiroga & González Novoa, 2011).

- **Cluster 3:** studies that identified direct drivers of change prior to participatory scenario planning and explicitly included uncertainty. They aimed to promote community-based solutions and recognized as a positive outcome having engaged social actors that are unrepresented in decision making (e.g. Mistry *et al.,* 2014).

- **Cluster 4:** studies that used modeling as a quantitative technique after a workshop and monitoring processes. They aimed to facilitate sharing experiences among stakeholders in a creative and collaborative way. In this cluster, a complex understanding of the current situation and the co-learning process between scientists and nonacademic stakeholders were highlighted by researchers as positive outcomes (e.g. Peterson *et al.,* 2003; Ravera *et al.,* 2011a, 2011b; Waylen *et al.,* 2015).

The second group, which makes predominant use of economic tools was concerned with the valuation of ecosystem services (Nelson *et al.,* 2009; Outeiro *et al.,* 2014), land use changes (Schneider *et al.,* 2012), combining agricultural productivity with conservation (Latawiec *et al.,* 2014), economically beneficial climate change adaptation strategies (Rosenthal *et al.,* 2013), and forestry and future land use (Radeloff *et al.,* 2011).

The third group's studies discuss issues from an ecological perspective. They encompass issues such as deforestations' causes and effects, landscape fragmentation (Piquer-Rodríguez *et al.,* 2015; Zanella *et al.,* 2012), land use change (Aguiar *et al.,* 2014; Del Toro *et al.,* 2015; Lawler *et al.,* 2014), bioclimatic niches (Giovanelli *et al.,* 2008; Uden *et al.,* 2015; Urbina-Cardona & Castro, 2010; Urbina-Cardona & Flores-Villela, 2010; West *et al.,* 2015), ecological interactions (Bello *et al.,* 2015; Jarnevich *et al.,* 2017), impacts of agriculture on biodiversity (Chaplin-Kramer *et al.,* 2015), effect of anthropogenic occupation to nature and nature's contribution to people (Duggan *et al.,* 2015; van Soesbergen & Mulligan, 2014; Verutes *et al.,* 2014), as well as general effects of agriculture and forestry on nature (Aguiar *et al.,* 2016; Giannini *et al.,* 2015; Müller *et al.,* 2014; Uden *et al.,* 2015). Studies investigating scenarios or future trends of the condition of marine ecosystems are scarce in the Americas but the review analysis of Teh *et al.* (2016) investigating the future of Canada´s oceans and marine fisheries is a good example to elucidate how environmental change and socioeconomic pathways will play a role on marine ecosystems integrity.

Forty seven percent (47%) of the studies analyzed include a multiple driver approach. The analysis revealed an impressive diversity for both direct and indirect drivers affecting nature. Among them, urbanization, climate change, political process and land use change were the most cited. In general, these local studies show that anthropogenic drivers affect nature and nature's contribution to people both indirectly through policy and directly through immediate changes in nature as caused by such factors as deforestation. Importantly, among the studies, a particularly strong correlation is found for land use change as a driver of deforestation.

Another important finding from the local literature regards to biological invasions that, acting in synergy with climate change, are predicted to increase areas suitable for exotic species such as reptiles like *Lithobathes catesbeianus* (Bullfrog) in Brazil and Colombia (Giovanelli *et al.,* 2008; Roura-Pascual & Suarez, 2008; Urbina-Cardona & Castro, 2010). By 2050, *Hemidactylus brookii* (now *H. angulatus*) and *Hemidactylus turcicus* could increase their range by 72.6% and 33.5% of Colombia's area, respectively.

The most common indicator to measure human's impacts on nature across the analyzed studies was deforestation, second was biodiversity loss. Although, the diversity of indicators was large among the analyzed studies.

With regards to indicators, the first group of studies used indicators of nature´s contribution to people such as freshwater quality, climate regulation, aesthetic values, value of biodiversity and resource availability. The value of ecosystem services and productivity were also found as indicators. Human well-being indicators were human vulnerability to natural disasters and dependency on ecosystem services.

The second group of studies used mostly monetary valuation of ecosystem services as an indicator. Typical economic indicators were land use and economic benefits of land use change as for example the shifts from agricultural to urban land use and cover (Schneider *et al.,* 2012).

The third group of studies mostly presented ecological indicators such as change in forest cover and connectivity, deforestation dynamics, species distribution, biodiversity, carbon storage and emissions, change in species compositions and abundance, and effects of anthropogenic activity on nature, such as water quality.

Among the studies, the most common trends linked to the "economy prevails" archetype were biodiversity loss due to agriculture or forestry and the negative impacts of urbanization. The positive impacts of more strict environmental conservation legislation found in the studies can be linked to the "policy reform and great transition" archetypes.

Studies showed very clear negative effects on nature by urbanization, intensified agriculture (Chaplin-Kramer *et al.,* 2015; Müller *et al.,* 2014) and forestry, energy production and climate change. However, by changing to sustainable agricultural practices, productivity could be increased with less impact to biodiversity (Latawiec *et al.,* 2014). One important recommendation found is that in political processes, the relationship between political dynamics and economic processes, communication and early stakeholder engagement as well as more equitable access to ecosystem services should be addressed by decision makers (Cárcamo *et al.,* 2014; Manuschevich & Beier, 2016).

In summary, the biggest challenge informing regional futures of nature and nature's contribution to people from local studies is that the limited number of studies, different methodologies and heterogeneity (in terms of indicators, drivers and trends) produce a number of different results. This makes scalability (from local to regional) a challenge yet to overcome. There is a clear need for the production of comparable studies at the local level that can aid to better understand the region. Narratives scenarios at the local scale, similar to the ones developed by the Global Environmental Outlook-6 for Latin America and the Caribbean, could well bridge this gap. Despite current scarcity of such studies, it was possible to draw preliminary findings on how the region can be informed through local studies. For example, the presence of agriculture expansion leading to loss in biodiversity illustrates a common trend from various local studies suggesting plausible scalability.

In conclusion, there are two major issues that emerge:

1. Although models can be a powerful tool to integrate and synthesize the complex dynamics of coupled human and nature systems, a major gap on modeling and scenarios, identified from the literature review is related to the lack of studies integrating changes in nature with changes in NCP and good quality of life. Consequently, the complexity of these interactions and feedbacks are still not fully represented in the models.

2. The second issue to point out regarding the current understanding of the relation between human and nature through modeling and future scenarios, concerns the scale and feedbacks considered in the analysis. Global models represent quite well broad trends and analysis, however, there remains a gap in downscaling this information and the feedback from the global approach to the regional and local: a gap to be filled in the future. As well, local studies, representing specific trends in a specific unit of analysis is not frequently upscaled to larger areas. Within this same logic, issues of telecoupling are not well represented either.

5.4 INFORMING THE FUTURE FROM REGIONAL STUDIES: FOCAL ISSUES WITHIN UNITS OF ANALYSIS AND OTHER ECOLOGICAL SYSTEMS

This section presents syntheses of the information contained in Chapters 2, 3, and 4; focusing on key issues within the IPBES framework. As it is not possible to comprehensively consider all of the units of analysis within each subregion, and that the units of analysis do not address some commonly recognized socioecological systems important in the Americas, we present the information at the regional level, and in the narratives, we concentrate on specific issues that we feel are illustrative of the issues in general. With respect to the information contained in the figures based on the IPBES framework, for NCP, indirect drivers, and direct drivers, the primary bullet items follow the nomenclature and taxonomy of the issues as presented in Chapters 2, 3, and 4. However, for the sub-bullets, as well as the boxes corresponding to quality of life, anthropogenic assets, and nature, we used the terminology as cited or interpreted from the literature. While this results in a profusion of terms, it also gives a sense of the lack of consistency in describing drivers and NCP in the literature; we felt this appropriate in order to convey the many ways that these factors are viewed and referred to.

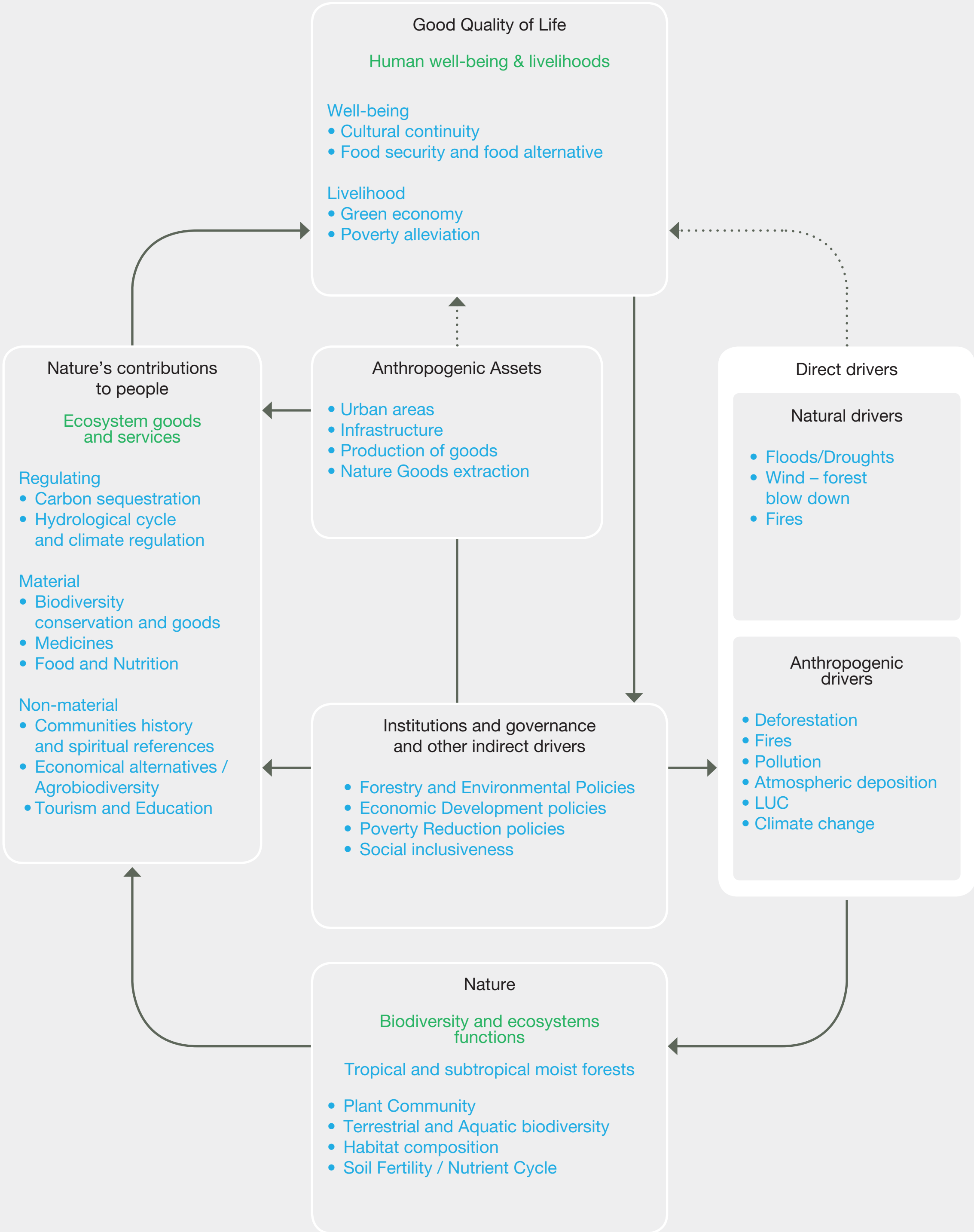
5.4.1 Tropical and subtropical dry and moist forests UAs – Trade-offs between multiple ecosystem goods and services and scale effects

5.4.1.1 Tropical and subtropcial moist forests

Forests are extremely important ecosystems because of their multiple functions in biodiversity conservation and ensuring long-term environmental stability, while providing a variety of economically-important products and services (De Costa, 2011). Tropical forests cover 10% of all land area (i.e. 1.8×107 km^2) (Mayaux *et al.,* 2005), and represent about half of global species richness. Clearing of these forests is estimated to account for 12 per cent of anthropogenic carbon emissions (Dirzo & Raven, 2003). Over half of the tropical-forest area (1.1×107 km^2) is represented by moist tropical forests (also called 'moist tropical forests', 'wet tropical forests', or 'tropical rainforests'), characterized by high tree-species diversity and high biomass density (Ter Steege *et al.,* 2003).

Asner *et al.* (2009), alarmingly wrote "In recent decades the rate and geographic extent of land-use and land-cover change has increased throughout the world's moist tropical forests. The pan-tropical geography of forest change is a challenge to assess- and improved estimates of the human footprint in the tropics are critical to understanding potential changes in biodiversity. We combined recently published and new satellite observations, along with images from Google Earth and a literature review, to estimate the global extent of deforestation, selective logging, and regrowth in moist tropical forests. Roughly 1.4% of the biome was deforested between 2000 and 2005". According to the Global Forest Resources Assessment (FAO, 2015) of the Food and Agriculture Organization of the United Nations (FAO), compiled by Keenan *et al.* (2015), indicate that, in the period from 1990 to 2015 Central America lost 25% of forest cover, South America lost 10%, North America gained 0.4% and the Caribbean gained 43%. At global level, the tropical forest suffers the biggest pressure, with higher deforestation rates. Despite the reduction in the past 25years, deforestation is still in high levels. In the period from 1995 to 2000, the raters were at 9.54 million/hectares/year, while from 2010-2015, the rates fell to 5.52 million/ha/year (Keenan *et al.,* 2015). Carbon emissions from tropical

Figure 5 3 **Tropical and subtropical moist unit fof analysis viewed in the IPBES conceptual framework. Source: own representation.**



deforestation were at the range of 2.9 ± 0.47 PgC/year during the period from 1990-2007 (Pan *et al.,* 2011). From the period from 2000 to 2005, Asner *et al.* (2009), estimated that about 20% of the moist tropical forest biome was undergoing some level of timber harvesting, and that forest regeneration on this unit of analysis was basically occurring in hilly, upland, and mountainous environments, which are areas considered marginal for large-scale agriculture and ranching. Aside from deforestation, another growing threat to moist tropical forests, especially to indigenous land and protected area, is mining (Ferreira *et al.,* 2014; Boillat *et al.,* 2017).

For biodiversity however, droughts, coupled with increased evapotranspiration from rising temperatures, can cause forest dieback expressed as the loss of both carbon and tropical species (Oliver L Phillips *et al.,* 2009). Moreover, there is a significant likelihood of future forest dieback in the Amazon under most climate change projections (Malhi *et al.,* 2009). The future of moist tropical forests has become one of the iconic issues in climate-change science (Zelazowski *et al.,* 2011). For instance, the extensive tropical rainforests of Amazonia affect the functioning of the Earth's climate through the exchange of large amounts of water, energy, and carbon with the atmosphere. During the past few decades, a large research effort has been devoted to understand the functioning of Amazonian ecosystems and their responses to deforestation, climate change, and altered fire regimes (Gloor *et al.,* 2015). Changes in forest species composition, increasing dominance of lianas and turnover rates have been reported (Laurance *et al.,* 2004; Lewis *et al.,* 2004; Phillips *et al.,* 2004). Based on an extensive field site network, Brienen *et al.* (2015) suggest a strong decrease in the Amazon forest net carbon sink. The increase on the frequency of extreme drought events was suggested to worsen these responses in the future (Feldpausch *et al.,* 2016). Moreover, there is a significant likelihood of future forest die back in the Amazon under most climate change projections and it is uncertain which species will adapt to novel climates projected to concentrate in tropical forest biomes (Zemp *et al.,* 2017). The main negative effects of the increasing climate variability on forests will likely be via occasional drier and hotter episodes particularly in those regions which have experienced a slight drying trend, i.e., the southwest and south of the basin (Gloor *et al.,* 2015). Seasonality and strength of carbon fluxes in the Amazon forest might be affected, in the short term, by climate change (Gatti *et al.,* 2014).

Aside from the fact that deforestation and forest degradation is the biggest threat for forest areas in the tropics, (Bustamante *et al.,* 2016), some studies show a tendency of the potential extent of moist tropical forests in future climate regimes between 2°C and 4°C, where a risk of forest retreat, especially in eastern Amazonia and Central America are highlighted. The main conclusion is that the water availability is the best determinant of the current distribution of moist tropical forests, which can dominate over other vegetation types only in high-precipitation, low water-stress environments; the change in the extent of the moist tropical forests niche is uncertain (Zelazowski *et al.,* 2011). Some global circulation models predict increase in drought frequency in the South American Amazon (Cox *et al.,* 2004); however few experimental data simulate the Amazon response to climate change (Davidson *et al.,* 2012). With lack of experimental data and the complexity of the forest ecophysiological process, in response to change in temperature and precipitation (mainly parameters simulated by global circulation models), models a decade ago simulated a dramatic amazon forest die back (Cox *et al.,* 2004). More recently a strong resilience of the Amazon forest has been suggested by simulations, much associated with the positive vegetation primary productivity response to the increase in the atmospheric carbon dioxide (Cox *et al.,* 2013; Huntingford *et al.,* 2013). Anadón *et al.* (2014) found that climate change will increase savannas at the expense of forests and treeless vegetation in tropical and subtropical Americas **(Figure 5.4)**, predicting a large shift

Figure 5 4 **Transition map for the forest–savanna system for the present time (1950–2000) and for the year 2070 under the RCP8.5 scenario in the tropical and subtropical Americas. Source: Anadón *et al.* (2014).**

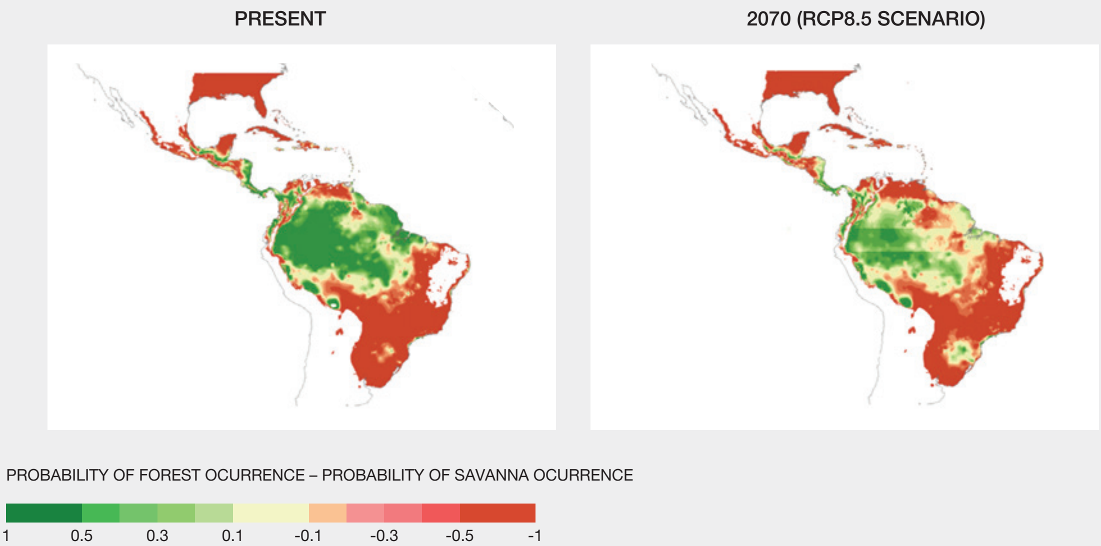
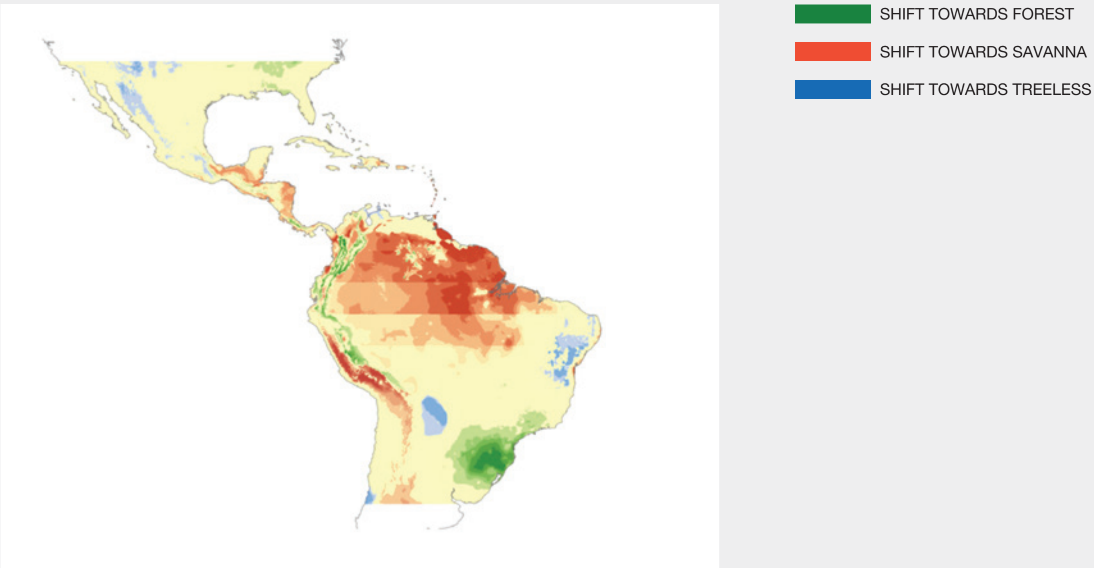


Figure 5 5 **Projected shift towards forest, savanna or treeless states for the year 2070 under the RCP8.5 scenario in the tropical and subtropical Americas. Source: Anadón *et al.* (2014).**



in the savannah-forest transition in the eastern Amazon, supporting the hypothesis that climate change will lead to more unsustainable states for theses ecosystems **(Figure 5.5)**.

However, the key message remains related to the ability of moist tropical forests to acclimate and adapt to future temperature changes. De Costa (2011) suggested that due to the narrower range of seasonal temperatures experienced by forests in the moist tropics, the capacity to adapt is considered to be lower than that of temperate forests. Indicative of this pattern is the reduction in sequestration of carbon observed during years of warmer temperatures and lower precipitation resulting from El Niño Southern Oscillation (De Costa, 2011) or even stronger seasonal patterns (Gatti *et al.,* 2014).

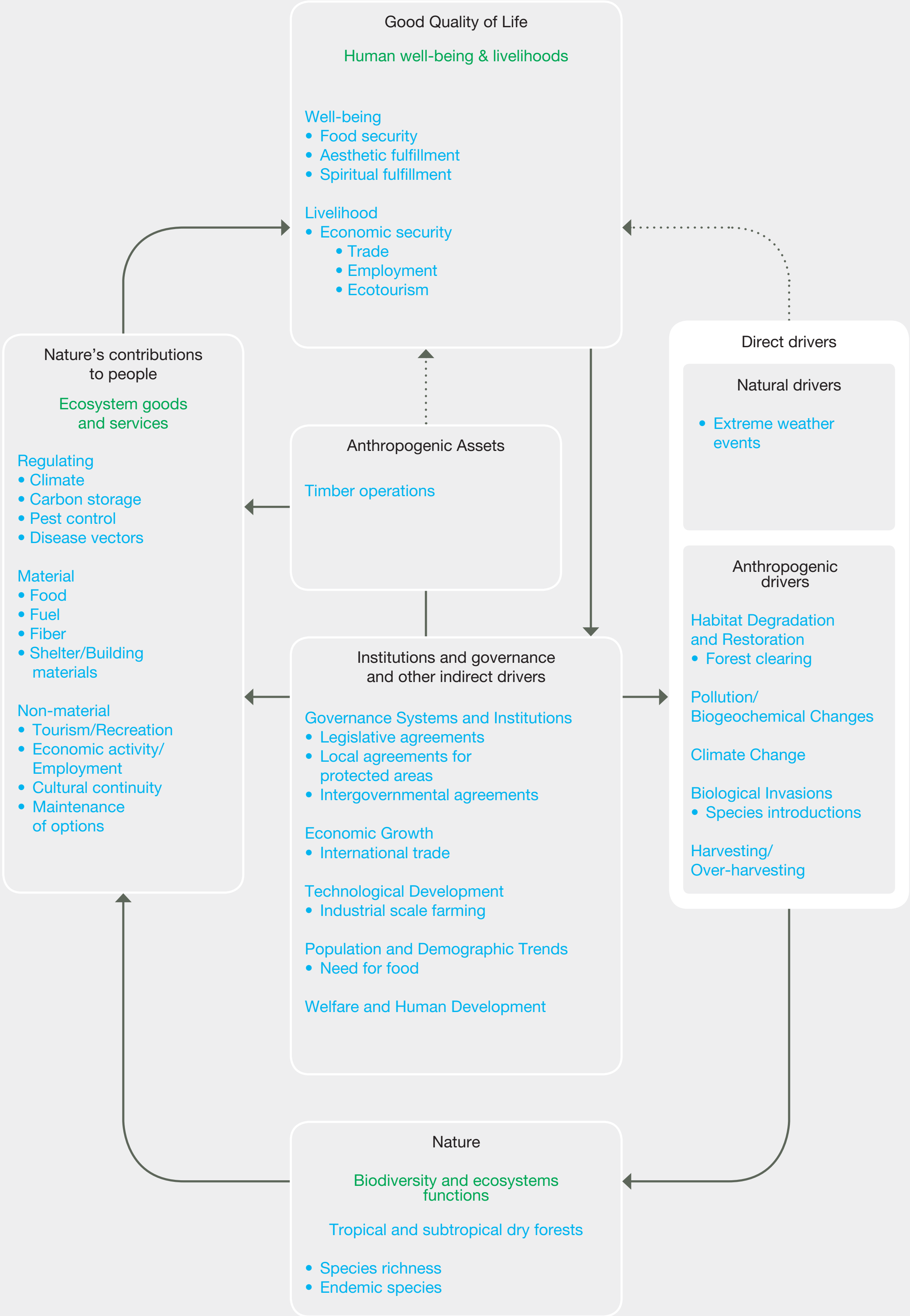
5.4.1.2 Tropical and subtropical dry forests unit of analysis

Tropical dry forests occur from Mexico, through Latin America and the Caribbean, with the most extensive area being the Gran Chaco of South America. The forests contribute to human well-being on a local scale through regulating services, such as erosion control and micro-climate regulation, and provisioning services, such as non-timber forest products (e.g. bushmeat, fodder, and firewood), and non-material NCP such as cultural identity. However, these services are becoming increasingly impacted due to land conversion that replaces these locally-relevant services by services relevant on larger scales, e.g commodity agriculture (Lapola *et al.,* 2013). Thus, changing global demographics, consumption patterns, and global trade are driving land conversion from tropical dry forest to other uses such as cropping and cattle ranching, leading to the loss and fragmentation of native ecosystems. These land-use changes produce a strong trade-off between ecosystem goods such as grains and beef for export and the regional or country level, economic benefit, versus ecosystem services relevant for local people. Further discussions are found in Chapter 3.

The evolving trade-off underscores one of the main challenges inherent in sustainable use of biodiversity, namely spatial scales as relevant to the generation of ecosystem goods and services as opposed to where their benefits are ultimately realized. These scale considerations include local social-ecological systems where ecosystems are converted and local population is displaced, the national scale where the different Chaco countries (Argentina, Bolivia, Paraguay), or Cerrado (Brazil), design and implement their agricultural and environmental policies, the regional scale where some environmental processes become relevant (e.g. climate regulation) and the global scale where driving forces originate (China´s demand for soybean meal to feed pigs and poultry) and where countervailing policies may be created (e.g. Reducing Emissions from Deforestation and Forest Degradation).

Thus, effective policies for addressing the conversion of dry tropical forest to other uses will need to be addressed at

Figure 5 6 **Tropical and subtropical dry forests units of analysis viewed in the IPBES conceptual framework. Source: own representation.**



various organizational scales. National governments affect land-use changes through agricultural (e.g. technology adoption), economic (e.g. currency devaluation, reduction of fiscal pressure) and environmental policies (e.g. land-use planning); companies and corporations that operate along the agro-industrial chain influence the rate and direction of land-use changes; international organizations (e.g. Roundtable for Responsible Soy) lobby national governments to increase or decrease agricultural expansion over native forests, etc. The policy and environmental challenges are to define effective and sustainable land use planning, which includes strong institutional arrangements, clear legislation and economic opportunities for conservation and sustainable production.

Just as there is a significant component of temporally changing demographics and consumption patterns, there are other temporal aspects to this issue, including the temporal considerations inherent to this unit of analysis. The decadal scale is relevant for climatic fluctuations (e.g. dry and wet periods) that naturally occur in the Gran Chaco and that strongly affect agricultural production. At the scale of centuries there may occur fluctuations in ecosystem state, such as changes in the dominant vegetation, with periods of woodland domination being followed by periods dominated by herbaceous (savanna-like) vegetation. Within periods dominated by woodlands like the current one, regeneration of dominant tree species (e.g. *Prosopis* spp., *Schinopsis* spp.) after land conversion may take more than 50 years due to the slow growth rate of these species.

The United Nations Environment Programme (UNEP, 2016a) considers three scenarios for Latin America and the Caribbean: 'economy prevails' scenario tends to maximize economic growth at the expense of social and environmental objectives. This approach is reactive in terms of policy responses. Consequently, economic growth instability increases, as does vulnerability to unforeseen events. Policy options in this outlook emphasize privatization of public services and attempts to internalize environmental and social externalities into the costs of production through market tools. On a 'Policy trade-offs' scenario, new policies and regulations are introduced to partially mitigate the adverse impacts of more than two decades of neo-liberal practices, in this scenario, population growth slows, urbanization stabilizes and emigration pressures reduce. The policy trade-offs scenario promotes greater transparency, policy effectiveness, and institutional coordination. However, environmental sustainability, even while a policy objective, remains a secondary priority for governments. Finally, a 'sustainability agenda' scenario assumes the implementation of policies to promote sustainable approaches to agricultural practices, rather than market signals, more conscientious tourism, and a more participative and coordinated strategy for energy trade. However, in some areas, this outlook may result in a slowing of technological intensity, as well as a shift towards local-level issues. In this case, policy options tend to prioritize the emphasis on building and keeping a social consensus through education and institutional strength (UNEP, 2016a). Whether considering spatial or temporal scales, the inherent trade-offs or synergies associated with this issue need to be considered fully.

These trade-offs include: forest loss and fragmentation increases agricultural area and production volumes at the expense of biodiversity; forest degradation increases accessibility of cattle to natural fodder, but decreases carbon sequestration on biomass; landscape homogenization facilitates agricultural operations but reduces livelihood options for local people, forcing them to migrate into urban areas, etc. Regardless of the ultimate trade-offs, this issue is urgent in that tipping points may be reached that eliminate a reasoned approach to the trade-offs, such as: regarding climate, the loss of forest cover alters the hydrological cycle and forces the system towards drier conditions; regarding vegetation, the degradation of woodland vegetation alters soil and climate conditions and shifts the system towards one dominated by scrublands.

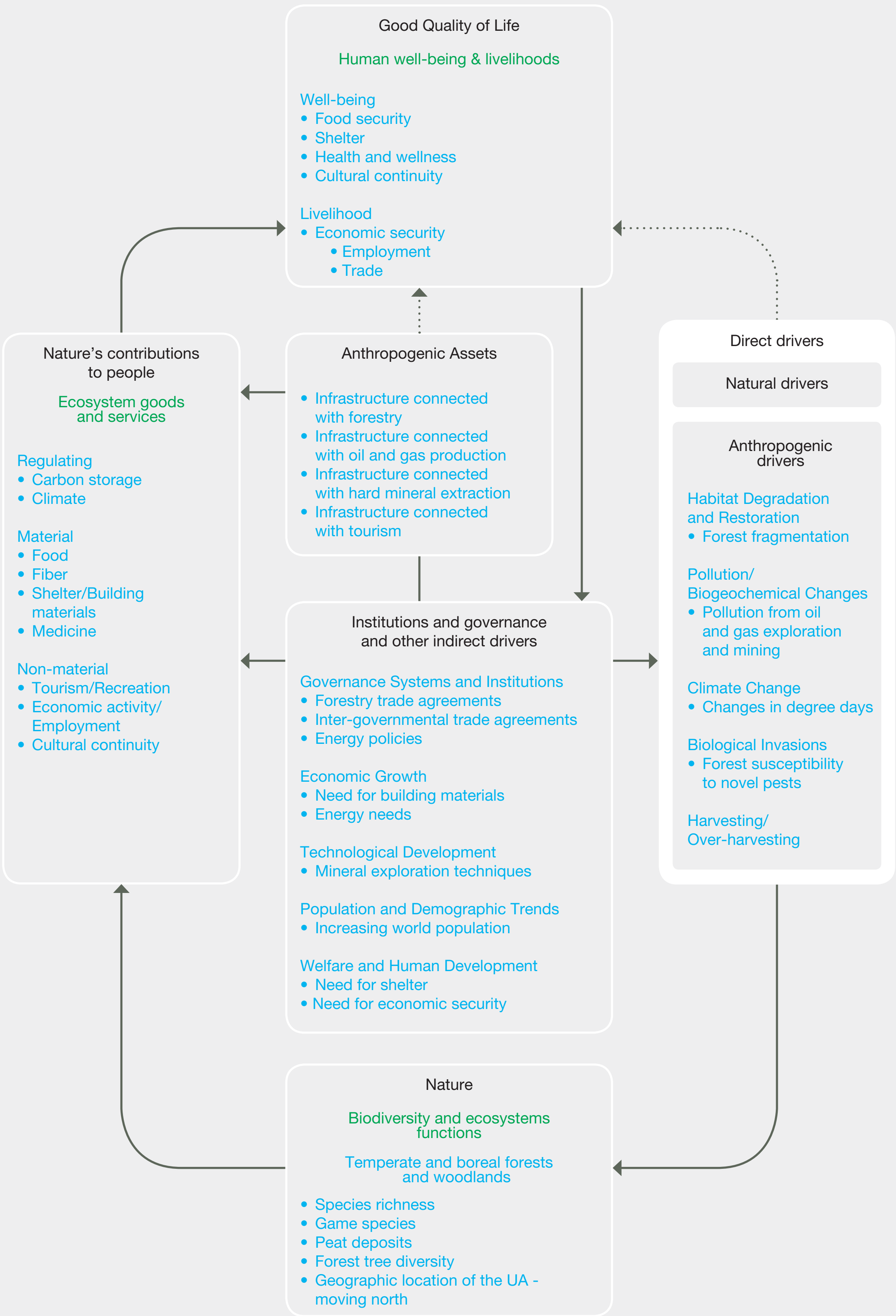
5.4.2 Temperate and boreal forests and woodlands units of analysis – Key to indigenous people and carbon storage

Temperate and boreal forests occur in the northern hemisphere of the Americas – mostly in the USA and Canada. The boreal forest covers northern Canada and Alaska with a belt of coniferous forests. Boreal forests, and the peatlands that many grow on, are critical for carbon storage. Temperate forests are located in eastern North America. They are comprised of a mix of deciduous, broadleaved and coniferous evergreen forests. Temperate rainforests – which are dominated by coniferous trees - are found on the on the West Coast of North America in British Columbia and in the USA´s Pacific Northwest. In addition, evergreen rainforest occurs in Chile.

Boreal forests are known for caribou *(Rangifer tarandus groenlandicus)*, moose *(Alces alces)*, bear (*Ursus* spp.), beaver *(Castor canadensis)*, rabbit and migratory birds, which are important to local and Indigenous communities. Indigenous communities have lived in the boreal forest for thousands of years. There are more than 600 primarily indigenous communities in the Canadian boreal region. They rely on the forest for physical subsistence and cultural wellbeing. Fish and waterfowl provide for a significant part of the subsistence diet for many remote communities.

In addition to the cultural and provisioning benefits provided to local populations **(Figure 5.7)**, carbon storage is a key

Figure 5 7 **Temperate and boreal forests and woodlands units of analysis viewed in the IPBES conceptual framework. Source: own representation.**



NCP. Climate change, which is considered the primary anthropogenic driver in this system, has resulted in temperatures changing faster in the high latitudes than in any other area on the planet (IPCC, 2013a).

The boreal landscape is dominated by an active natural disturbance driven by large area stand-replacing wildfire and insect outbreaks (Price *et al.,* 2013). Changes in climate, atmospheric carbon dioxide concentrations and fire regimes have been occurring for decades in the global boreal forest. Future climate change is likely to increase fire frequency and insect outbreaks. Warming in the boreal region is projected to be substantially above the global average. According to the IPCC (Intergovernmental Panel on Climate Change), temperatures in the northern boreal have increased at twice the global rate. Boreal forests are particularly sensitive to warming because of their soils (e.g. peat, permafrost) and likelihood of increased incidence of fire disturbance.

Predictions of future climate largely agree that Canada's boreal forests will experience substantial warming (Plummer *et al.,* 2006). Lenton (2012), argues that the boreal forest (and arctic) is subject to a tipping point due to strong internal feedback systems; an increase of 4oC global warming (7oC above current levels in the forest) will result in a marked increase in susceptibility to disease. If such a tipping point is reached, there could be significant changes in the landscape (i.e. tree die-off, conversion to grassland) and release of carbon.

Resource extraction, oil and gas development, and timber harvesting are increasingly fragmenting the boreal region, which is impacting migratory connectivity, ecosystem integrity, habitat resilience and species diversity, especially for migratory species. Additionally, the role of infectious plant diseases, mediated by invasive species, will continue to be a significant issue negatively affecting the temperate forests in the future (Chapter 3).

Boreal forests are experiencing the most rapidly changing climate (along with tundra) anywhere on Earth and are likely to be impacted in critical ways in coming decades. Predicted climate change is anticipated to cause shifts in species ranges, with an average northward shift of about 700 km for Canadian tree species; with some species expected to shift as much as 1000 km (northwards (sugar maple *(Acer saccharum)*, black willow *(Salix nigra)*, American basswood *(Tilia americana)* and white alder *(Alnus rhombifolia)* (McKenney *et al.,* 2007)). Biodiversity gains are anticipated in Canada's maritime provinces, including Quebec, Ontario, northern prairies and Alaska, with up to 60 new tree species possibly appearing in some areas, although low soil fertility might limit their migration (McKenney *et al.,* 2007). Extreme fires in intensity and extent have threatened forests in recent decades partially as the result of forest management practices that have permitted decades of deadwood (fuels) to accumulate (Oswalt & Smith, 2014). Drought is exacerbating wildfires in western forests, particularly in California in the USA and Alberta in Canada.

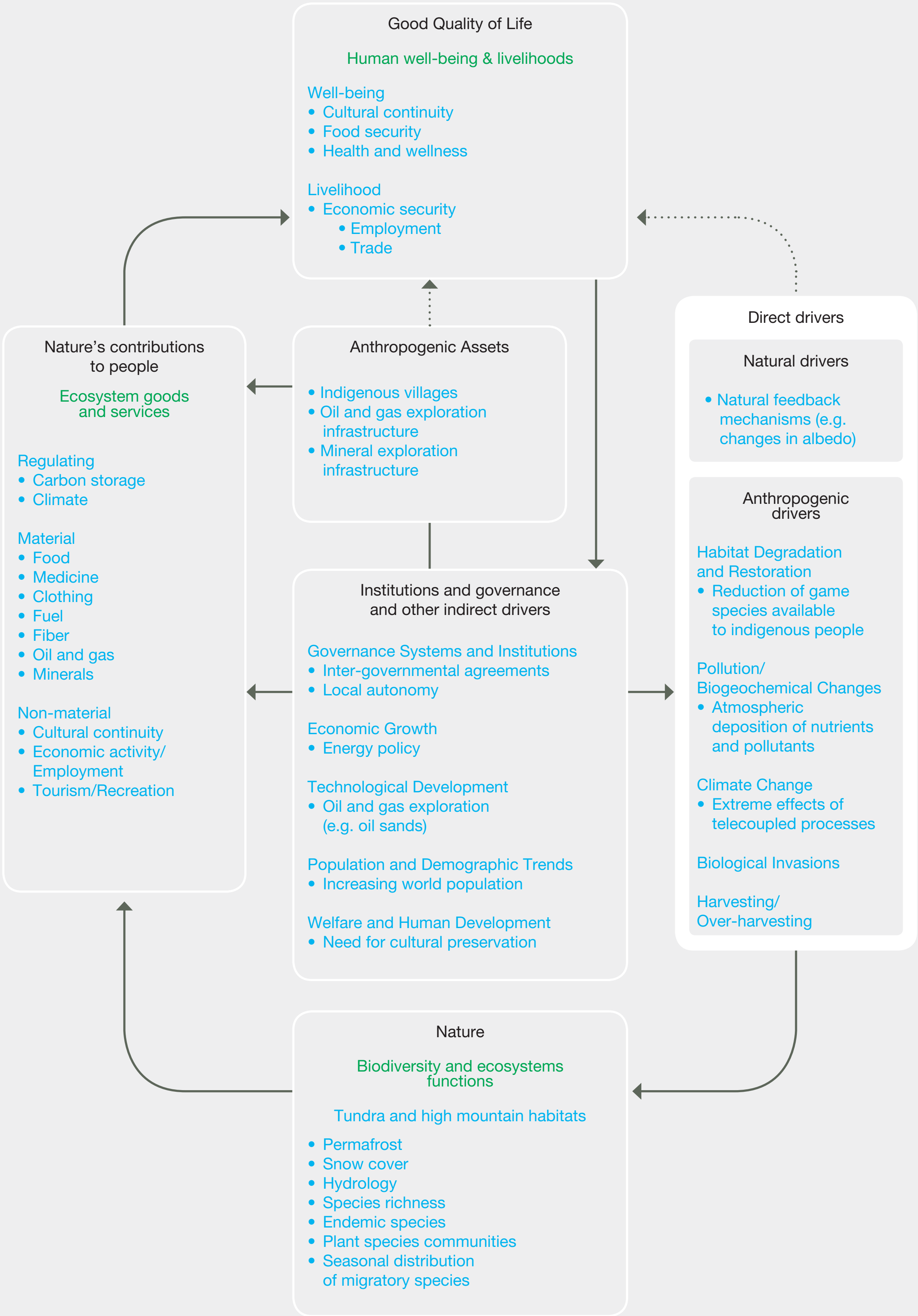
5.4.3 Tundra and high mountain habitats units of analysis – Remote, but not remote enough

Tundra occurs in two settings within the Americas; at high elevations ("alpine tundra") and in the high latitudes ("arctic tundra"). Arctic tundra is circumpolar in its distribution and accounts for a large amount of land area across the USA and Canada (Chapter 2). Adjacent marine areas of the arctic are also critical habitat for numerous tundra species. It presents a unique set of circumstances with respect biodiversity and NCP, namely that of all the units of analysis, Tundra is the most closely linked with respect to NCP and local ecosystems and that the primary drivers affecting the system are almost wholly external to the region in which the unit of analysis occurs. Tundra includes well-known fauna, such as barren ground caribou and muskoxen *(Ovibos moschatus)*, which are important to indigenous populations from subsistence and cultural standpoints **(Figure 5.8)**. While difficult to separate, it is perhaps this latter consideration that is the primary NCP for Tundra, for while the physical needs of the indigenous people associated with Tundra could, conceivably, be replaced with market goods, the culture of these peoples is intimately related to biodiversity of the system; loss of which would threaten the cultures continuity.

Aside from the cultural and provisioning NCP accrued to local populations depicted in **Figure 5.8**, the NCP of carbon storage is of concern on a global basis. Arctic tundra is estimated to store approximately 50% of the world's soil carbon (Tarnocai *et al.,* 2009), mainly in the form of permafrost (perpetually frozen soil). But climate change, which is considered the primary driver in this system, has resulted in temperatures changing faster in the high latitudes than in any other area on the planet (IPCC, 2013a) (Chapter 4). Thus, the situation with respect to Tundra provides a clear example of telecoupling, i.e. where cause and effect are separated geographically, but are clearly related.

The warming in the Tundra, and its neighbouring marine areas, has resulted in several changes that have affected the Tundra, including: thawing of the permafrost (Walker *et al.,* 2006), changes to the plant communities (reduction of graminoid species in favour of shrubs and expansion of the boreal forest) (Hu *et al.,* 2010; Lloyd *et al.,* 2003) (Chapter 3), increased frequency of fires, and changes in neighbouring sea ice conditions (Bhatt *et al.,* 2010). These changes result in a lowering of the local albedo (the reflectivity of the Earth's

Figure 5 8 **Tundra and high mountain habitats units of analysis viewed in the IPBES conceptual framework. Source: own representation.**



surface) in the immediate area in the case of shrubs and fires resulting in a positive feedback to climate change and thawing of the permafrost. Due to the amount of carbon stored in the permafrost, the change of tundra from a carbon sink to a carbon source is also of great concern from a global perspective. Adding to the concern is the consideration that warmer temperatures and change in vegetation adds uncertainty to what was considered a relatively stable biome. This uncertainty stems from unknowns regarding the natural processes associated with the tundra. For example, fires which were once rare in the tundra may be increasing in frequency and perhaps extent (Hu *et al.,* 2010) and these fires may increase the rate of stored carbon release (Mack *et al.,* 2011). Additionally, as with the Boreal Forest, Tundra is also subject to a tipping point or threshold with loss of the native plant communities whenever 1000 degree days is exceeded (IPCC, 2014; Lenton, 2012).

Uncertainty is also associated with respect to existence of a "tipping point" with respect to degradation of the permafrost, i.e. a point at which the degradation is irreversible and accelerates (IPCC, 2014). Some modellers believe that such a tipping point exists and that it could be reached within the next 100 years (Scheffer *et al.,* 2012). If such a tipping point is reached, there would be a massive release of greenhouse gases. In that event, it is anticipated that over time the area currently occupied by arctic tundra would be replaced by boreal forest. The implications of this scenario are that the rate of climate change would increase, flora and fauna would be further endangered or driven to extinction and the cultures and traditional ways of indigenous people throughout the Holarctic would be severely impacted.

The issue of melting permafrost and its implications is a particularly intransigent problem for several reasons. The ultimate source of the drivers affecting the system are not internal to the system, rather, they originate faraway geographically, i.e. anthropogenic greenhouse gasses, and are exacerbated through the effects of a positive feedback acting locally and through teleconnection.

With temperatures in the Arctic rising twice as fast as the global average, climate threatens to alter biodiversity and ecosystem functioning in Tundra in the coming decades (Pithan & Mauritsen, 2014; Screen & Simmonds, 2010). Vegetation models predict significant northward range expansion of boreal species into Tundra, leaving few refugia for tundra-specialist species by 2050 (Kaplan & New, 2006; Pearson *et al.,* 2013; Hope *et al.,* 2015). Thus, while the intrusion of boreal species may augment species richness in Tundra, the potential extinction of tundra-adapted taxa may detract from it (CAFF, 2013; Chapin *et al.,* 2000). The overall balance of these processes is uncertain. As sea ice declines, shipping in the Arctic may be a dispersal mechanism for invasive species (CAFF, 2013). Many future changes in Tundra are predicted to be rapid nonlinear transitions, rather than smooth gradual changes. Among such "regime shifts," the Arctic Council (2016) predicts decreased carbon storage capacity, drying soils, and increased woody vegetation. Experimental and modeling work from several authors across Arctic Resilience Assessment document (Artic Council, 2016) support for these conclusions (for carbon storage, see Abbott *et al.,* 2016; Hu *et al.,* 2015; Lara *et al.,* 2017; Li *et al.,* 2014; Mack *et al.,* 2004; Natali *et al.,* 2015; Schuur *et al.,* 2013; Schuur *et al.,* 2015; Sistla *et al.,* 2013; Sitch *et al.,* 2007; Sweet *et al.,* 2015; Webb *et al.,* 2016).

Treeline advance in North America will continue to reduce the extent of alpine habitat (Harsch *et al.,* 2009), while deciduous shrub growth and overall plant productivity above treeline will increase due to warming (Raynolds *et al.,* 2014). Habitat degradation may also occur through nitrogen deposition (Dentener *et al.,* 2006), with the potential to reduce species richness (Walker *et al.,* 2006).

Distribution modeling predicts northern Andean birds will lose 30-40% of their ranges with compositional changes (Velasquez-Tibata *et al.,* 2013); páramo and puna are predicted to experience reduced species richness and species turnover (Ramirez-Villegas *et al.,* 2014). The biodiversity of hyper-arid alpine areas, where many species depend on moisture supplied by peat bogs could be especially vulnerable. A recent assessment for páramo (Buytaert *et al.,* 2011) concluded that changes in precipitation patterns, increased evapotranspiration and alterations of soil properties will have a major impact on water supply, which will further affect species composition. Warming is expected to have a major impact on seasonal water flow all along the Andes due to loss of glaciers, although the latter will depend on future precipitation trends along the Andes (Vuille, 2013). However, given the complex landscape and regional climatic variation, there are large uncertainties regarding the responses of high Andean biodiversity and ecosystem functions to climate change.

The possible futures for the tundra under the scenario archetypes is somewhat limited due to the facts that the indirect and direct drivers at play are remote relative to the region and the fact that climate change effects in terms of temperature change are more extreme for this region than any other on the globe. Under the Market Forces archetype we can expect the continued reduction of sea ice and thawing of the permafrost to continue as this simply represents a continuation of the factors that have resulted in the impacts seen thus far. Under the Fortress World, archetype we can expect to see a more rapid deterioration of the permafrost and perhaps surpassing of a tipping point with respect to greenhouse gasses release due the ecological processes inherent to the Tundra. The Policy Reform archetype scenarios could be a significant contributor to lessening of the factors at play in the Tundra, but given the fact that climate change effects appear to be greatest at the high latitudes, a very concerted effort would have to be made to adopt policies lessening or reversing greenhouse gasses emissions. Because of the telecoupling and teleconnection aspects involved with the tundra, this scenario would require a coordinated effort on a global scale, as there is little that local populations and policymakers can do to affect the drivers involved. This latter consideration, namely that an effort on a global scale is needed, argues that to truly avoid a tipping point in the Tundra, an approach within the Great Transition archetype will be required.

Northern ecosystems are highly dynamic and variable, however, climate change is considered to be increasing the nature and range of variability and adding new kinds of stresses that are outside what is considered 'normal' as defined by both scientists and indigenous and local knowledge (ILK) (Huntington *et al.,* 2007). This is likely to continue with implications for arctic biodiversity and Indigenous communities that depend on Tundra for their culture and livelihoods. While Indigenous communities are highly adaptive, options for tundra as a biome are limited. In other regions and for other units of analysis, natural adaptation by the biome is possible… arid areas may expand, temperate forests may move north, animals may shift their range along with changing climate envelopes, as have small mammals in North America (Myers *et al.,* 2009). However, as tundra is already at the extreme reaches of the globe, such adaptive responses are limited to non-existent.

5.4.4 Tropical and subtropical savannas and grasslands unit of analysis – Agriculturalization

Agriculture is the most important anthropogenic activity responsible for terrestrial biotic resource commodities, producing 2121.6 million tons of grain, 391.6 million tons of oilseed and 120.5 million tons of cotton globally in 2008 (USDA, 2009; UNEP 2010). Wood harvesting, generally associated with tropical and subtropical regions, is another important activity for terrestrial biotic resource production, accounting for 1.55 billion m^3 of wood annually (FAO, 2009). Other activities implying significant terrestrial biotic resource extraction include grazing and energy production, which are relatively smaller compared to the two previous categories. In addition, relatively insignificant amounts of terrestrial biotic resource are extracted through recreational sports (mainly hunting) and pharmaceutical uses.

Tropical and subtropical grasslands, savannas and shrublands are well represented in South America **(Figure 5.10)**. The Latin America and the Caribbean region support large areas of tropical savannas and temperate grasslands. The Río de la Plata grasslands are the largest complex of temperate grasslands ecosystems in South America, covering approximately 750,000 km^2 within the Pampas of Argentina and the Campos of Uruguay, northeastern Argentina, Paraguay, Bolivia (Chaco ecoregion) and southern Brazil. The highest rates of endemism in the grasslands of the region are found in the páramo and puna systems, covering the upper parts of the tropical Andes from southern Venezuela to northern Peru (WWF, 2016).

Tropical grasslands have, and will continue to be under pressure to support global demand for biomass and food, resulting tropical forest and savannas conversion for this purpose. Habitat change in particular in tropical regions has been a main cause of global losses of biodiversity. One of the areas where this transformation is resulting in transformation of land use is the savannas in the Chaco Region **(Figure 5.11)**, as result of land demand for soybean production, cotton and cattle expansion.

Grasslands in general, are the units of analysis that as a whole present a rising trend in all major pressures on biodiversity: land degradation and land use change; climate change; land-based pollution; unsustainable use of natural resources and invasive alien species. Regional

Box 5 1 Dealing with Ecological Variability and Change in Human-Caribou Systems.

Indigenous communities from tundra (arctic and sub-arctic) regions of Canada and the USA are highly dependent on barren ground caribou *(Rangifer tarandus groenlandicus)* as a foundation of culture and livelihood. There are between 10-15 subpopulations of barren ground caribou in northern Canada and Alaska; both science and ILK tell us these populations tend to rise and fall in a 40-70 year cycle. Although there is much adaptive capacity within northern communities based on ILK, climate change as well as resource development are creating new stresses on human-caribou systems. For example, the Bathurst caribou, which last peaked at 475,000 animals, has declined by 90%, which has had dramatic implications for the diets and well-being of local Inuit, Dene and Metis peoples. Booms in mineral resource development such as diamond and rare earth metal mining, in the absence of a cumulative effects framework will lead to major challenges to arctic biodiversity as well as the sustainability of arctic peoples and livelihoods. The preservation of these resources for use by indigenous people is a major goal in this region (Environment Canada, 2016; Gunn *et al.,* 2011; Parlee *et al.,* 2013).

Figure 5 9 **Tropical and subtropical savannas and grasslands unit of analysis viewed in the IPBES conceptual framework. Source: Own representation.**

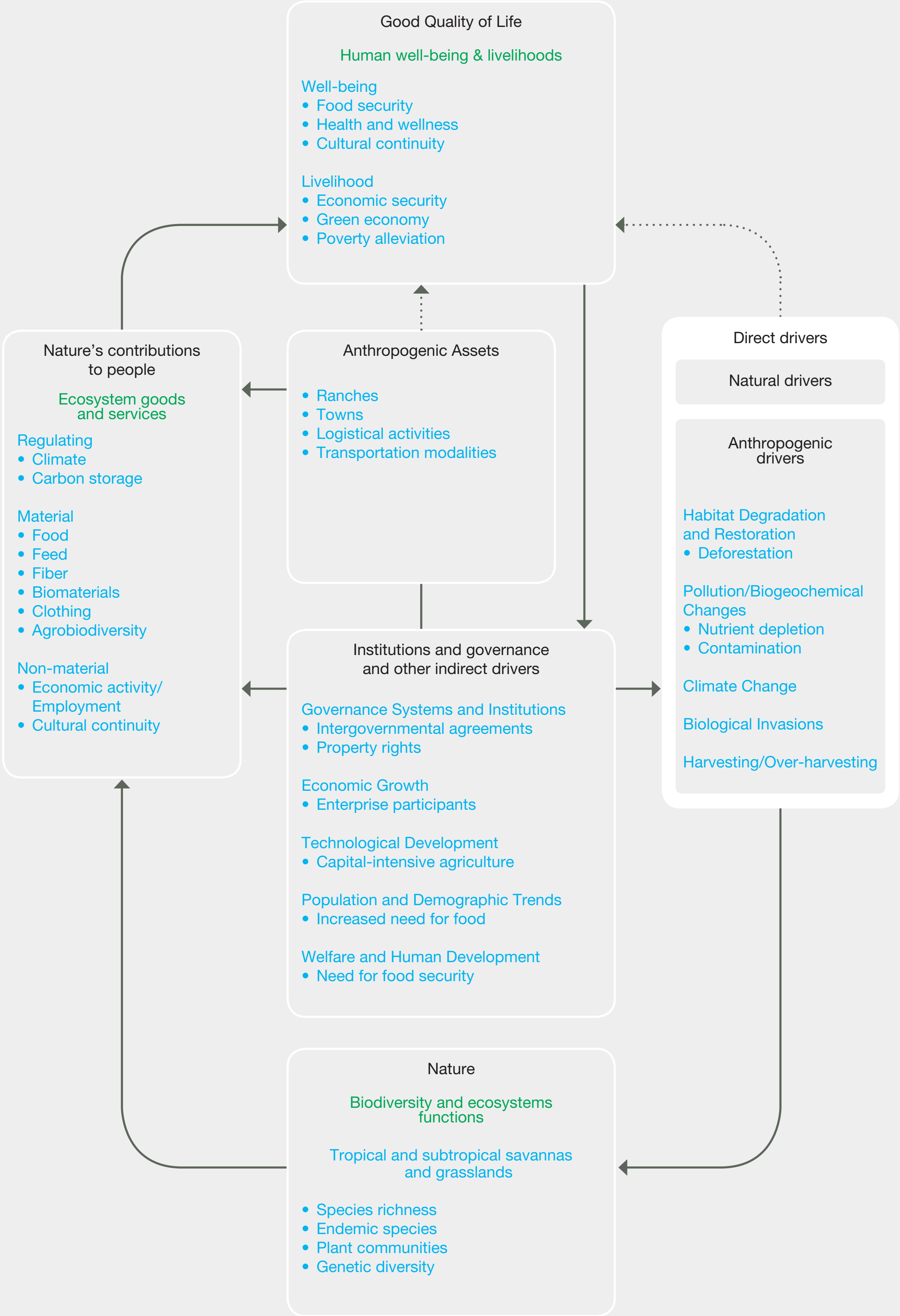


Figure 5 10 **Map of biogeographical realms and biomes derived from WWF Terrestrial ecoregions dataset. Source: Map produced by UNEP-WCMC (2016) using data from Olson *et al.* (2001).**

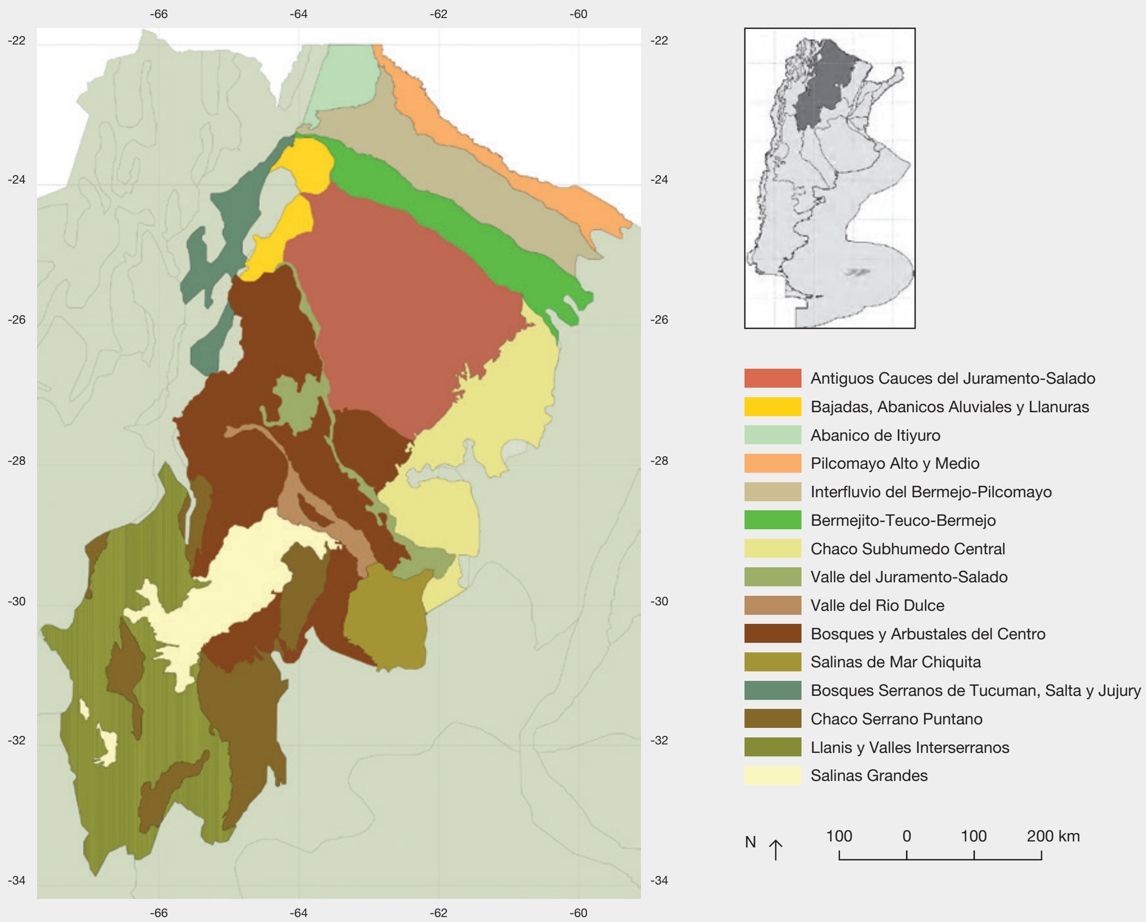
biodiversity declines are most dramatic in the tropics. A recent analysis by Brooks *et al.* (2016), using the UNEP (United Nations Environment Programme) regional and subregional classification as employed at the International Union for Conservation of Nature global red list database, found that 13,835 species occur within the Latin America and the Caribbean region, and that 12 per cent of these are threatened with extinction. In America, tropical and temperate grasslands were a good provider of "new lands", with soils rich in nutrients and good structure, and could be directly used for agriculture. Trends show a rising demand of land from these areas (UNEP, 2014). The food context is accompanied by rising demands for biofuels, biomaterials and biomass that compete among others with food supply. Changing diets in the national and international context, produce trade-offs on the regional and local level and models of agriculture production.

Native grasslands and savannas formerly occupied truly immense areas of the Americas and large areas still exist, though in varying states of ecological integrity, such as Pampas/Chaco/Espinal, Great Plains/savanna, and Rolling Plains/Cerrado. However, much of the grasslands and savannahs of the Americas have been greatly impacted, especially in North and South America. Different organizational scales are directly related to the grassland transformations. International trade and global demand for food, feed, biomass for biofuels, biomaterial and others, resulted in government policies that promote exports, which in turn are driving forces transforming lands for extensive agriculture and cattle grazing to fit the requirements of international markets. The issue is generating two syndromes that affect sustainability of grasslands: *agriculturisation* and *pampeanisation* (savannisation) (Manuel-Navarrete *et al.,* 2005; Pengue, 2005).

Grasslands current scenario and regional analysis

During the last 20 years, significant challenges exist in any attempt to address the continued land use changes from grasslands and savannahs to agricultural systems due to spatial, economic and temporal considerations. Tropical and subtropical savannas, represented by the Chaco Region, are a good example of the deforestation expansion with focus on soybean expansion for sustaining international demand. Forest cover change monitoring in the Gran Chaco region in South America was undertaken using visual interpretation of Landsat satellite images, taken at monthly intervals throughout 2013. The Gran Chaco Americano is a region of forest habitat converted to savanna (Morello *et*

Figure 5 11 **Map of Chaco seco ecoregion and its ecosystem complexes. Source: Morello *et al.* (2012).**



al., 2012), with exceptional biological diversity and unique ecological processes being impacted. "It covers an area of 1,066,000 km^2 in four Latin America and the Caribbean countries; most of the region is in Argentina, followed by Bolivia, Paraguay and in smaller proportion, Brazil. Changes in land use were detected in 502,308 ha in 2013, the equivalent to a deforestation rate of 1,376 ha per day. Paraguay had the highest proportion of land use change recorded with 236,869 ha, followed by Argentina with 222,475 ha, and then Bolivia with 42,963 ha. According to the spatial distribution and trend of deforestation identified at the provincial, departmental, and municipal level, the Boqueron and Alto Paraguay departments had the highest rates of deforestation recorded around the Gran Chaco region". (UNEP-WCMC, 2016). In Argentina, deforestation is concentrated in the provinces of Santiago del Estero, Salta and Chaco; whereas in Bolivia the province with the largest area of change was Santa Cruz.

With a loss of over half a million hectares of forests in 2013, the land-use change in the Gran Chaco region is of great concern, and is primarily driven by the international demand for food, particularly meat production in Paraguay and soybean in Argentina (Caballero *et al.,* 2013). Trade-offs in terms of land demand, rural development and national incomes are critical issues. Local or international goals could produce different results.

Main drivers are related to changing diets in western and eastern societies, China demands and the introgression of financial markets and big investors in rural communities and an expanding middle-class (UNEP, 2014) are changing the main global goal for societies: food security. On the other hand, decisive action is needed to change the present trajectory. Policies, which would limit or counter the demand of land and land use changes, particularly in developing countries, where cashcrops are seen as an opportunity to take advantage of a global demand. Agricultural intensification and expansion of arable land in tropical and subtropical grasslands for international trade will continue to expand. Latin America and the Caribbean region is regarded as second, only to sub-Saharan Africa, in terms of the potential for further arable expansion (Lambin *et al.,* 2013), and despite droughts and water scarcity in some parts, it also holds the highest share of global renewable water resources (UNEP, 2014). Growth in sugarcane, palm oil and coffee plantations, as well as expansion of livestock production continues, often leading to deforestation, fragmentation, and overgrazing of the converted pasturelands (Michelson, 2008).

In particular, the Atlantic coastal forests, as well as tropical savannas are the most rapidly changing biomes in the region, threatened by advancing agricultural frontiers and rapidly growing cattle production (Magrin *et al.,* 2014). This expansion and intensification of agriculture and pastureland is resulting in a decline in the area and quality of habitats and an associated increase in pollution of water courses and loss of biodiversity.

5.4.5 Temperate grasslands unit of analysis – Agricultural intensification

Rapid economic growth and social inequity have created certain associated pressures on the natural resources of this unit of analysis, particularly associated with the agricultural intensification. Demand for new lands and land use changes are the driving forces in the business as usual scenario. This is directly related to global trends in demand for biomass (agroindustry, biofuels and biomaterials). Conversion of grasslands to croplands is one of the key drivers in this situation. Grassland losses are significant, even in relation to other major biomes in North America. Most of the grassland loss in Canada occurred before the 1930s as a result of such conversion to cropland (UNEP, 2016b). Estimates of total loss prior to the 1990s include 97 per cent of tallgrass/savanna in southern Ontario, 70 per cent of prairie grasslands, by far the largest of Canada's grasslands, and 19 per cent of bunchgrass/sagebrush in British Columbia (Federal, Provincial, Territorial Governments of Canada, 2010). Fragmentation and land use changes is generating a degradation of natural resources and climate change, particularly where fire is used as a management tool. In Latin America and the Caribbean, the use of fire in agriculture is widespread in the region. Native forests, grasslands and other natural habitats are burned after being cleared to provide more land for agriculture; in some areas fire is also used as part of crop rotation practices. Overall, emissions from agriculture and deforestation-related fires in the region are a major contributor to atmospheric trace gases and aerosol mass concentrations (UNEP, 2016a).

Grasslands are following the fate of native forest areas. Demand for land is the driving force on the last native grassland. These changes occur in certain hotspots whose locations reflect the close and complex links between land cover, agriculture and consumption patterns both inside and outside the region (Hecht, 2014). Processes like forest clearing for creating pastures and agricultural land are still important, but have shifted from forests to other natural ecosystems, like Cerrado (Brazilian savanna) and grasslands, where soybean crops are replacing native grasslands in Argentina, Bolivia, Brazil, Paraguay, and Uruguay. Cattle production and feedlots are other main factor. In the USA, land-use scenarios assume that suburban and exurban areas will expand by 15–20 per cent between 2000 and 2050, cropland and forest areas are projected to decline compared to 1997, by 6 per cent and 7 per cent, respectively, by 2050 (Brown *et al.,* 2014).

Several practices and policy issues are being implemented for better understanding and decision-making. Argentina recently implemented a national zoning plan (i.e., the Forest Law) to reduce further forest loss (Piquer-Rodríguez *et al.,* 2015). For example, grasslands in Uruguay are increasingly under sustainable production systems that promote soil conservation, which is reducing land degradation (Hill & Clérici, 2013).

Agriculturization is a primary process in temperate grasslands with concentration in grain and crops production and displacement of cattle production to feedlots or other areas more marginal. The process has been well investigated by Gallopin *et al.* (2003) at the Economic Commission for Latin America and the Caribbean. New technologies play a relevant role in terms of agriculturization process on grasslands **(Figure 5.13)**. The incorporation of modern technologies such as transgenic crops, no tillage practices, precision farming, herbicides and chemicals promote strong transformation to practically the whole of the remaining grasslands of the Americas.

5.4.6 Drylands and deserts unit of analysis – Exceptionally fragile diversity, resource demands, and ever-diminishing moisture

Due to the unpredictable aridity of drylands (primarily cool and hot deserts, as well as arid and semi-arid shrubland, in Mesoamerica- and North America), both the biota and the human cultures associated with drylands have evolved a remarkable set of adaptations and cultural traditions to deal with this unpredictability (Chapter 2). Thus, despite the harsh conditions, or perhaps because of them, this biome has exceptionally high levels of biodiversity in several groups, notably plants, mammals and reptiles; there are over 30,000 plant species in the southwest USA and the State of Arizona in the USA has over 200 snake species, 2/3 the number of species in the entire Amazon (Chapter 3).

Figure 5 12 **Temperate grasslands unit of analysis viewed in the IPBES conceptual framework. Source: own representation.**

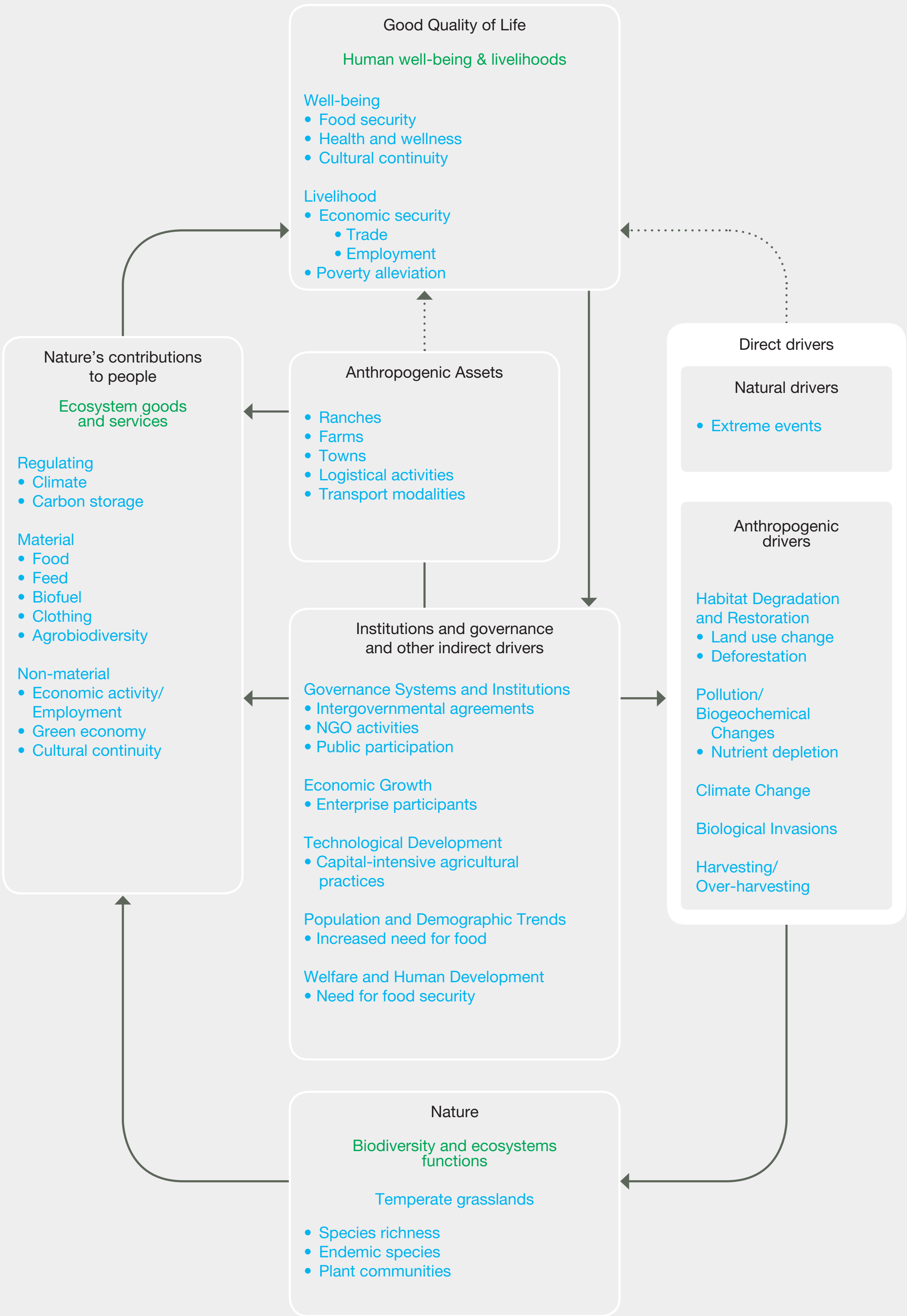
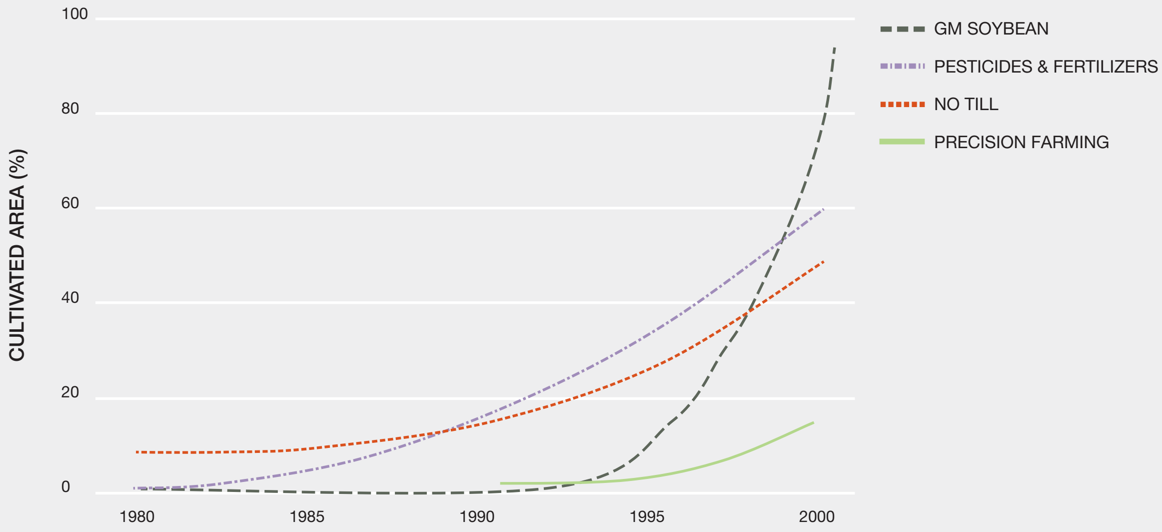


Figure 5 13 **Technology incorporation for soybean production in farming systems of Argentina between 1980 and 2000. Source: Satorre (2005) and Viglizzo *et al.* (2011).**



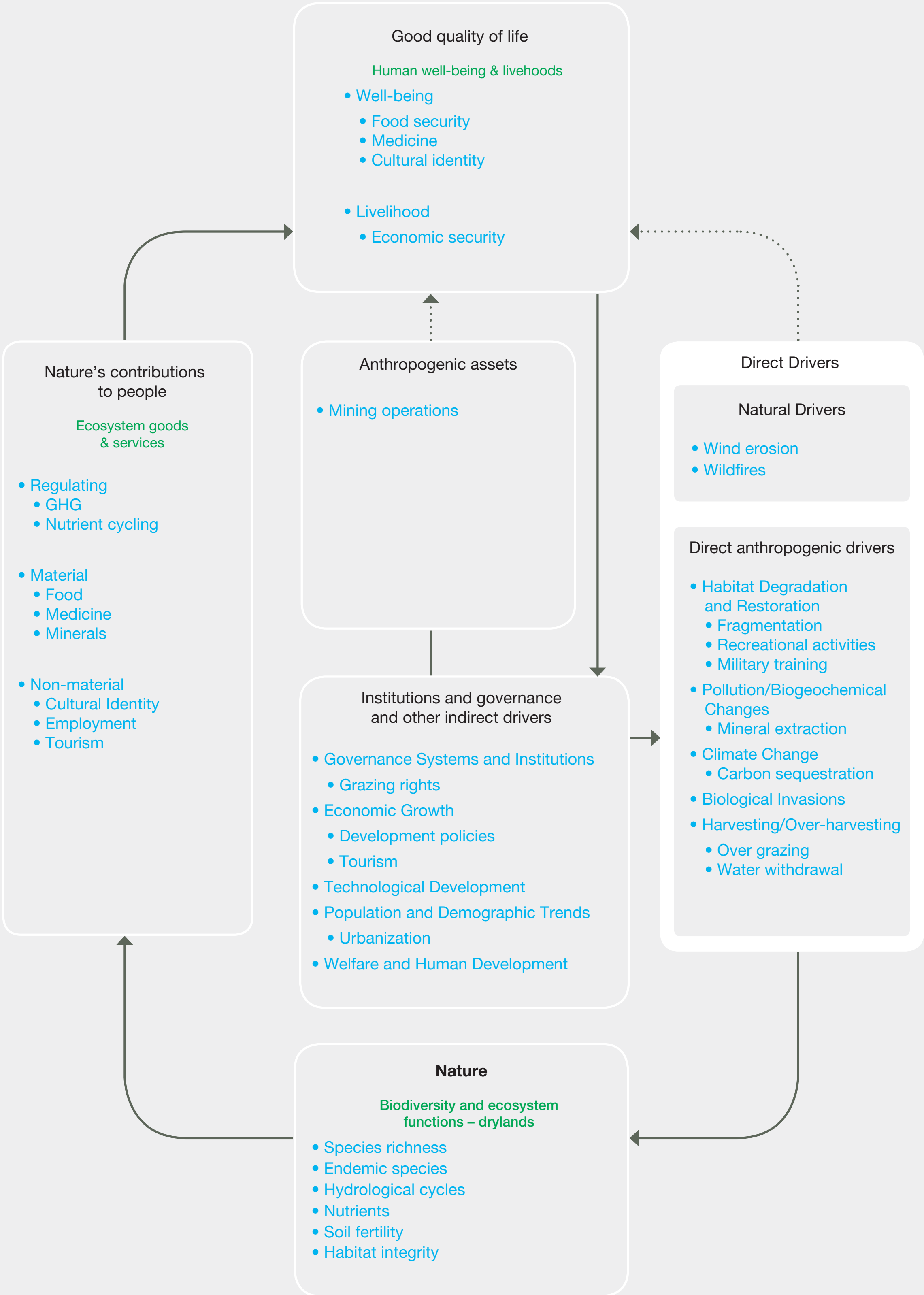
Despite water limitations, this biome provides significant provisioning services such as cattle grazing and agricultural production, though the latter is highly dependent on a non-sustainable use of irrigation via groundwater withdrawal and over allocation of surface water. However, in many cases, agricultural activities are abandoned: croplandsdue to water shortage and over grazing severely damages rangeland, resulting in the dominance of non-native species, such as *Cenchrus ciliaris* (Chapter 3). Based on the Fragmentation Index reported in (Chapter 3) only about 4% of undisturbed drylands remain, which puts it barely above the index for grasslands, one of the most heavily impacted biomes, with the main drivers being agriculture and mineral extraction. The future of drylands under climate change is unclear; temperatures may increase or stay the same.

Climate change forecasts indicate an increase in temperature, but no clear trend in annual precipitation in drylands in North America, although timing of events is likely to shift (Cook & Seager, 2013). As a consequence, potential evapotranspiration and drought severity will increase in dryland regions. Drought conditions are already common in the desert southwest, and drought periods are expected to become more frequent, intense, and longer (Garfin *et al.*, 2014). The consequences for biodiversity are not entirely established, although drought results in a large decline in plant cover and richness, which likely impacts wildlife populations (e.g. Mulhouse *et al.*, 2017). However, some predictions indicate that desert ecology will be impacted, resulting in perhaps half of the bird, mammal and butterfly species in the Chihuahuan Desert being replaced by other species by 2055 (Chapter 2). Drought also reduces free surface water, a resource already severely limited in most dryland regions and this reduction will affect wildlife. For instance, drought impacts desert reptiles because there is less free water for them and their prey. As many reptiles rely on their diets to obtain water if they cannot drink free water, they may die from dessication if they cannot eat enough (Schmidt-Nielsen, 1997). Drought has even more severe consequences for amphibians, as most require free water in which to live and reproduce.

Although arid land vegetation tends to show high resilience to climatic fluctuations, currently the driest part of the loma desert vegetation appears to be at a tipping point. According to the fifth IPCC report, this area of the desert, and northward, is predicted to experience higher temperatures, but possibly more precipitation over this century, whereas more southerly parts of the desert are predicted to experience increased temperature and decreased precipitation. Increased rainfall could eventually detain present loma dieback. However, the southern end of South American desert is expected to dry further, in which case its vegetation could follow a similar trajectory today seen in the more northerly lomas. Overall, climate change and rampant development in coastal areas of Chile could become major threats to endemic western dryland biodiversity. Currently 35% of Chilean table grapes are grown in the southern part of the desert biome and its transition to the Mediterranean-climate area in Chile (ODEPA, 2013). Given expected increasing water scarcity in an increasing arid climate, grape-growing activity is likely to further affect terrestrial and aquatic biodiversity.

Although fire is far less prevalent in Caatinga than in adjacent Amazonian forest and Cerrado (de Araújo *et al.*,

Figure 5 14 **Drylands and deserts units of analysis viewed in the IPBES conceptual framework. Source: own representation.**



2012), fire frequency could increase with increasing aridity, predicted by the fifth IPCC report. This, however, will depend upon how woody cover evolves taking into account that vegetation response of Caatinga to precipitation tends to be nonlinear (Souza *et al.,* 2016) and that a carbon dioxide fertilizing effect is possible. That Caatinga lies adjacent to wetter biomes is positive for providing habitat suitability elsewhere under climate change (c.f. Oliveira & Cassemiro, 2013).

As with the Tundra, climate change is the major threat to drylands, though urbanization is also a serious, continuing threat. Drylands would be expected to continue to be impacted by changing climate under the Fortress World and Market Forces archetype. While improvements with respect to climate change can be expected under the Policy Reform archetype, it is likely that scenarios that can be classified under the Great Transition archetype are the only ones that could reverse current trends.

5.4.7 Wetlands – Policy potentialities

Wetlands constitute one of the more ubiquitous types of ecosystems throughout the Americas, providing a wide range of NCP and occur as a significant component within the following units of analysis: temperate and boreal forests, montane systems, grasslands, tundra, freshwater surface waters and water bodies, coastal habitats, and production systems. Although scattered across these units, wetlands have the shared charateristic that they are areas where the soil is saturated at a frequency and duration such that the soils are physically and chemically modified to form "hydric soils" (e.g. peat) and the vegetation is dominated by plant species adapted to growing in saturated conditions; such species are referred to as "hydrophytes" (e.g. cattails (*Typha* spp.)) (Laboratory, 1987). Wetlands may be characterized by standing water throughout the year (e.g. marshes), or water may never be visible at the surface of the ground, though saturation is close enough to the surface as to affect the soils and influence the plant community (e.g. some temperate swamps). Thus, wetlands are transitional between purely aquatic ecosystems and purely terrestrial ecosystems.

Wetlands are recognized as providing the full range of ecosystem goods and services defined in this assessment **(Figure 5.15)**. For example, they provide provisioning services, such as food in the form of waterfowl, seafood, and cultivated rice (*Oryza sativa* and *O. glaberrima*); regulating services in the form of groundwater recharge and discharge zones, shoreline protection, as well as contaminant removal; and cultural services, such as aesthetic enjoyment, recreation, and are important culturally, such as the role of wild rice (*Zizania palustris*) in the culture of some Native North Americans (Mitsch & Gosselink, 2007; Vennum, 1988).

As noted above, wetlands occur as a significant component in seven of the 17 units of analysis recognized in this assessment. Indeed, they occur to at least some extent in all of the units, except deep water habitats. The importance of wetlands is amply demonstrated in terms of NCP by **Figure 5.15**.

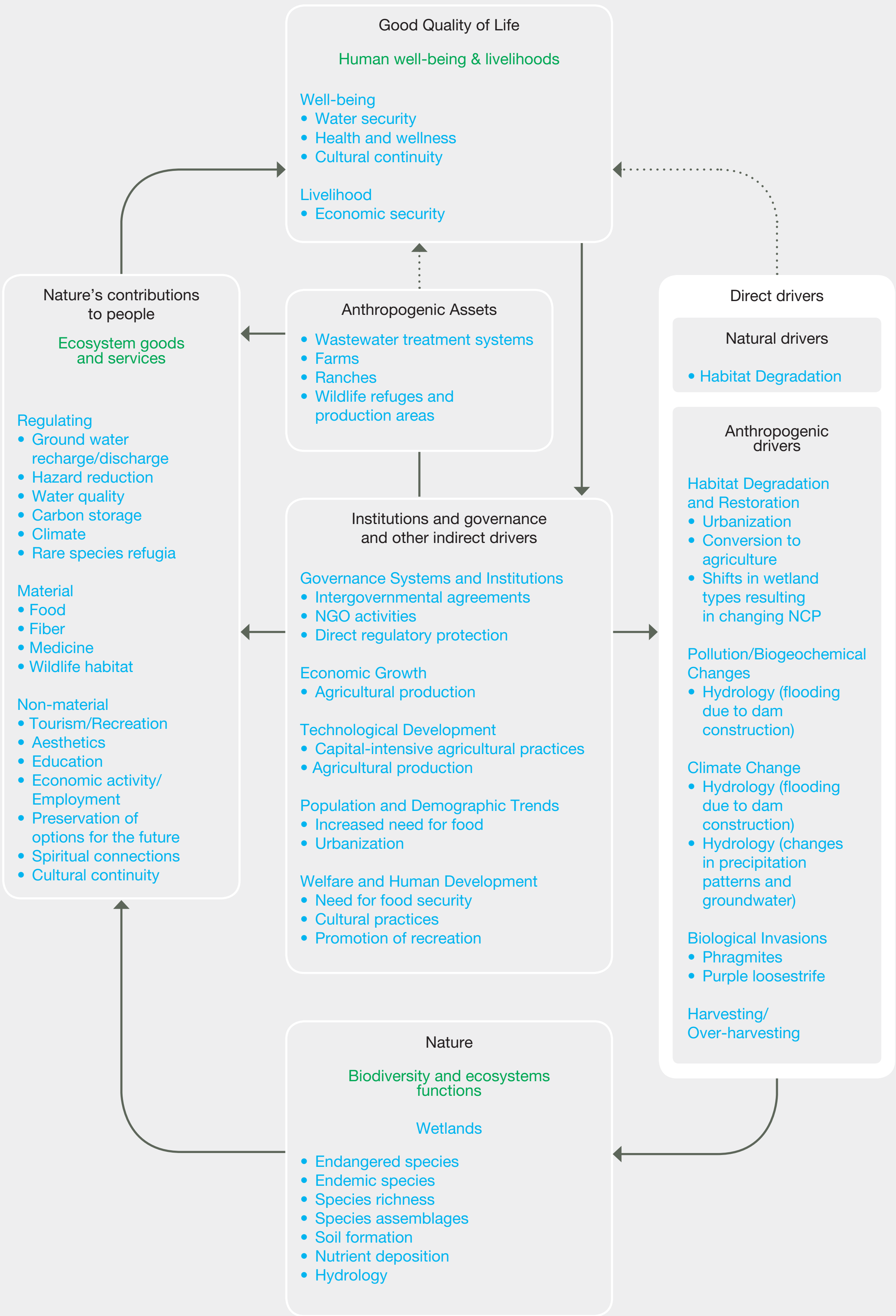
On a worldwide basis, 64% of the wetlands that existed in 1900 have disappeared (Davidson, 2014; Ramsar, 2006). The reasons for this decrease are varied, but are primarily due to changes in land use, with the majority of wetland loss attributable to conversion to agriculture and forestry (Poulin *et al.,* 2016). Ramsar has monitored 1,000 sites since 1970 and has found that wetland loss continues, with these sites shrinking by an average of 40% by 2008. This loss of wetland is not distributed uniformly on a global basis. Dixon *et al.* (2016) found that for Oceania, North America and Africa, the rate of wetland loss has substantially decreased. However, rates of loss for Asia and Europe continue fairly unabated.

For North America, the reduction in the rate of loss has been accomplished primarily through policy intervention. The USA Federal Government has enacted laws and regulations protecting wetlands, as well as encouraging conservation measures through government programs, and in the non-Governmental organization sector. While Canada has no specific Federal legislation protecting wetlands (Environment Canada, 2016), it does have a national policy of wetland conservation on Federal lands (Canada, 1991). However, wetland protection is provided indirectly at the national level through a variety of laws and regulations including, Canada Wildlife Act, Fisheries Act, Migratory Birds Convention Act, Species at Risk Act, and Canadian Environmental Assessment Act. Additionally, Canadian provinces have enacted a variety of laws intended to conserve wetlands (Rubec & Hanson, 2009).

To assess the effectiveness of these measures specifically in the USA, the federal government began monitoring the extent and type of wetlands in the coterminous USA in 1970, as well as the quality of the wetlands more recently (Dahl, 2011; USEPA, 2011). Dahl (2011) reported that the rate of wetland loss in the USA has decreased from an annual loss of 185,425 ha in 1950-1970 to 5,590 ha in 2004-2009; a decrease of 97%. In fact, in the period of 1998-2004, there was an actual net gain in wetlands in the USA of 12,955 ha per year.

In addition to the work by Dahl (2011), Dixon *et al.* (2016) has evaluated wetland trends for all of North America and found that 4% of inland wetlands were lost in the period 1970-2008, while 28% of coastal/marine wetlands were

Figure 5 15 **Wetlands viewed in the IPBES conceptual framework. Source: own representation.**



lost, for an overall loss of 17% for the two classes of natural (not manmade) wetlands. It is notable that the 4% loss of inland wetlands in North America compares to 31%, 39%, 59% loss of inland wetlands in Africa, Asia, and Europe, respectively. On the other hand, Poulin *et al.* (2016) have assessed the effectiveness of recently established provincial policy in Quebec. They found that despite legislative mandates for wetland mitigation, nearly all wetlands subject to permit agreements were lost without commensurate wetland mitigation (though other forms of mitigation did come into play, such as upland preservation).

While these figures argue for the effectiveness of policy efforts, they mask other underlying considerations.

The capability of any ecosystem to delivery its characteristic suite of goods and services is dependent on the integrity of the structure and function of the ecosystem. While Dahl (2011) reports that for the period of 2004-2009, wetland losses were statistically insignificant overall, there were quite decided shifts in wetland types. For that period, freshwater wetlands actually increased by 8,900 ha, but this increase was attributable to an increase in agricultural, industrial and urban ponds. Non-forested freshwater wetlands (which were considered in the report to be the ones expected to have a reasonable degree of ecological integrity) actually decreased by 72,900 ha, with forested wetlands decreasing by 249,200 ha; while the types and level of ecosystem goods and services delivered by constructed agricultural, industrial and urban ponds are not the same as lost from the forested systems, they may nevertheless deliver more NCP for a specific service, such as food production.
The tension between the valuation of different wetland ecosystems and their associated NCP is also exemplified by somewhat conflicting legislation. For example, while there is federal legislation in Canada protecting naturally occurring wetlands, there is also local legislation, such as Ontario's Tile Drainage Act that promotes drainage of wetlands for agricultural purposes (Environment Canada, 2016). A similar situation exists in the USA at the state and local levels.

It is also instructive to look at the land use changes that accounted for the shifts in wetland types during the period of 2004-2009 **(Table 5.1)**.

Conversion to silviculture accounted for the greatest decrease in wetland extent, while "Other" accounted for the greatest gain. "Other" includes land use changes that are so recent that the ultimate land use category could not be determined. However, it also included newly constructed wetlands and establishment of conservation easements. Thus, it is apparent from **Table 5.1**, that wetland loss continues with respect to underlying causes. These causes also point to other factors contributing to wetland loss. The conversion to deep-water habitats is largely from salt marsh loss resulting from wave action encroachment allowed by fragmentation of salt marsh associated with oil and gas production. Similarly, urban and rural development can have synergistic effects through increased nutrient, heavy metal, and other pollutant loading to nearby wetlands.

The United States Environmental Protection Agency (USEPA, 2011) considers these latter concerns as potential threats to the quality of wetlands. For example, they list road runoff as a source of copper, lead, and vanadium contamination. Similarly, they point out that agricultural activities can be the source of heavy metals such as cadmium, copper, nickel and tin, as well increased nutrient and sediment loads to wetlands. The overall effects of these contaminants may be reflected in the fact that wetlands in areas with intense agricultural activities also tend to have lower floristic quality compared to areas with less intense agriculture.

Historically, wetland degradation near large urban centers has been particularly acute. This trend is likely to continue, given the limited options for avoiding land use conflicts in

Table 5 1 **Changes in wetlands attributable to indicated land use classification 2004-2009. Source: Dahl (2011).**

Land use category	Net change in wetland area (hectares) attributable to change to indicated land use
Deep Water	-46,947
Urban Development	-24,951
Rural Development	-27,101
Silviculture	-124,429
Agriculture	40,494
Other	157,738

densely settled areas. Climate change is a growing threat to wetlands across North America. Across the peatlands of Canada and Greenland, climate change is likely causing widespread permafrost degradation, alterations of snow and ice regimes, and changes in ultraviolet radiation (Jeffries *et al.,* 2013). Changes in freshwater geochemistry including eutrophication arising from the release of stored nutrients in permafrost and deepening of the active soil layer have been reported (Meltofte, 2013). In boreal peatlands, climate change is expected to trigger increased drought and so increased fire frequency and peat loss (Galatowitsch *et al.,* 2009). Climate change projections for the prairie pothole region suggest shifts in hydrology that will make most of the region unsuitable breeding and migratory habitat for waterfowl (Galatowitsch *et al.,* 2009; Johnson *et al.,* 2005). Climate maladaptation by the agricultural sector, needing to secure more water sources, seems likely to result in water diversions and groundwater extraction, adversely altering wetlands in many parts of North America, including the prairie pothole and Everglades wetland landscapes (Galatowitsch *et al.,* 2009; National Research Council, 2014).

Wetlands in seasonal tropical climates, as is the case of the Palo Verde wetland, are governed by extreme seasonal hydrologic fluctuations and are characterized by rapid vegetation responses to changes in water level. Climate change models in the seasonal Palo Verde wetlands in Costa Rica predict reduced rainfall and a drier wet season. Based on the distinctive composition of wet and dry season vegetation, and high species richness in the wet season, local loss of diversity is predicted accompanied by increased abundance of drought-tolerant emergent species (Osland *et al.,* 2011).

Given a general tendency for increased aridity and changes in seasonal rainfall distribution in South America over the coming century, wetlands are likely to be negatively impacted by climate change (Junk, 2013). However, there are many uncertainties given regional climatic variation. For example, some climate models show increases in rainfall and in discharges of the Paraguay Basin, while others show reductions (Marengo *et al.,* 2016).

The two main drivers affecting wetlands currently and expected to continue to do so in the future **(Figure 5.15)** are habitat degradation and climate change. With respect to habitat degradation (i.e. primarily conversion of wetlands to agricultural use), the information presented above speaks to the feasibility and potential effectiveness of policy intervention in wetland conservation and, thus, speaks to the potential implications of the archetypes. The majority of wetland loss that has occurred in North America occurred, as the land was being settled and converted to agriculture. We see this driver still taking place in other areas of the Americas, notably South America where land is being converted to agricultural purposes, such as growing soybeans. Thus, under the Market Forces archetype, we would expect to see continued loss of wetlands in areas that do not already have protections. Under Fortress World, we would expect a similar, though likely more severe, trend as market forces and expanding populations requiring food would result in the same trend observed in North America in the 1800 to mid-1900s. The relative effectiveness of policy intervention is well-evidenced by the above discussion and thus, under the Policy Reform archetype one would expect a reduction in the rate of wetland loss where it is still prevalent, though depending on the policies, shifts among wetland types may occur as the do in USA, with concomitant shifts in the exact NCP provided. The adoption of policies, such as those in USA and Canada and the recent significant set aside of the Llanos wetlands of Bolivia, could be a significant boon to maintaining the NCP provided by wetlands. The set aside in Bolivia also points to what might happen under the New Sustainability Paradigm archetype (i.e., an archetype similar to the Policy Reform and the Great Transition group of archetypes). Despite being in a region where land use changes to agriculture is proceeding at a substantial rate; it is possible to set aside ecosystems whose NCP values are recognized.

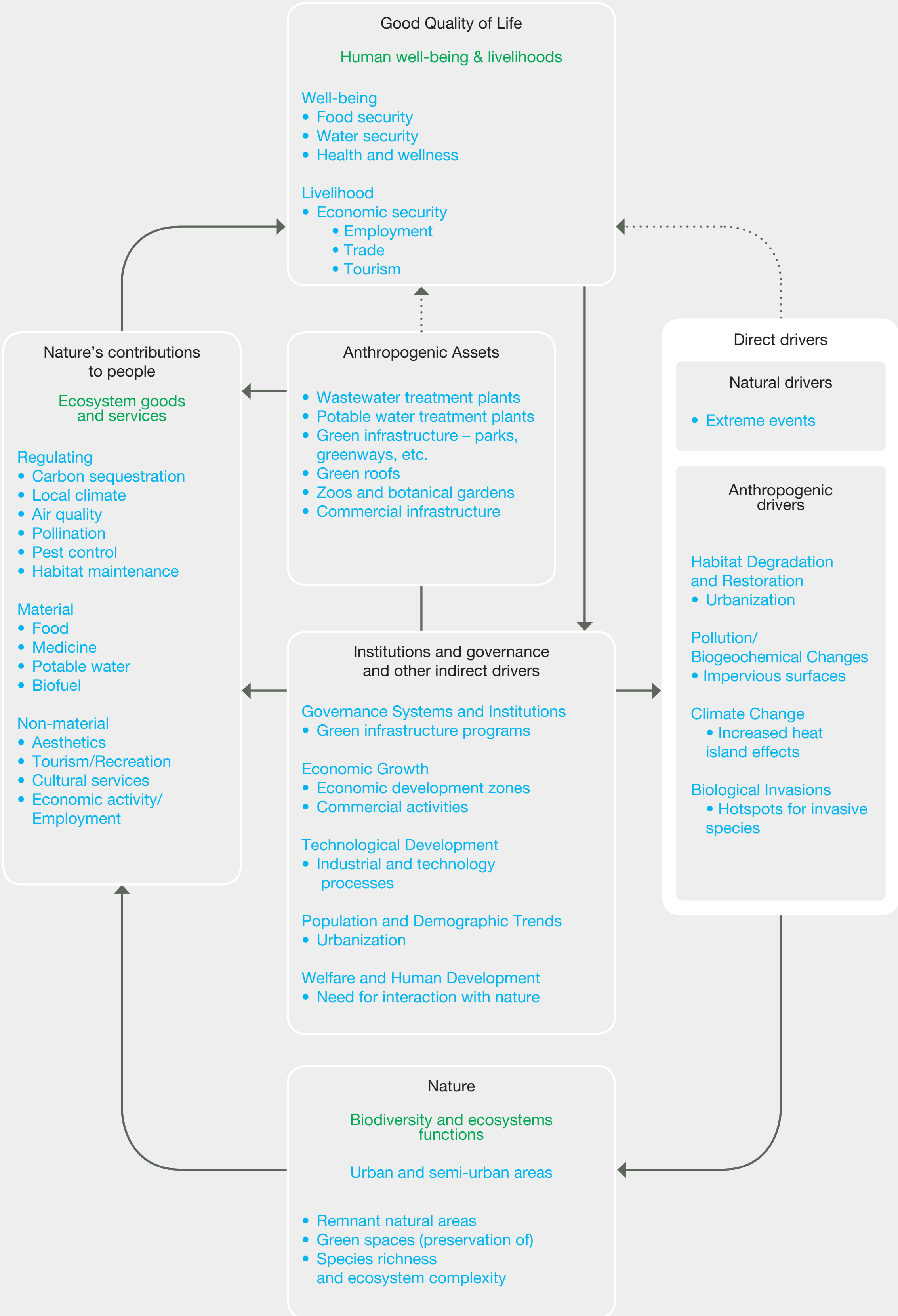
While the Policy Reform family of archetypes hold promise with respect to addressing land use changes, it is likely a much less effective scenario for curbing wetland impacts due to climate change. Additionally, climate change may also result in increased water withdrawal from wetlands or the aquifers that supply groundwater-fed wetlands. Thus, agriculture and climate change can be viewed as synergistic drivers, and for reasons covered under Tundra and Boreal Forest, effective approaches in dealing with this synergistic pairing will require more radical approaches, consistent with the Great Transition family of scenarios.

The above focal analysis provides a good indication of the complexity of determining what “the best” use of world’s natural capital is. Multiple drivers, teleconnections, telecoupling, differing socio-economic conditions, and differences in cultures and values are all considerations in trying to create a sustainable world. Section 5.6 discusses the detailed considerations in developing specific scenarios that can inform the policy process in attaining this goal.

5.4.8 Urban/Semi-urban – Effects on multiple aspects of human well-being

Urbanization will continue as world population grows and may have its greatest effect in intermediate-sized cities, which have the highest growth rates (Chapter 2). The continuation of urbanization will impact other units of

Figure 5 16 **Urban/Semi-urban viewed in the IPBES conceptual framework. Source: own representation.**



analysis, such as agricultural systems and can result in significant impacts to NCP provided by those systems, such as provisioning of food (Chapter 3). For example, Schneider *et al.* (2012) estimates that by 2030, urban expansion in the Midwest of the USA may reduce agricultural land that could feed up to 532,000 people.

While urban centers are impoverished ecological systems relative to many ex-urban areas (including agricultural systems and the landscapes within which they are imbedded (Chapter 3), they still host a variety of species and underpin a variety of ecosystem services, especially with respect to regulating and cultural services (Chapter 2).

Some urban areas, such as the City of Detroit, Michigan, USA, park systems contain remnant tracts of vegetation that are only slightly changed from pre-settlement times due to the fact that they were parts of estates before urbanization spread to their area and were protected as part of park systems (Weatherbee & Klatt, 2004). Indeed, one of the natural communities (Mesic Flatwoods) recognized in Michigan, was first described just a few years ago based on the urban park Belle Isle, located in the Detroit River, between the downtowns of Detroit and Windsor, Ontario, Canada (Cohen *et al.,* 2015). These observations argue for continued inventorying of the biological assets in urban areas, even in areas that are considered highly urbanized and studied (Chapter 3).

Perhaps the greatest impact on biodiversity due to urbanization may be indirect, through the continued reduction of human-nature interactions, which have been shown to be beneficial to people in general and even utilized in human medicine as an adjunct to cancer treatment (Chapter 2) (Cimprich & Ronis, 2003; Louv, 2008). The disconnect from nature is likely to result in disaffection toward nature and reduced motivation to protect, due to a lack of understanding.

It is in the area of urban planning that some of the greatest opportunities for meeting the Sustainable Development Goals (SDG) by employing technological advancement in preserving and enhancing the function of urban ecosystem and mitigating the negative consequences of urbanization exist. For example, the use of designed wetlands for the treatment of storm runoff and sanitary wastewater can lower point pollution of surface water, provide wildlife habitat, and afford cultural opportunities to enjoy nature. More study is needed to determine adequate amounts of greenspace for human well-being from a variety of perspectives, Shanahan *et al.* (2016) have shown significant effects with 30 minutes per week of exposure to natural surroundings. There is strong evidence for a positive effect of the number of urban greenspaces on biodiversity; a relationship well established on the principle of MacArthur and Wilson's Theory of Island Biogeography (Macarthur & Wilson, 1967). Indeed, the mathematical relationship between available habitat and species diversity has been described for a number of systems.

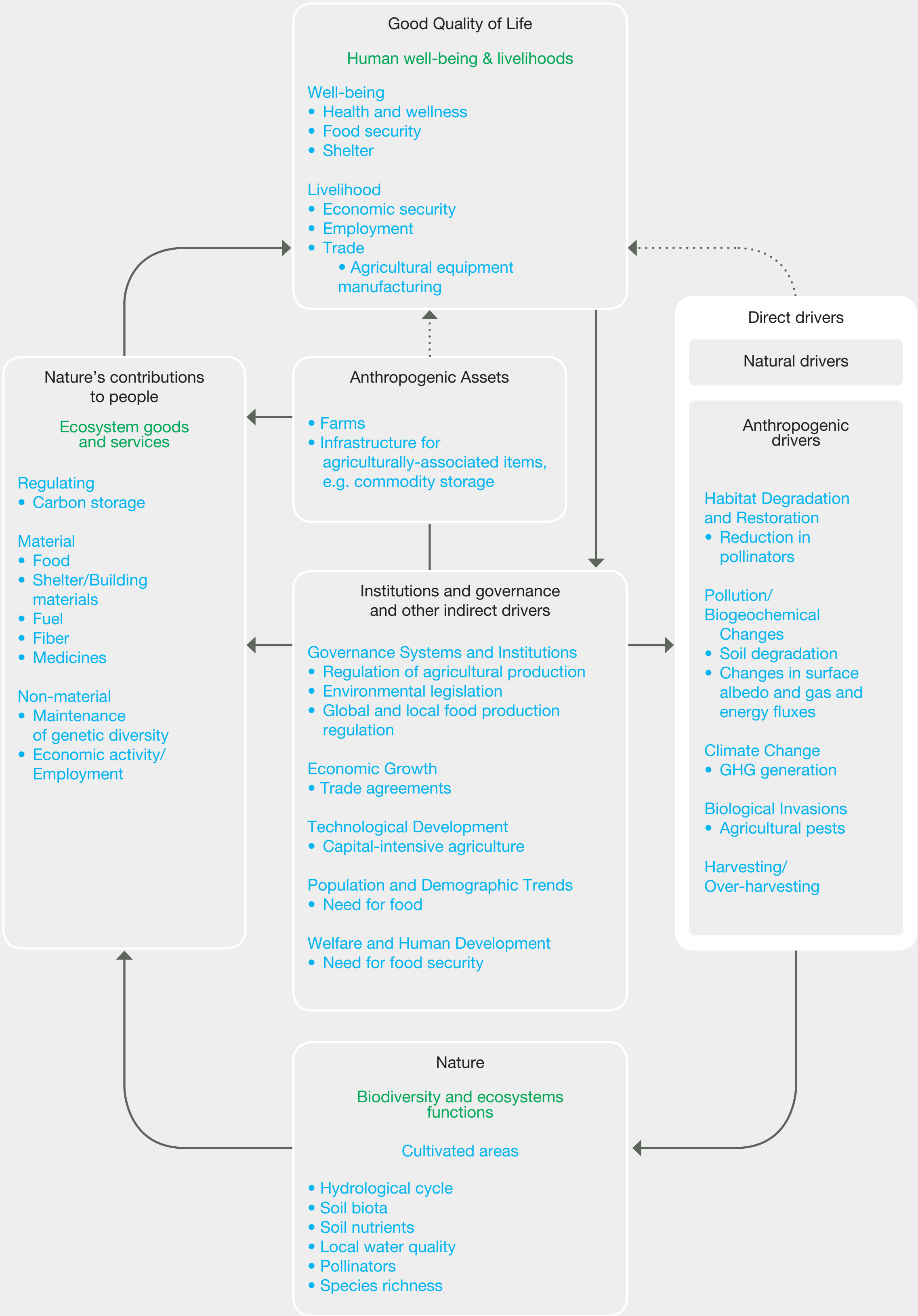
As with most human endeavours, such as the development of agriculture and technological advances, urbanization has both significant benefits and costs. Urbanization is associated with increases in quality of life in terms of food availability, sanitation, and healthcare; it is also associated with environmental degradation, poverty, unemployment, and violence. It will take public discourse and development of sustainable development policies to insure maximization of benefits and minimization of costs.

As urbanization is one of the main causes of land use changes, reduction of the effect of this driver in urban areas themselves will require concerted effort in land use planning. Thus, various approaches within the Policy Reform and Great Transition archetypes hold promise for biodiversity conservation with respect to urbanization.

5.4.9 Cultivated areas (including cropping, intensive livestock farming, etc.)

The agricultural land in Latin America and the Caribbean showed one of the larger expansions in the past 50 years (Martinelli, 2012). The challenge the region faces is to meet the large potential for food, fiber and fuel production aligned with conservation of one of the larger and unique collections of biodiversity, on the planet. Most of the increase in production was associated to the expansion of extensive agriculture over forests and natural ecosystems areas (Willaarts *et al.,* 2014). In Brazil, one of the larger agricultural commodity producers in the regions, circa 20% of the Amazon rain forest and 50% of the dry forest (Cerrado) was lost due to the expansion of agriculture in the past 40 years (Aguiar *et al.,* 2012; Bustamante *et al.,* 2012). Also, pressures over the Chaco area (Bolivia, Paraguay and Argentina) due to increase of grain and beef production is critical. Latin America and the Caribbean has a key role in the international agriculture products market, as a leading exporter and producer of soybean, sugar, coffee, fruits, poultry, beef and bio-ethanol (Martinelli, 2012). The greenhouse gases emissions portfolio in the region is strongly centered in process of land cover change (deforestation, forest degradation, land degradation) (Aguiar *et al.,* 2012) and land use by agriculture and cattle ranching. According to Sy *et al.* (2015), analyzing the 2010 global remote sensing survey of the FAO - Global Forest Resources Assessment, pasture was responsible for more the 70% deforestation in Northern Argentina, Western Paraguay, and eastern portion of the Brazilian Amazon (the arc of deforestation), whilst deforestation driven by commercial

Figure 5 17 **Cultivated areas (incl. cropping, intensive livestock farming, etc.) viewed in the IPBES conceptual framework. Source: own representation.**



cropland (12-14%) had an increased pattern in time, and the hotspots found in Brazil (south western Amazon), Northern Argentina, Eastern Paraguay and Central Bolivia. In Brazil, Argentina and Mexico agriculture has already surpassed the emissions derived from deforestation (UNFCCC). Broader data published by (Graesser *et al.,* 2015) indicate that, for the entire Latin American region, 17% and 57% of forest replacement was due to new cropland and new pastureland.

The agricultural expansion and production varies strongly in the region, and production has distinct level of cropping efficiency and intensity in different countries and biomes. Thus, intensification and extensification processes have driven the agriculture expansion in the region in the past decades. Most commoditized agriculture is highly technological and is related to private and commercial companies, but small holder agriculture plays a critical role on food production at local and regional scale (Boillat *et al.,* 2017). Land tenure and demography in the region also play a role in the dynamic of land use change processes. The demographic configuration of the Latin America and the Caribbean region has low population density in the rural area and one of the most urbanized regions on the planet (e.g. almost 80% of the population lives in cities) (UNEP, 2014). Land tenure is a critical issue. In Mexico, Bonilla-Moheno *et al.* (2013) showed differences in woody cover, in natural vegetation landscape units, from common-pool systems of land tenure, in contrast to communal and private regimes, where the latter ameliorate, reducing the deforestation process.

5.4.10 Inland surface waters and water bodies/freshwater unit of analysis – The case of multiple demands/multiple drivers on natural capital

Water is fundamental to all living things, the chemistry of life occurs in aqueous solution. Whether an organism occurs in terrestrial, sub-terrestrial, marine or freshwater environments it is dependent on water. Thus, all of biodiversity, as well as the NCP stemming from that diversity, link to water. While marine systems dominate the globe in areal extent, human well-being is, arguably, more closely linked to freshwater, if for no other reason than the human need for drinking water.

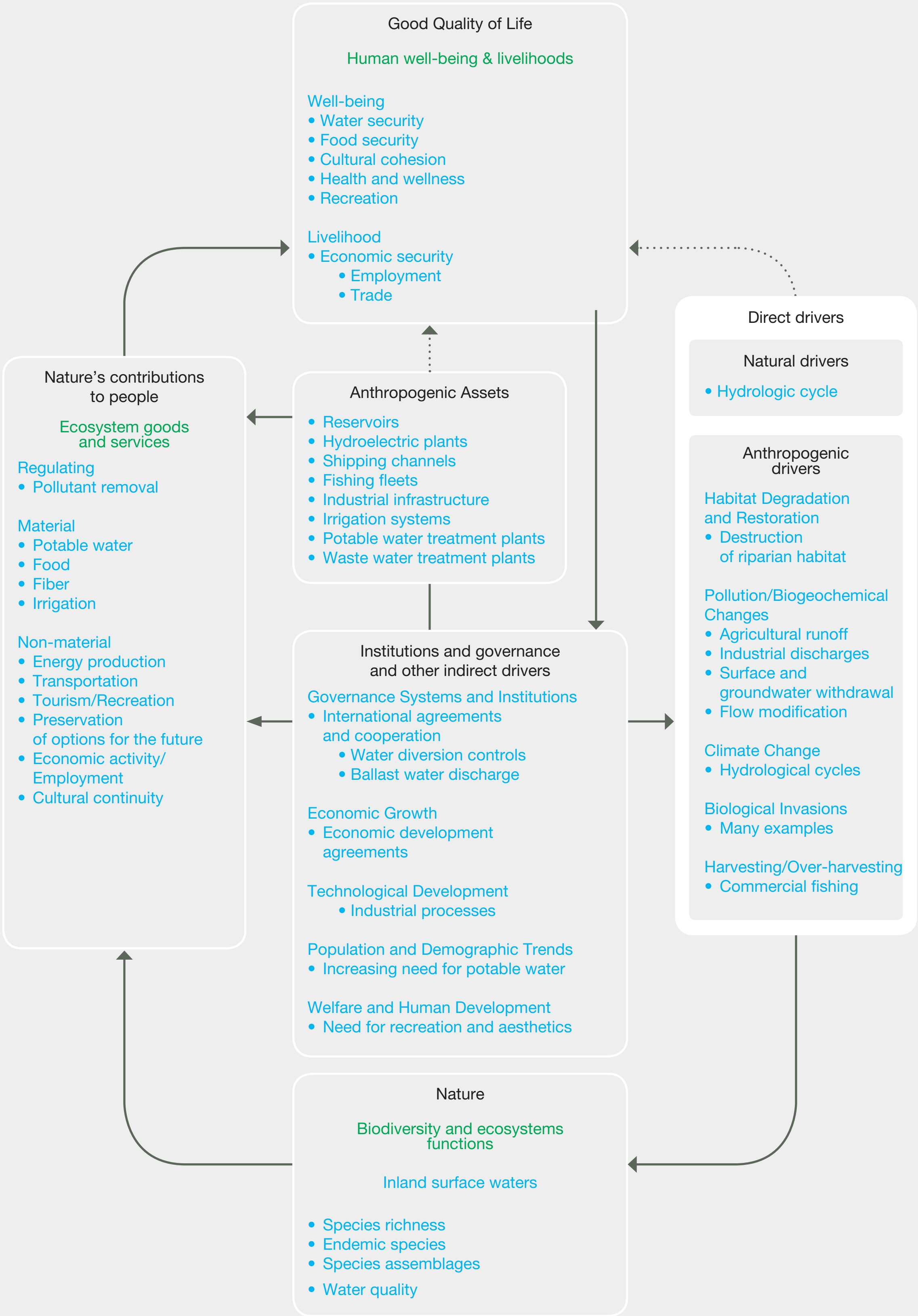
The distribution of water is heterogeneous, as is the specific need for water. The demands on freshwater systems are large and extremely diverse. For example, though both are areas of high intensity agriculture, the need for irrigation in the Upper Midwest of the USA is much lower than for the central valley of California. Ironically, in the Upper Midwest where rainfall tends to be adequate, 20% of the world's freshwater is found in the Great Lakes. Thus, there can be major disconnects between need and occurrence of this natural capital.

Sustainable Development Goal 6 is "Ensure access to water and sanitation for all." Chapter 2 makes clear the NCP of freshwater systems and are presented **Figure 5.18**. Indeed, the criticality of water as a resource, in terms of sustainability, economic activity (including as a source of jobs), and human health have been emphasized, respectively, in the last three World Water Reports (WWAP, United Nations World Water Assessment Programme, 2015, 2016, 2017). While Chapter 3 describes both discouraging and encouraging trends, the challenges facing this unit of analysis are made clear by the discussion of drivers in Chapter 4.

Two primary drivers that act synergistically are demographics and agriculture. It is expected that water use will continue to rise both absolutely and on a per capita basis due to increasing populations throughout the Americas and agricultural intensification, respectively. Though irrigation technology has improved via such aspects as in-field moisture sensors, the adoption of these technologies is slow (WWAP, United Nations World Water Assessment Programme, 2015). As agriculture intensifies, especially in South and Mesoamerica, increased pressure will be placed on freshwater systems due to water withdrawal and eutrophication due to nutrient-laden runoff. Though point-source pollution has been much reduced in North America, the same does not apply regarding non-point source pollution and agriculturally-related nutrient inputs are a major concern in the Mississippi River basin and western Lake Erie of the Great Lakes. The aspect of water withdrawal is especially troubling in Mesoamerica where, in certain areas, a third of aquifers are already over-allocated. But water withdrawal is also a serious problem as well as in North America where there is a dependence on "fossilized water" (aquifers that are not being replenished) for irrigation. The combination of the need for drinking water and irrigation is particularly problematic in the southwest USA where up to 76% of river flows are withdrawn annually (the Colorado River frequently does not reach the Sea of Cortez and its delta is 10% of what it used to be).

Linked drivers, including urbanization and energy needs, provide a challenge to freshwater systems and simultaneously meeting SDG 7 (sustainable energy) and 15 (eliminate biodiversity loss). There is no doubt that energy production via burning of fossil fuels has significant environmental consequences and that sustainable energy sources are needed, especially if urban energy needs are to be met. However, the three main current sources of sustainable energy, namely solar, wind and hydro, all come with their own ecological footprint. Hydropower is a source being widely considered in South America and there are

Figure 5 18 **Inland surface waters and water bodies/freshwater unit of analysis viewed in the IPBES conceptual framework. Source: own representation.**



currently a number of dams either under construction or being planned. While these will provide reliable energy, they also come with an environmental price including disruption of fish migration routes, increased sediment deposition upstream, channel scouring downstream, and disruption (increased and decreased) of annual flooding of riparian terraces traditionally used for agriculture.

While freshwater systems are undeniably an important resource to humans as drinking water, freshwater is also critical to the biological resources found in lakes, streams, and rivers. The Americas are exceptional in their freshwater resources. For example, as noted in Chapter 3, the Americas contribute 47% of the freshwater that flows to the oceans and the freshwater of the Americas is home to over 5,000 species of fish, which provide subsistence food, commercial food, and sport opportunities. However, these and other freshwater biological resources in the Americas are threatened by habitat degradation (e.g. construction of dams for hydroelectric power), climate change, pollution (as in the water quality issues for Lake Erie discussed above), and invasive species (e.g. Asian carp and zebra mussels in North America) resulting in higher extinction rates than for most terrestrial biomes (Dove, 2009; Chapter 3).

These drivers will continue to present recurring and likely increasing, challenges to freshwater resources as we approach 2050. While serious threats exist to the Americas' freshwater systems, there is also evidence that planning and international cooperation in addressing these threats through policies and intergovernmental agreements have helped some freshwater systems, notably the Laurentian Great Lakes in North America. Coordinated water pollution control by Canada and USA, and the formation of the International Joint Commission on the Great Lakes have achieved substantial levels of success in protecting the Great Lakes with respect to water removals and diversions (International Joint Commission, 2016) and reductions in petroleum, pesticides, heavy metals, and nutrient pollution since the 1970s (Hartig *et al.,* 2009). For example, water clarity has vastly increased in Lakes Michigan and Huron, phosphorous levels have been reduced to the extent that they are now considered a limiting nutrient in the lakes, chloride levels in Lakes Huron, Erie, and Ontario have decreased (reversing a 150-year trend of increasing levels).

These improvements are credited with recovery of a number of biological resources, including bald eagles *(Haliaeetus leucocephalus)*, peregrine falcons *(Falco peregrinus)*, lake sturgeon *(Acipenser fulvescens)*, lake white fish *(Coregonus clupeaformis)*, walleye *(Sander vitreus)*, and burrowing mayflies (*Hexagenia* spp.) (an important prey item in fish diets) (Hartig *et al.,* 2009). While improvements have been noted in these measures, other pollutants, such as silica and nitrogen, have increased (Binding *et al.,* 2015; Chapra *et al.,* 2009; Dove, 2009; Dove & Chapra, 2015).

Thus, while policies and international cooperation has been helpful in North America, it is clear that futures that include scenarios from the Fortress World or Market Forces archetypes will not be enough to stem the increasing pressures of non-point pollution, climate change, and invasive species even at the subregion. True paradigm shifts will be required throughout the Americas to address impacts to freshwater, especially in terms of water quality and availability, in the face of increasing reliance on pesticides, fertilizers, and irrigation in agriculture in response to increasing populations and climate change. It is clear that to make progress towards the Aichi targets and SDG, serious consideration should be given to devising scenarios designed within the Policy Reform and Great Transition archetypes.

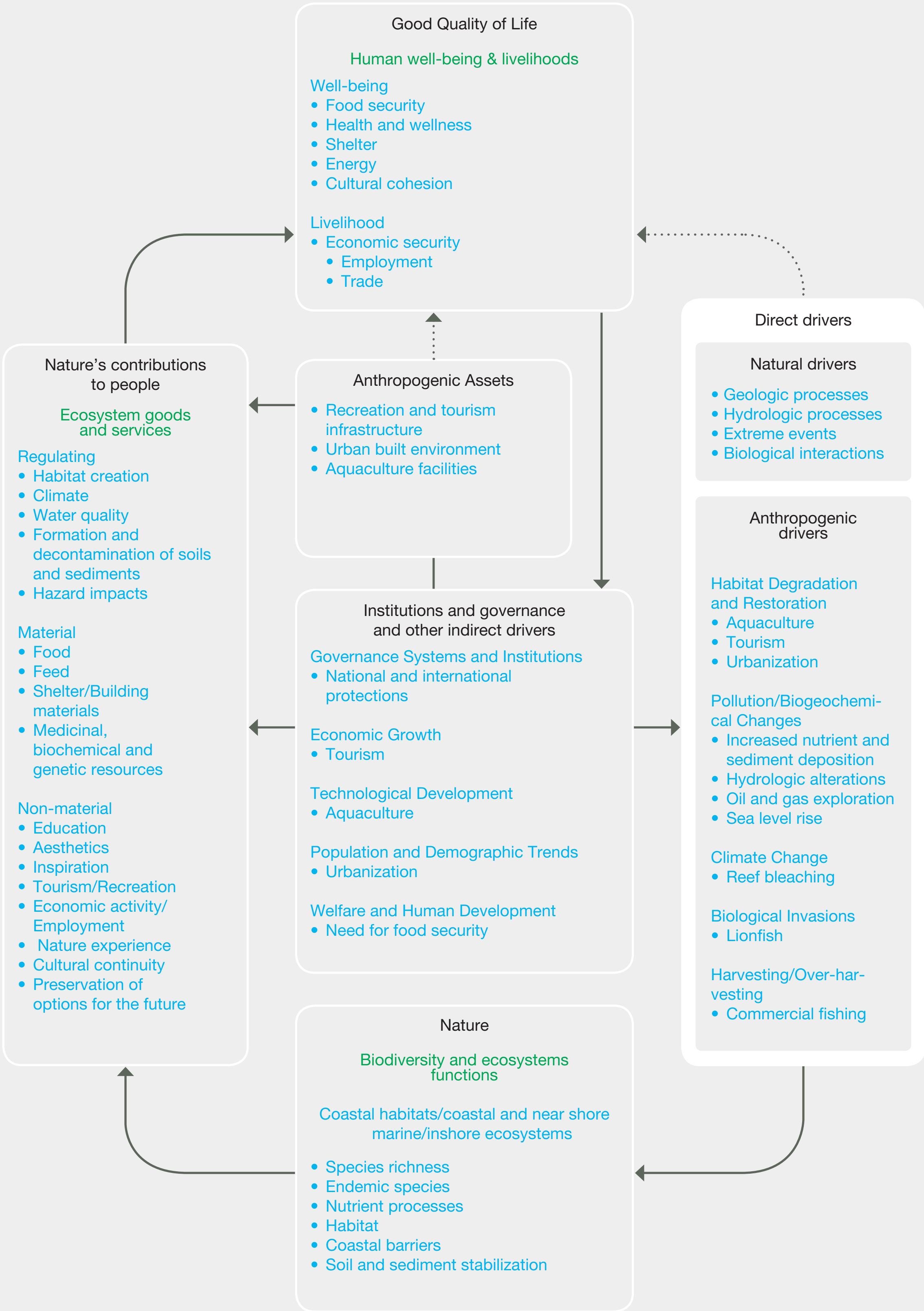
5.4.11 Coastal habitats/coastal and near shore marine/inshore ecosystems unit of analysis

Coral Reefs. According to Knowlton (2001) the combination of nutrification, global warming, and loss of top members of the food chain (and introduced chemicals) is unprecedented over the last 65 million years. Bozec *et al.* (2016) concluded that reduced fishing for parrotfish and other herbivores would make reefs more resilient to warming and ocean acidification. Global warming is placing Caribbean coastal ecosystems under further stress. Predicted increased severity of hurricanes and greater rainfall seasonality for the region are also likely to increase stress (Fish *et al.,* 2009). According to the IPCC fifth assessment report, under 4°C warming, widespread coral reef mortality is expected with significant impacts on coral reef ecosystems, this will imply a high risk of extensive loss of biodiversity with concomitant loss of ecosystem services (CB Field *et al.,* 2014).

Mangroves. These wetland systems occur along coastal areas from the subtropics in North America to the tropical and subtropical regions of Central and South America. Like most wetlands, they provide a range of ecosystem goods and services. They provide provisioning services in the form of food production (Engle, 2011); regulating services in the form of storm protection, coastal protection, and erosion control (Anthony & Gratiot, 2012a; Marois & Mitsch, 2015; Zhang *et al.,* 2012) and cultural services in the form of recreation and aesthetic enjoyment (Mitsch & Gosselink, 2007) **(Figure 5.19)**. Indeed, they are considered some of the most productive wetlands on Earth from the standpoint of providing habitat for fisheries and wildlife.

On a global basis, it is estimated that over 60% of the world's wetlands have been lost and this is largely due to land use changes, primarily conversion to agricultural systems (Ramsar, 2006); these losses are not uniformly

Figure 5 19 **Coastal habitats/coastal and near shore marine/inshore ecosystmes unit of analysis viewed in the IPBES conceptual framework. Source: own representation.**



distributed among wetland types or geographic areas, but the losses continue. Between 1980 and 2007, 25-35% of the world's mangrove forests were lost (FAO, 2017a; Inniss & Simcock, 2016; MEA, 2005). Moreover, Marois and Mitsch (2015) state that the majority of remaining mangrove forests are located within 25 km of major urban centers. Recent figures indicate that the loss of mangrove forest has continued with an additional loss of 1-2% per year, though higher rates occur in some regions. It is notable for this assessment that from 1980 – 2007, there has been a loss 24-28% of the areal extent of mangroves in the Caribbean with much of the loss due to conversion to urbanization, fuel wood, solid waste disposal, and aquaculture (Anthony & Gratiot, 2012b; Inniss & Simcock, 2016).

With anticipated rises in sea level and more and more intense storm events associated with climate change, this loss of mangrove forest is of concern due to their role in storm surge attenuation, shoreline protection, and soil erosion prevention. The attenuation of normal wave energy by mangroves is well known. However, it has become increasingly recognized that mangrove forests may play a significant role in ameliorating the effects of severe storm and tsunami-generated waves. Danielsen (2005) reported that villages that had a mangrove barrier suffered relatively fewer deaths from the Indian Ocean tsunami than villages without such a barrier. While some have questioned the efficacy of mangroves in the case of tsunamis, Zhang *et al.* (2012) have convincingly demonstrated the protective value of mangroves in the case of hurricane Wilma that had landfall in southwest Florida USA. They showed that a 7-8 km wide mangrove forest reduced inundation by 80%, thus protecting inland freshwater wetlands from saltwater encroachment.

Mangroves also play a role in prevention of soil erosion. Along the northern coast of South America, sediment-laden waters from the Amazon River form extensive areas of shifting mud flats. These mud flats extend thousands of kilometers along the coast and are stabilized by mangroves. However, in some areas, the mangroves have been removed for development, or dikes built to establish aquaculture operations, isolating the mangroves. In those areas, the protective stabilization provided by the mangroves is no longer there, resulting in erosion of the mud flats and conversion of the shore to sand. The sandy soils do not support vegetation and are highly erodible requiring local communities to install expensive shoreline armoring, such as rip-rap or concrete break walls (Anthony & Gratiot, 2012b).

Conservation of the mangroves in an area may also have synergistic effects. Engle (2011), reviewed the available information on ecosystem services associated with wetlands in the Gulf of Mexico, including shrimp production. Juvenile shrimp develop in coastal wetlands, primarily marshes. However, as in the case of mangrove forests, there is an on-going loss of coastal marsh in the Gulf of Mexico primarily resulting from changes in flow patterns induced by oil and gas exploration (Rangoonwala *et al.,* 2016). As shrimp habitat decreases, it has been found that juvenile shrimp use other coastal wetlands, such as open bays and seagrass areas. Thus, there may be ancillary benefits to the shrimp industry from mangrove conservation by providing alternative habitat for juvenile shrimp.

Despite efforts to restore mangroves in some areas in the Americas (http://www.mangroverestoration.com/), expansion of aquaculture and will likely continue to reduce the extent of this valuable ecosystem. Alongi (2002) predicted that over the next 25 years, unrestricted tree felling, aquaculture, and overexploitation of fisheries will be the greatest threats worldwide, with lesser problems being alteration of hydrology, pollution and global warming. In contrast, Ellison and Farnsworth (1996) felt that climate change would likely cause fringing mangroves to vanish. However, in recent years, mangroves have been spreading northward in Florida, expanding their range in response to warming (Cavanaugh *et al.,* 2014). Since they are not likely to be harvested for wood or removed for aquaculture, this northward move may counterbalance some of the threats. In the Caribbean, rising sea levels will likely have a large impact on coastal areas, although mangroves have been shown to keep pace with sea level rise in some areas of the Caribbean such as Belize (McKeeand Feller, 2007).

Although mangroves provide various NCP, undeniably contributing to human well-being by reducing fatalities associated with extreme events, the drivers resulting in the loss of mangroves also contribute to human well-being; thus we have to consider the full range of consequences involved. Conversion of mangrove forests for agriculture or aquaculture contributes to food supply, urbanization may result in the general increase of the standard of living of those in the urban areas. So too, all of these drivers are associated with economic activity of one sort or another and may contribute to alleviation of poverty. Thus, various considerations need to be taken into account when evaluating the sustainable use of mangroves. Datta *et al.* (2012) present an approach that can help to resolve these questions of both negative and positive consequences. They review the results of a number of community-based mangrove management efforts and provide a number of observations regarding factors that contribute to the success of such efforts, such as ensuring the voices of the those depending on the mangroves for subsistence are heard and that the benefits derived from the management efforts, including the economic benefits, are distributed equally regardless of socio-economic status of the recipients.

Clearly, the situation and necessary considerations in the case of mangroves, and the NCP they supply, differ substantially from the issues with Tundra wetlands. In the case of mangroves, the drivers are both direct and indirect, and while some, such as climate change (which causing some latitudinal change northward, (Inniss & Simcock, 2016)) are global, others, such as land use change are very local. So too, there are costs and benefits in terms of NCP that are related to the relevant drivers (e.g. aquaculture provides food and economic activity). There is also clear evidence that local populations can have a direct effect on the resource, including the NCP that it supplies.

Thus, the scenario archetypes have slightly different implications in this case and pathways to a sustainable future are possibly more flexible. Under the Fortress World archetype, it is still likely that mangroves in the Americas will continue to suffer losses, though an extreme acceleration of impacts, as would be anticipated for Tundra wetlands is less likely, due to local recognition of the NCP of mangroves in terms of local fisheries and shoreline protection. However, this may be overbalanced by a presumed increase in urbanization or other land use changes, as cooperative agreements and existing protections in some areas may roll back.

As with the Tundra wetlands, a future under the Market Forces archetype will likely result in the continued degradation of this resource throughout the Americas. Assuming an even greater reliance on market forces, there may be an actual increase in impacts to mangroves, as the NCP most easily monetized, such as aquaculture, urbanization and coastal development, will likely increase; these being the factors most often cited in current impacts to mangroves, especially in the Caribbean.

A future under a Policy Reform archetype scenario holds potential for real reduction in impacts to mangroves. Again, considering the most important drivers affecting mangroves, aquaculture, urbanization, and coastal development, these are factors that are amenable to policy intervention at various levels of governance. Indeed, Innis *et al.* (2016) recognizes that legislation is a viable avenue for protection of mangroves and cites examples of where this has been implemented. However, as these drivers also associated recognized socio-economic benefits, complete elimination of impacts is unlikely.

Innis *et al.* (2016) suggest a number of avenues for potential mangrove conservation, including: legislation; conventions and protected areas; management, education and restoration projects; and emerging conservation strategies, such as Reducing emissions from deforestation and forest degradation plus. These are all approaches that could be incorporated into policy developments under the Policy Reform scenario. These are also approaches that could be instituted at a variety of governance levels and are more amenable to including NCP that are not as easily monetized, such as preservation of human life from severe storms. The approach described by Datta *et al.* (2012) is a clear example of using a decided paradigm shift, including local stakeholder input that resembles the Policy Reform scenario. Under such an approach, a balancing of social, economic, and cultural interests would be possible and could optimize the NCP of mangroves.

Seagrasses. Seagrasses are the only flowering plants (class Monocotyledoneae) that are found in the marine environment. They are present in all continents except Antarctica (Green & Short, 2003). In spite of the low global species diversity of seagrasses (72 species of seagrasses distributed into six families, (Short *et al.* 2011)) compared with the terrestrial angiosperms (250,000 species approx.), these marine flowering plants can have distributional ranges that extend for thousands of kilometers of coastline along 6 geographical bioregions: 1) Temperate North Atlantic, 2) Tropical Atlantic, 3) Mediterranean, 4) Temperate North Pacific, 5) Tropical Indo-Pacific, and 6) Temperate Southern Oceans (Short *et al.,* 2007). These widespread marine angiosperm evolved from terrestrial origins and have been present in the marine coastal waters for over 100 million years (Les *et al.,* 1997); they constitute one of the richest and most important coastal habitats (Short *et al.,* 2011), ranked among the most valuable ecosystems on Earth (Costanza *et al.,* 1997, 2014).

Seagrass beds provide key ecological functions for maintaining healthy estuarine and coastal ecosystems (Cullen-Unsworth & Unsworth, 2013; Duarte *et al.,* 2008; Moore & Short, 2006), enhancing biodiversity and water quality in the immediate environment and adjacent habitats (Duarte, 2002; Green & Short, 2003; Beaumont *et al.,* 2007). Their canopies enhance the settlement of suspended particles and prevent resuspension; their root systems help to bind sediments over a long-term; and they release oxygen from photosynthesis. Their above and below ground systems also have a major role in coastal protection; holding and binding sediments, they prevent the scouring action of waves directly on the benthos, thus seagrasses, likewise mangroves and corals, dampen the effects of wave and current energy, reducing the processes of erosion and turbidity and increasing sedimentation (Green & Short, 2003).

Seagrass meadows, corals and mangroves, supply habitat, shelter and breeding ground for important marine species, including numerous commercially important fish and shellfish species (Hughes *et al.,* 2009; Orth *et al.,* 2006). In addition to these nursery functions, seagrass beds are also feeding ground for protected species (Christianen *et al.,* 2013) and seabirds (Shaughnessy *et al.,* 2012). Thus, seagrasses and mangroves and corals, contribute to various trophic levels of the soft-sediment coastal ecosystems enhancing overall productivity and biodiversity (Green & Short, 2003).

Summarizing, these units of analysis provide a wide range of ecosystem services, including raw materials and food, coastal protection, erosion control, water purification, maintenance of fisheries, carbon sequestration, and tourism, education, and research **(Figure 5.19)**. Apart from providing a wide array of ecosystem services, aquatic angiosperms are valuable biological indicators integrating environmental impacts over measurable and definable timescales (Martínez-Crego *et al.,* 2008; Orth *et al.,* 2006). Under a changing climate context, their regulation service on organic matter accumulation could play a critical role in long-term carbon sequestration. As perennial structures, seagrasses are one of the few marine ecosystems which store carbon for relatively long periods (Green & Short, 2003). Therefore, these coastal plant communities could play an important role in climate change mitigation and adaptation (Duarte *et al.,* 2013), not only in carbon sequestration (Fourqurean *et al.,* 2012) but also in coastal protection (Ondiviela *et al.,* 2014).

However, estuarine and coastal habitats have been historically altered and degraded (Halpern *et al.,* 2008) and seagrass beds in particular, are undergoing a global decline (Waycott *et al.,* 2009a). Seagrasses and their NCP are subjected to many pressures, both anthropogenic and natural (Green & Short, 2003) **(Figure 5.19)**. Natural causes of seagrass decline include geological (i.e. coastal uplift or subsidence); meteorological events (i.e. major storm events); and specific biological interactions (e.g. eelgrass wasting disease) (Muehlstein *et al.,* 1991) **(Figure 5.19)**. Whereas, human induced threats are now widespread (Green & Short, 2003). Without considering climate change and its consequences, anthropogenic impacts range from estuarine and coastal habitat degradation; direct impact inducing fragmentation or loss of seagrass beds; increase of nutrient and sediment runoff; introduction of invasive species; hydrological alterations; and commercial fishing practices (Orth *et al.,* 2006) **(Figure 5.19)**. Although seagrass declines have been related to a combination of impacts rather than individual threats (Orth *et al.,* 2006), two major causes of loss were identified by Waycott *et al.,* 2009: direct impacts from coastal development and dredging activities; and indirect impacts from declining water quality, i.e eutrophication (Dennison *et al.,* 1993; Krause-Jensen *et al.,* 2008; Short & Burdick, 1996).

Due to the above mentioned multi-drivers of change, seagrass meadows are among the most threatened ecosystems, with loss-rates comparable to those reported for mangroves, coral reefs, and tropical rainforests (Waycott *et al.,* 2009a). Their habitat is being lost and fragmented overall (Duarte, 2002; Hughes *et al.,* 2009); over the last two decades, up to 18% of the documented seagrass area has been lost (Boudouresque *et al.,* 2000; Green & Short, 2003; Kirkman, 1997; Short *et al.,* 2006), with rates of decline accelerating in recent years (Waycott *et al.,* 2009a). This present situation of declining seagrasses may be exacerbated by increasing human induced pressures (Nicholls *et al.,* 2007; Wong *et al.,* 2014) and additional global change drivers (Short & Neckles, 1999), including global warming (Jordà *et al.,* 2012a) and sea level rise (Saunders *et al.,* 2013). Considering the key role of seagrasses in the ecosystem function, their decline might be detrimental to those species that depend on them, including economically important fishes and invertebrates (Hughes *et al.,* 2009); and considering moreover, that seagrass meadows are often dominated by a single seagrass species, the loss of only one seagrass species might initiate a negative cascade of effects for the whole biome (Duarte, 2002; Hemminga & Duarte, 2000).

Recent climate change has already impacted marine environments with documented effects on the phenology of organisms; the range and distribution of species; and the composition and dynamics of communities (Richardson *et al.,* 2012). In the coming decades, coastal systems and low-lying areas will increasingly experience adverse climate-related impacts (IPCC, 2014). Global mean upper ocean temperatures have increased over decadal times scales from 1971 to 2010, with a global average warming trend of 0.11 ºC per decade in the upper 75 m of the ocean (IPCC, 2013b). The global ocean is predicted to continue warming during the 21st century (Collins *et al.,* 2012) and it is very likely that, by the end of the century, over 95% of the world ocean, regional sea level rise will be positive (Church *et al.,* 2011).

Pressures to seagrasses derived from global climate change have been extensively summarized (Björk *et al.,* 2008; Duarte, 2002; Short & Neckles, 1999). Among the overall potential impacts of climate change, three major threats are associated with intertidal habitat forming species: increases in sea surface temperature (e.g. Jordà *et al.,* 2012), sea level (e.g. Saunders *et al.,* 2013), and frequency and intensity of storms together with their associated surge and swells (e.g. Ondiviela *et al.,* 2014).

Intertidal and near-shore benthic habitats are characterized by strong vertical patterns in the distribution of organisms (Harley & Paine, 2009), being elevation relative to mean sea level a critical variable for the establishment and maintenance of biotic coastal communities (Pascual & Rodriguez-Lazaro, 2006). Consequently, zonation patterns are likely to shift following the environmental changes (Lubchenco *et al.,* 1993). Wernberg *et al.* (2011) found several large and common species retreated south in seaweed communities, which could have substantial negative implications for ecological function and biodiversity.

Temperature has important implications on the geographic patterns of seagrass species abundance and distribution (Walker, 1991), being considered as one of the main variables controlling the seagrasses distribution at global scale (Greve & Binzer, 2004). Waycott et al (2007) predicted that the greatest impact of climate change on seagrasses will be caused by increases in temperature, particularly in shallower habitats where seagrasses are present.

Temperature increase may also alter seagrass abundance through direct effects on flowering and seed germination (Jordà *et al.,* 2012a; Massa *et al.,* 2009; Olsen *et al.,* 2012). Since changes in seawater surface temperature would differ geographically the effects would vary between locations and therefore, some meadows could be favoured by the temperature increase; e.g. Hootsmans *et al.* (1987) found experimentally that temperatures rising from 10 ºC to 30 ºC significantly increased *Zostera noltii* seed germination. Short and Neckles (1999) concluded that, under global climate change, an average annual temperature increase will decrease productivity and distribution of seagrass meadows growing in locations with temperatures above the optimum for growth, or near the upper limit of thermal tolerance. In this sense, projections of future distribution of the intertidal seagrass *Z. noltii* performed using a highly accurate habitat suitability model based on mean and minimum seawater surface temperature, showed that the changes in seawater surface temperature derived from global warming would promote an important change in the distribution of the species, triggering a poleward shift of 888 km in the area suitable for the species by the end of the 21st century (Valle *et al.,* 2014).

This shift in the species' distribution would turn into a reduction of the species climatic niche: those populations under seawater surface temperature thresholds higher than the temperature ranges required by the species (i.e. southernmost populations) would become extinct by 2100, and the colonization of the predicted suitable areas in the northernmost estuaries could be unlikely because *Z. noltii* populations have shown a low recolonisation rate from estuary to estuary (Chust *et al.,* 2013; Diekmann *et al.,* 2005) and might not shift their suitable habitat northward at a pace comparable to warming rates, especially in regions where the species is restricted to intertidal estuarine zones. Koch *et al.* (2013) also stated that many seagrass species living close to their thermal limits will have to up-regulate stress-response systems to tolerate sub-lethal temperature exposures. Therefore, physiological capacity of adaptation of the species would determine the vulnerability degree of seagrasses to climate change. Although photosynthesis and growth rates of marine macro-autotrophs are likely to increase under elevated carbon dioxide, its effects on thermal acclimation are unknown (Koch *et al.,* 2013). Jordà *et al.* (2012b) reported that it is unlikely that enhanced carbon dioxide may increase seagrass resistance to disturbances such as warming.

Eutrophication is a major threat to submerged aquatic vegetation, and with more people living near the coast and the high costs of controls, the likelihood is that submerged aquatic vegetation will continue a downward trend. However, in some areas that have undergone restoration and controls on nutrients, such as Chesapeake Bay in the USA there has been some recovery (http://www.chesapeakebay.net/indicators/indicator/bay_grass_abundance_baywide). In cases where nutrient limitations are implemented, recovery is a very slow process, involving the replacement of fast-growing macroalgae with slower-growing plants. Simulation models predict recovery times of several years for fast-growing seagrasses to centuries for slow-growing seagrasses following nutrient reduction (Duarte, 1995).

Scenarios archetypes for seagrassess are very similar to those for mangroves, under Fortress World and Market Forces direct and indirect pressures to seagrasses will increase and additional global change drivers will take place, thus seagrasses will continue to suffer losses. NCP of seagrasses are not as recognized as those from mangroves and therefore an extreme acceleration of impacts might occur.

Even though present declining trends in seagrasses exceed more than 10 times the increasing trends (Waycott *et al.,* 2009a), water quality improvements and habitat remediation are leading to encouraging results regarding the potential of seagrasses to recover (Barillé *et al.,* 2010; Dolch *et al.,* 2013). Thus under a Policy Reform scenario archetype, a reduction in impacts to seagrasses might be possible.

Under a Great Transitions scenario archetype where there is a high awareness and concern about the negative repercussions derived from the loss of biodiversity and ecosystem functions of these habitats, policy changes that allow seagrasses to become targeted for conservation and restoration, and promotes attenuation of global warming, seagrass meadow decline might be reduced and recovery might occur.

Salt Marshes. In recent years, many previously healthy marshes in the Americas show adverse effects from sea level rise (such as ponding, where water remains on the marsh surface during low tide and plants get water-logged), and it is questionable whether they will be able to keep up. The actual rate of sea level rise in the future will affect which marshes can keep up. Other marshes are being restored, a very expensive procedure. There are some attempts to increase their elevations (Ford *et al.,* 1999), but given the inevitability of sea level rise at an accelerated rate, it is highly probable that extensive areas will continue to be lost. The invasive reed, *Phragmites australis*, which has reduced plant diversity in many brackish marshes in the East coast of the USA and is often removed in restoration projects, allows marshes to increase their elevation more rapidly (Rooth & Stevenson, 2000) and might better enable marshes to keep up with sea level rise.

5.4.12 Cryosphere unit of analysis

Arctic sea ice is an important habitat for many species in northern Canada and Alaska. Sea ice includes both multi-year ice (fast ice) as well as seasonal ice. The extent of multi-year sea ice in the circumpolar north is highly variable and subject to cyclical drivers such as the North Atlantic Oscillation (Delworth *et al.,* 2016). The range in area of sea ice varies on a yearly basis from 15 million km^2 on average to 7 million km^2, considering September as reference. However, this is theorized to be changing due to climate change.

Figure 5 20 **Cryosphere unit of analysis viewed in the IPBES conceptual framework. Source: own representation.**

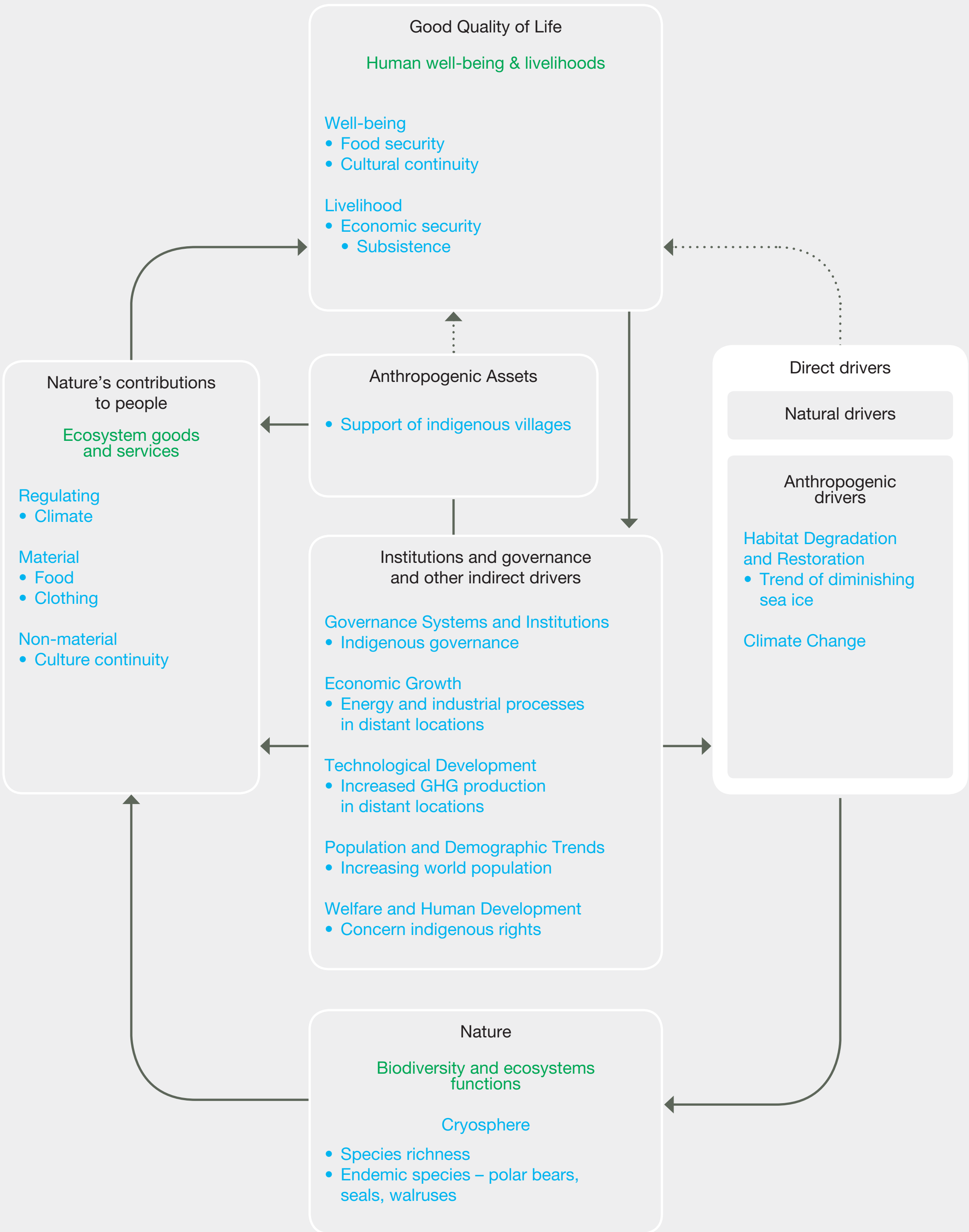
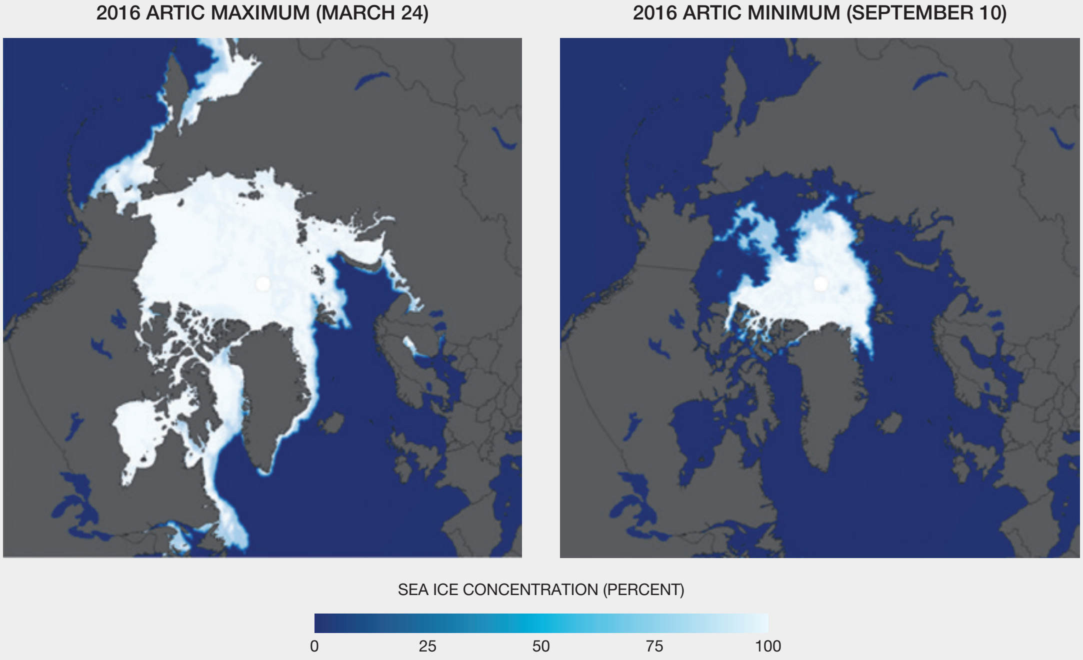


Figure 5 21 Artic Sea ice conditions during the winter and summer seasons (year 2016). Source: https://earthobservatory.nasa.gov/Features/SeaIce/page3.php.



Sea ice provides provisioning services as habitat for many arctic species including polar bears, seals, and walruses, which in turn provide economic and health benefit to northern peoples. Sea ice is also considered to be providing regulating services related to climate change impacts (e.g. regional and global air and water temperatures) (Parmentier *et al.,* 2013). There are also valuable cultural services in the form of tourism and recreation that are sometimes considered, as the arctic becomes a greater interest globally (Stewart *et al.,* 2017).

5.5 MAJOR TRENDS OF NATURE AND NATURE'S CONTRIBUTIONS TO PEOPLE IN THE AMERICAS: LEARNING FROM GLOBAL SCALE LITERATURE

Extensive efforts have been allocated to develop global biodiversity databases and integrated assessment models with the aim of understanding past, present and future trends of nature and nature's benefit to people (e.g. Alkemade *et al.,* 2009; Leadley *et al.,* 2010; PBL, 2014, 2012; Pereira *et al.,* 2010). Results from these models aim to facilitate decision makers developing policies and strategies to achieve conservation targets and sustainable uses of natural resources. They can also be used to engage the larger public in thinking about the kind of future they really want (PBL, 2012). Although most of these databases and models have a global scope, several approaches can be used to extract the most relevant information on major trends for the Americas. Here we based our approach on the results available in raw format from the Global Biodiversity model for policy support (http://www.globio.info/), a modeling framework to calculate the impact of environmental drivers on biodiversity for past, present and future. Global Biodiversity Model for policy support was developed under collaboration between Netherlands Environmental Assessment Agency, UNEP/Global Resource Information Database - Arendal and UNEP-World Conservation Monitoring Centre.

The Global Biodiversity Model for policy support was designed to quantify past, present and future human-induced changes in terrestrial biodiversity at regional to global scales (Alkemade *et al.,* 2009; PBL, 2016). The time frame of the period over which projections are made is 1970 – 2050. The model is built on a set of cause-effect relationships to estimate the impacts on biodiversity through time of six human-induced environmental drivers: land use, climate change, atmospheric nitrogen deposition, habitat fragmentation, disturbance by roads and disturbance through human encroachment in otherwise natural areas (PBL, 2016).

The spatial information on environmental drivers used by Global Biodiversity Model for policy support is mainly derived from the Integrated Model to Assess the Global Environment 3.0 (Stehfest *et al.,* 2014). In the Integrated Model to Assess the Global Environment -Global Biodiversity Model for policy support framework, models of socioeconomic drivers, such as climate change, land-use change and pollution, are linked with models that analyze impacts on the environment and biodiversity allowing assessment of the impact of human induced environmental drivers on biodiversity and exploring policy options in the form of intervention scenarios to reduce biodiversity loss (IPBES, 2016). Using the Integrated Model to Assess the Global Environment - Global Biodiversity Model for policy support framework, trends in biodiversity under future plausible policy scenarios have been projected, including the expected outcome in the absence of additional policies to prevent biodiversity loss (business-as-usual scenario). The results of Integrated Model to Assess the Global Environment - Global Biodiversity Model for policy support have provided information for policymakers at the international level on current biodiversity status and future trends (Alkemade *et al.,* 2009). Specifically, model projections have been used to analyze how combinations of technological measures and changes in consumption patterns could contribute to achieve global sustainability goals by 2050 (PBL, 2012) and to inform within the fourth Global Biodiversity Outlook how sectors can contribute to the sustainable use and conservation of biodiversity (PBL, 2014).

In Global Biodiversity model for policy support, biodiversity responses are quantified as two main indicators: Natural areas and Mean Species Abundance relative to the natural state of original species. Natural areas indicator includes calculated natural areas and forestry, excluding plantations. Mean Species Abundance indicator expresses the mean abundance of original species in disturbed conditions relative to their abundance in undisturbed habitat, as an indicator of the degree to which an ecosystem is intact (PBL, 2016). The Mean Species Abundance indicator uses the species composition and abundance of the original ecosystem as a reference situation. Mean Species Abundance values have been quantified based on a synthesis (meta-analysis) of empirical species monitoring data in disturbed habitat compared to an undisturbed reference situation, reported in comparative studies derived from the literature. It covers the following taxonomic groups: mammals, birds, amphibians, reptiles, terrestrial invertebrates and vascular plants (PBL, 2016).

To project future trends of the indicators Global Biodiversity model for policy support made use of the trend scenario derived from the baseline scenario of the third Organization for Economic Cooperation and Development Environmental Outlook (OECD, 2012) as a benchmark to construct a business-as-usual future. Additionally, the model uses 3 alternative pathways that represent possible routes to achieve the sustainability targets: (1) Global technology, (2) Decentralized Solutions, and (3) Consumption Change **(Table 5.2)**. Under the terminology used thus far in this assessment, these three pathways roughly equate to a combination the Policy Reform and Great Transitions archetypes.

Under the trend scenario (business as usual) SDG will not be achieved; the model assumes that world development continues to be characterized by a focus on economic development and globalization (Market Forces scenario archetype) and no pro-active policies to reduce the risks associated with environmental degradation are presumed (PBL, 2012). The scenario also assumes a continuing increase in the consumption of food, the production of material goods and services and the use of energy, although with a tendency towards saturation at high-income levels **(Table 5.2)**.

The pathways represent different ways to strengthen and direct, or redirect, the technologies, preferences and incentives in society in more sustainable directions (PBL, 2012). Each alternative pathway would achieve ambitious global sustainability targets in 2050, such as limiting climate change to 2 °C, stabilizing biodiversity loss and providing full access to energy, water and food, but differ fundamentally in their approach **(Table 5.2)**. The first pathway (Global Technology) assumes the adoption of large-scale technologically-optimal solutions to address climate change and biodiversity loss from a “top-down” approach with high level of international coordination (PBL, 2012), under this pathway the most important contribution comes from increasing agricultural productivity on highly productive lands.

The second pathway (Decentralised Solutions) relies on local and regional efforts to ensure a sustainable quality of life from a “bottom-up” managed system where small-scale and decentralized technologies are prioritized (PBL, 2012), under this pathway the major contribution is linked to avoided fragmentation, more ecological farming and reduced infrastructure expansion. The last pathway (Consumption Change) contemplates a growing awareness of sustainability issues which leads to changes in human consumption patterns and facilitates a transition towards less material- and energy-intensive activities (PBL, 2012), this implies a significant reduction in the consumption of meat and eggs as well as reduced wastage, which leads to less agricultural production and, thus, the reduction of the associated biodiversity loss.

Original data from Global Biodiversity Model for policy support was developed based on Integrated Model to Assess the Global Environment regions, those regions within the Americas are: (1) Canada, (2) USA; (3)

Table 5 2 **Assumptions of business as usual, global technology, decentralised solutions and consumption change scenarios for the year 2050. Sources: PBL (2012), Visconti *et al.* (2016)**

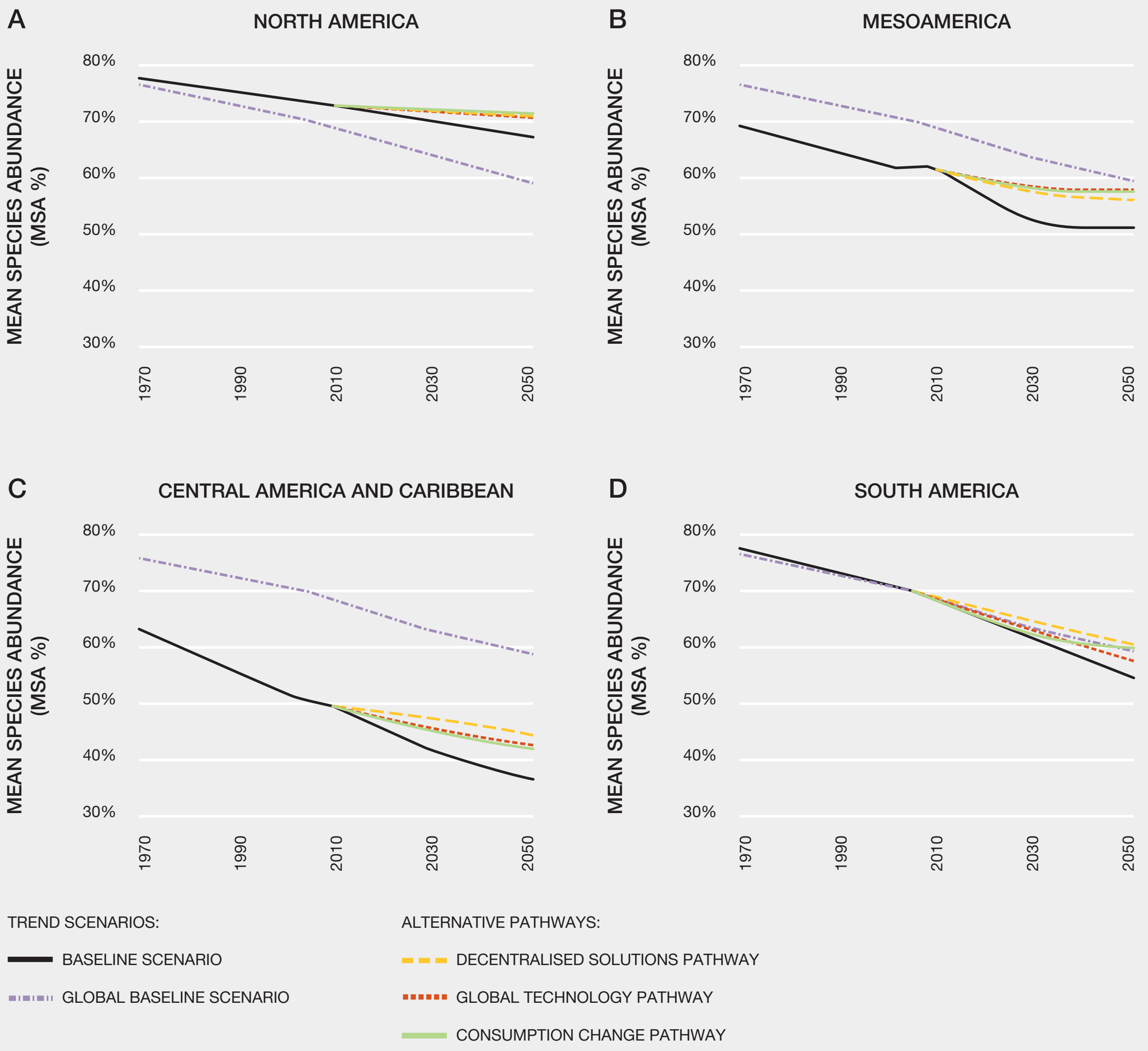
	Business as usual	Global technology	Decentralised solutions	Consumption change
Access to food	272 million people are projected to still be undernourished by 2050	Trend	Inequality in access to food due to income inequality converges to zero by 2050	Inequality in access to food due to income inequality converges to zero by 2051
Consumption	65% increase in energy consumption in the 2010–2050, 50% increase of food consumption	Trend	Trend	Meat consumption per capita levels off at twice the consumption level suggested by a supposed healthy diet (i.e., low beef, pork intake, resulting in 10 g beef, 10 g pork and 46.6 g chicken meat and eggs per person per day) (Stehfest *et al.*, 2009; Willett, 2001)
Waste	Stable 30% of total production	Trend	Trend	Waste is reduced by 50% (15% of production)
Agricultural productivity	Yield increase by 0.06% annually (+27% by 2050)	In all regions, 30% increase in crop yields and 15% increase in livestock 'yields' by 2050, compared with the Trend scenario	In all regions, 20% increase in crop yields and 15% increase in livestock 'yields' with least possible impacts on biodiversity (Biodiversity: Mean Species Abundance in agricultural area 40% higher than in the Trend scenario)	In all regions, 15% increase in crop yields by 2050, compared with the Trend scenario
Protected areas	No further protected areas respect to 2010	17% of each of the 7 realms; Expansion allocated far from existing agriculture	17% of each of the 779 eco-regions; Expansion allocated far from existing agriculture	17% of each of the 65 realm-biomes; Expansion allocated close to existing agriculture
Greenhouse gas emissions and decarbonisation rate	Greenhouse gas emissions are projected to increase by 60% and historical annual decarbonisation rate of 1% to 2% is projected to continue	To meet the 2°C target, atmospheric greenhouse gas concentrations are held below 450 parts per million carbon dioxide equivalents (40% to 50% reduction) and decarbonisation rate undergo an improvement of 4.5% to 6% (3 to 4 times the historical rate).		
Forestry	+30% in clear-cut, +35% plantation, -2.5% selective logging. No reduced impact logging	Forest plantations supply 50% of timber demand; almost all selective logging based on Reduced Impact Logging	Forest plantations supply 50% of timber demand; almost all selective logging based on Reduced Impact Logging	Forest plantations supply 50% of timber demand; almost all selective logging based on Reduced Impact Logging

Greenland; (4) Mexico; (5) Central America and Caribbean; (6) Brazil; (7) Rest of South America. In order to show a detailed picture of what is happening in the Americas region, Integrated Model to Assess the Global Environment regions have been aggregated to match as much as possible IPBES Americas subregions (North America, Mesoamerica, the Caribbean and South America) (Chapter 1). Two out of the four IPBES regions has been properly matched (1) North America, where Canada, USA and Greenland have been aggregated; and (2) South America, where Brazil and the rest of South America have been joined. The other two IPBES subregions couldn't be represented because data cannot be disaggregated, thus data from Mexico are presented alone as a country study case, and data from Central America and Caribbean are presented together as a region.

Trends in biodiversity loss indicated by mean species abundance

Biodiversity loss, indicated by Mean Species Abundance, will continue under Trend scenarios and the three alternative pathways **(Figure 5.22)**. Under Global Baseline scenario and Baseline scenario for the Americas, Mean Species Abundance is projected to decrease from 76% in 1970 to 59-60% in 2050. Trends in subregions from 2010 to 2050 under Baseline scenario (business as usual) show a decline from 73% to 67% for North America, from 61% to 51% for Mexico, from 64% to 37% for Central America and Caribbean, and from 68% to 55% for South America. Thus, whilst North America would experience less loss than the global and regional trends and the rest of subregions, Central America and Caribbean would experience the larger

Figure 5 22 **Trends in biodiversity loss indicated by mean species abundance percentage under the global baseline scenario, the trend scenario for the Americas (baseline scenario), and the alternative pathways by 2050 in A North America; B Mexico; C Central America and Caribbean; and D South America. Source: PBL Netherlands Environmental Assessment Agency (2012 and 2014).**



loss of biodiversity under business as usual scenario **(Figure 5.22c)**. These declines in biodiversity could be slowed down or reduced under the 3 alternative pathways, being Desentralised Solutions the pathway leading to best results for all subregions except Mexico where Global Technology and Consumption Change could represent a better option. Under the Desentralised Solutions pathway, Central America and Caribbean could prevent their biodiversity loss by 8% compared to business as usual scenario, whereas North America and South America could reduce biodiversity loss by 5% under the same pathway and Mexico could achieve a reduction of 6% in comparison to business as usual under both Global Technology and Consumption Change pathways. In summary for the American region, under business as usual scenario, a loss of almost 40% of all original species in the Americas is expected while under the three pathways to sustainability 35 to 36% loss is presumed to occur.

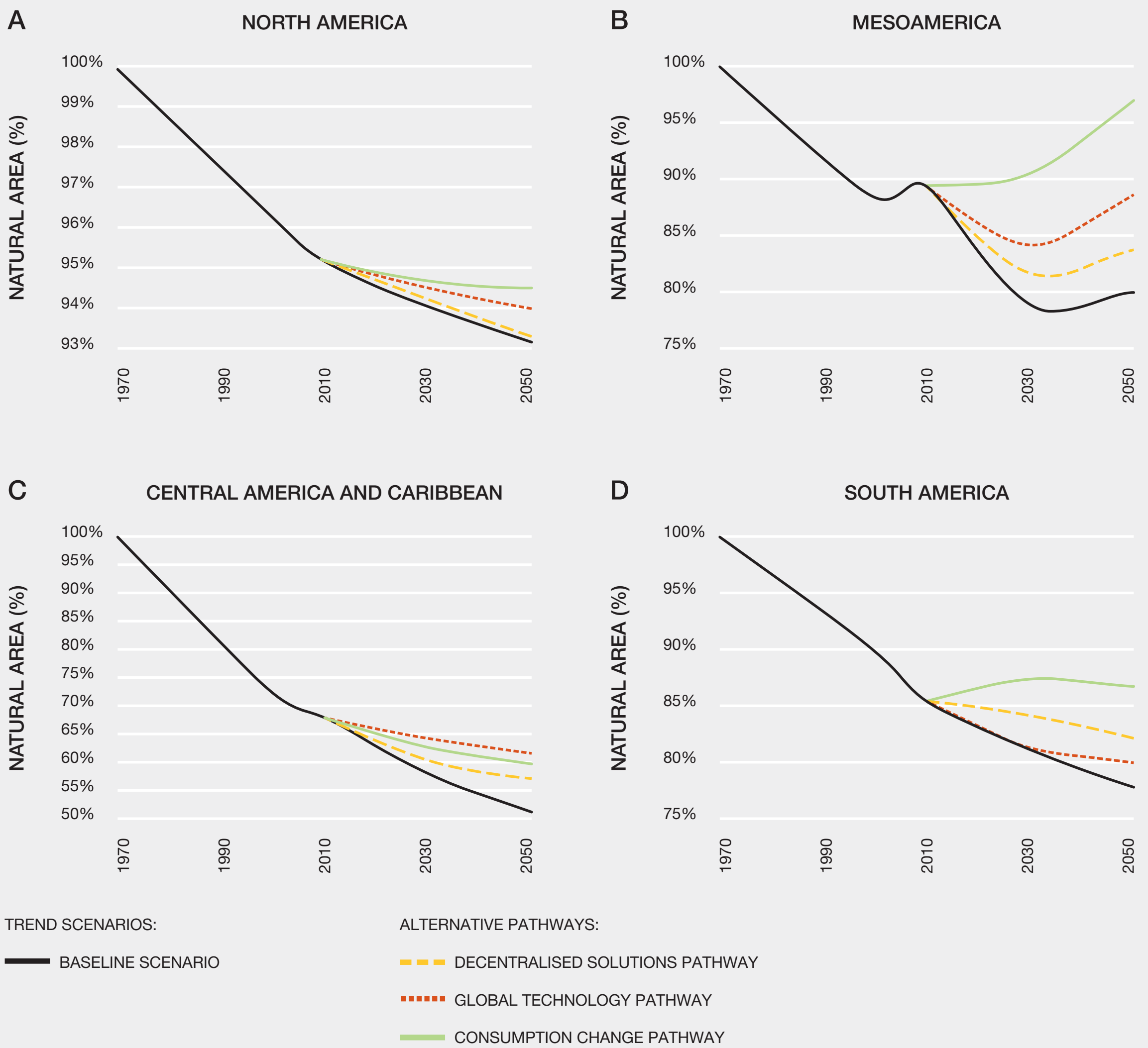
Trends in biodiversity indicated by natural area

Projections of biodiversity loss indicated by natural area show declining trends under Baseline scenario and the three alternative pathways, however, the projected loss by 2050 is expected to be less under the three transition pathways to sustainability in comparison to the business as usual scenario **(Figure 5.23)**. Model projections indicate that Consumption Change pathway would lead to the best results for all regions except for the Central America and Caribbean, where Global Technology pathway could lead to a higher increase in natural area in comparison to the Desentralised Solutions and Consumption Change pathways results **(Figure 5.23c)**. Under Consumption Change pathway Mexico could stabilise its natural areas almost to their original extent in 1970 **(Figure 5.23b)**.

Pressures driving biodiversity loss

Pressures to nature are predicted to increase by 2050 under the Trend scenario (business as usual) and the three alternative pathways, negatively affecting biodiversity as indicated by a potential reduction of the Mean Species Abundance index **(Figure 5.24)**. However, the magnitude of the pressures by 2050 is expected to be less under transition pathways to sustainability in comparison to the business as usual scenario (i.e., baseline scenario). Under the transition pathways to sustainability, climate change mitigation, the expansion of protected areas and the recovery of abandoned lands significantly contribute to reducing biodiversity loss. Although, in comparison to the projection of baseline scenario for 2050, a reduction of pressure to biodiversity driven by crops, pastures and climate change is expected under the three pathways to sustainability, other pressures to biodiversity such as forestry, biofuels and abandoned land are expected to increase. Under Baseline scenario, climate change is projected to become the fastest growing driver of

Figure 5 23 **Trends in natural area percentage under the trend scenario for the Americas (baseline scenario), and the alternative pathways by 2050 in A North America; B Mexico; C Central America and Caribbean; and D South America. Source: PBL Netherlands Environmental Assessment Agency (2012 and 2014).**



biodiversity loss by 2050. The Central America and Caribbean subregion would experience larger pressures to biodiversity than the other subregions, which will be mainly driven by expansion of crops.

Relative share of each sector to additional biodiversity loss

Projections outputs for the baseline scenario regarding the attribution of biodiversity loss, as indicated by Mean Species Abundance percentage, to different production sectors show a similar pattern for all subregions: crop and livestock is the sector with the higher increasing trends, followed by energy and traffic sector, wood production, hunting, gathering, recreation and tourism shared sector, and industry sector **(Figure 5.25)**. Pressures driven by those production sectors will be slowed down, or even be reduced, under the three alternative pathways, however crop and livestock will continue to have major impact in the Central America and Caribbean subregion resulting in the region with the higher percentage of biodiversity loss as indicated by Mean Species Abundance percentage.

Figure 5 24 **Pressures driving biodiversity loss indicated by means species abundance percentage under the trend scenario from 1970 to 2050 and predicted pressures to be driving biodiversity loss under the alternative pathways by 2050 in A North America; B Mexico; C Central America and Caribbean; and D South America.**

BAU: Business-as-usual; GT: Global Technology pathway; DS: Decentralised Solutions pathway; CC: Consumption Change pathway. Source: PBL Netherlands Environmental Assessment Agency (2012 and 2014).

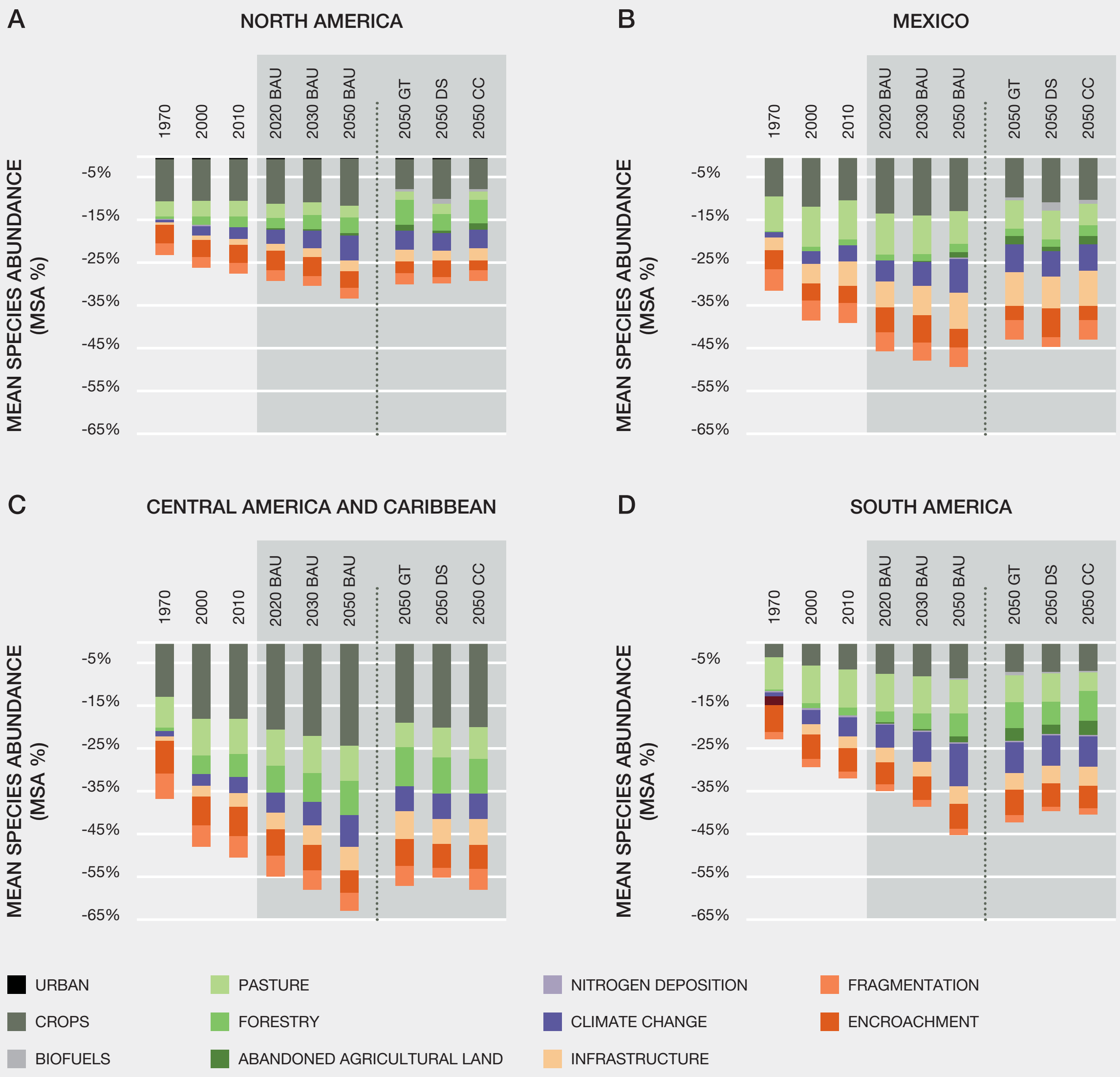
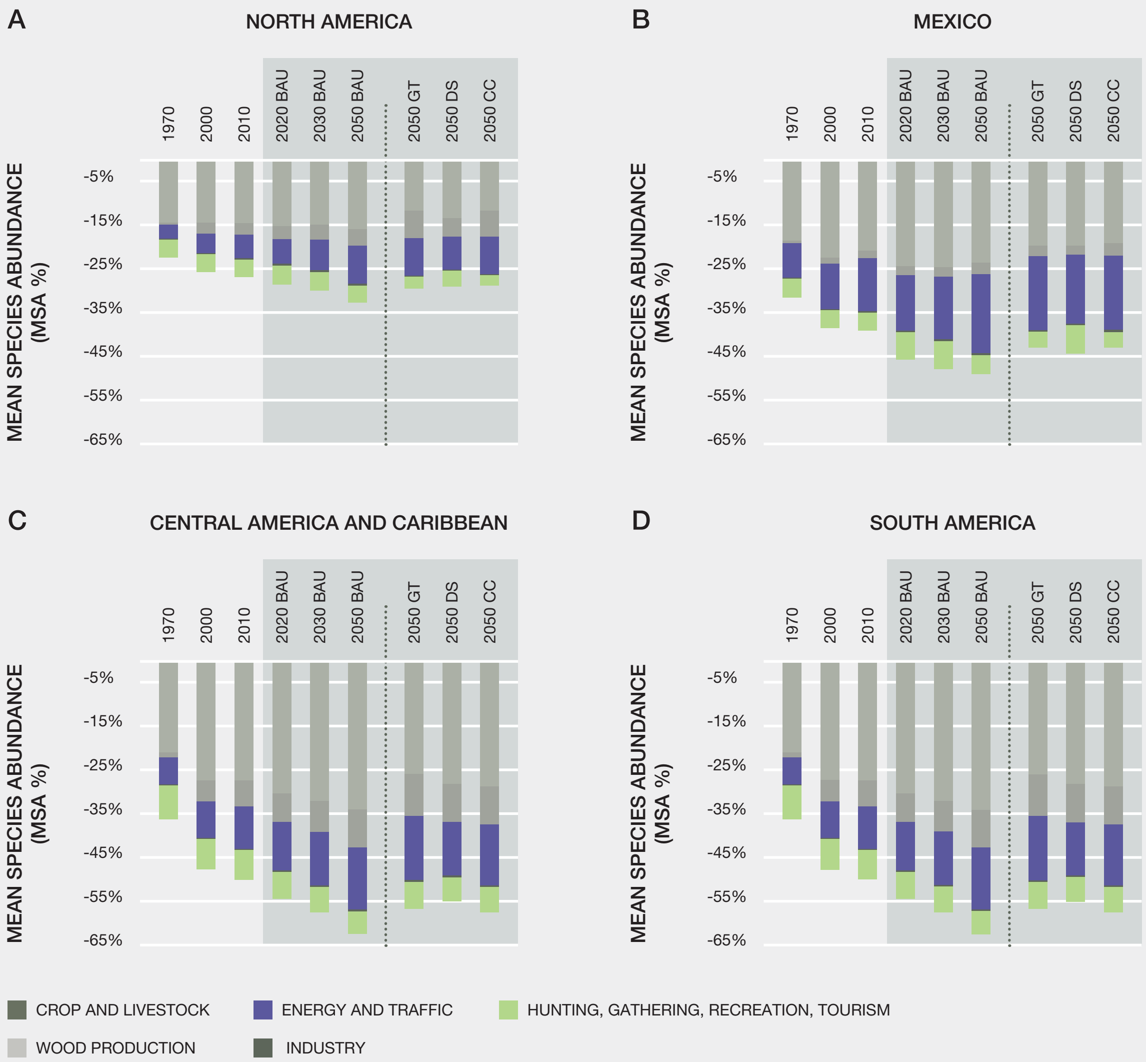


Figure 5 25 **Attribution of biodiversity loss indicated by mean species abundance percentage to different production sectors under the trend scenario from 1970 to 2050 and the alternative pathways by 2050 in A North America; B Mexico; C Central America and Caribbean; and D South America.**

BAU: Business-as-usual; GT: Global Technology pathway; DS: Decentralised Solutions pathway; CC: Consumption Change pathway. Source: PBL Netherlands Environmental Assessment Agency (2012 and 2014).



Projected relative losses of biodiversity per sector

Projected relative losses of biodiversity (Mean Species Abundance) per sector under the three different pathways, compared to trend (Baseline scenario) indicate that actions leading to land use change (reduction of crops and reduction of the use of pastures by livestock grazing) and climate change mitigation would significantly contribute to reducing biodiversity loss **(Figure 5.26)**. As indicated above, pressures driven by forestry, demand of biofuels and abandoned land are expected to increase under the transition pathways to sustainability, which will be translated in an extra loss of biodiversity driven for those sectors in comparison to projections under business as usual scenario.

Trends in land use

According to the projected trends in land use, extent of natural areas will decrease from 2010 to 2050 under business as usual scenario in all subregions **(Figure 5.27)**. The Central America and Caribbean subregion will experience a significant reduction in comparison to the rest. However, under transition pathways to sustainability, these trends would be reduced in all subregions by 2050. The sustainability pathways are thought to strengthen and direct, or redirect, the technologies, preferences and incentives in society to more sustainable directions, for instance to achieve the Aichi targets and the SDG. Trends in land use show that the Consumption Change pathway

Figure 5 26 **Biodiversity loss by 2050 indicated by Mean Species Abundance % compared to trend scenario in the different pathways as a consequence of changes in the different pressures: land use, climate change, nitrogen deposition, habitat fragmentation, disturbance by roads and disturbance through human encroachment in otherwise natural areas in A North America; B Mesoamerica; C Central America and Caribbean; and D South America.**

GT: Global technology pathway; DS: Decentralised solutions pathway; CC: Consumption change pathway. Negative percentage values mean extra loss compared to trend and positive percentage values mean less loss compared to trend. Source: PBL Netherlands Environmental Assessment Agency (2012 and 2014).

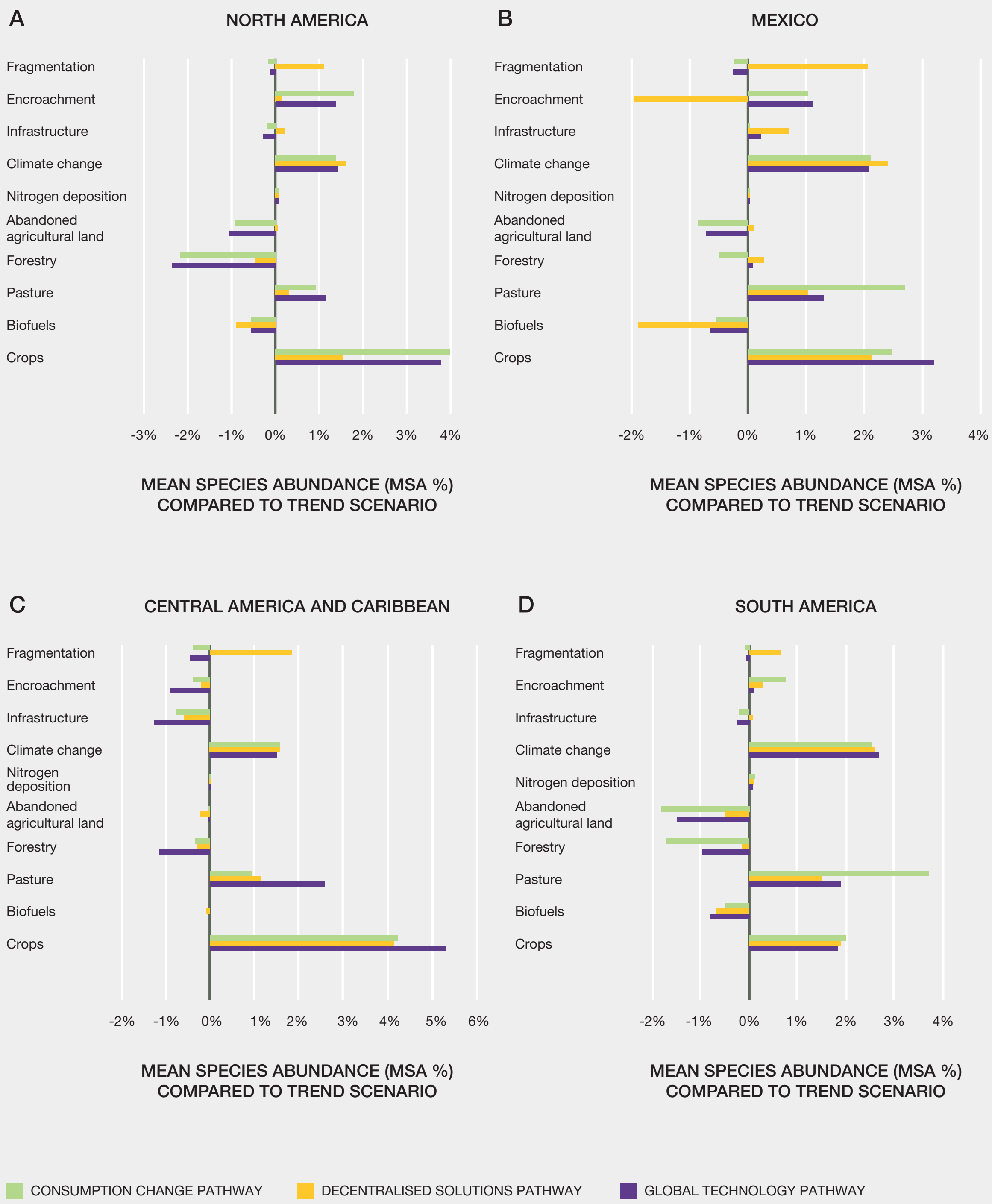
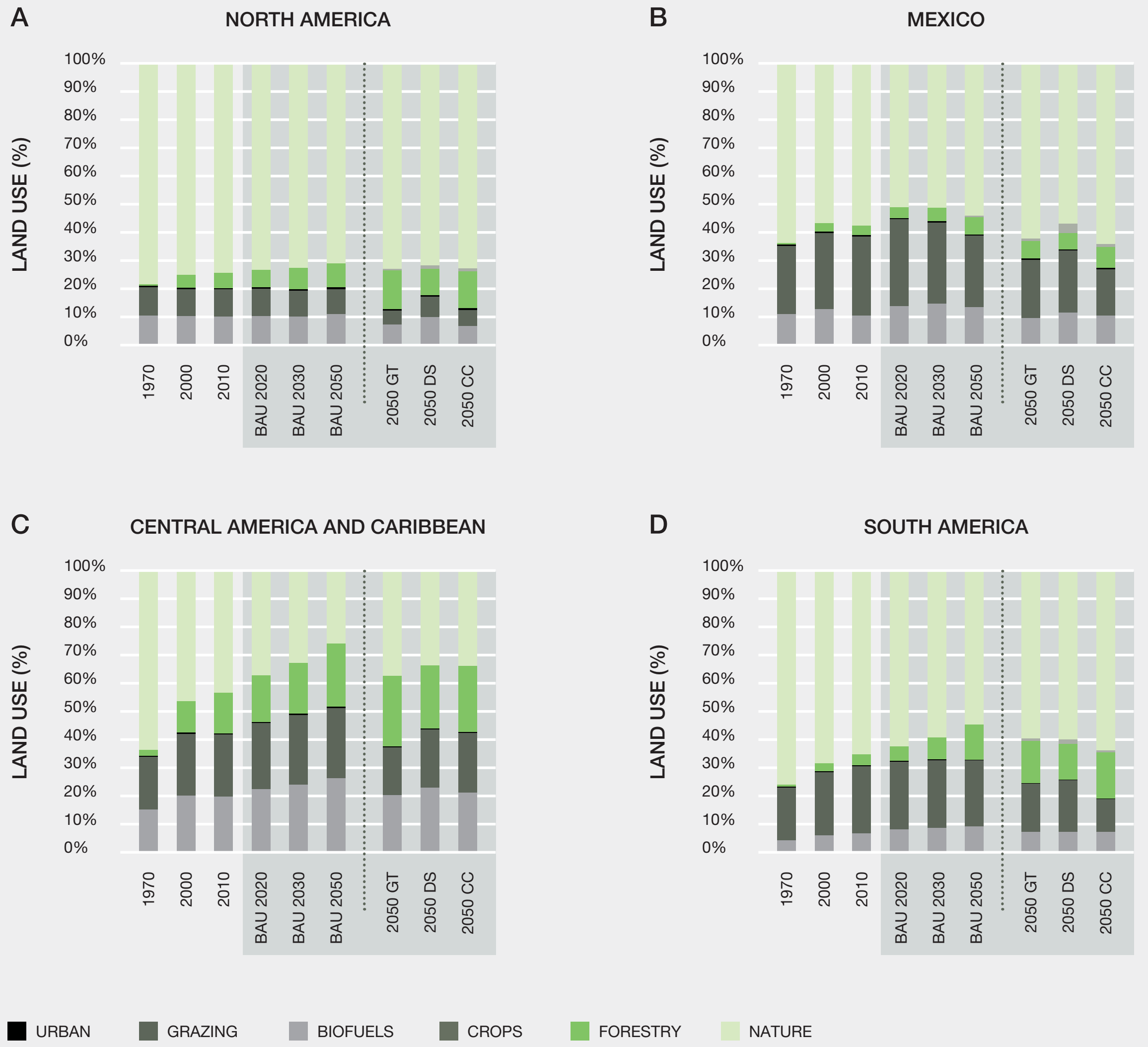


Figure 5 27 **Trends in land use indicated by area percentage under the trend scenario from 1970 to 2050 and the alternative pathways by 2050 in A North America; B Mexico; C Central America and Caribbean; and D South America.**

BAU: Business-as-usual; GT: Global Technology pathway; DS: Decentralised solutions pathway; CC: Consumption change pathway. Source: PBL Netherlands Environmental Assessment Agency (2012 and 2014).



would lead to an increase of Natural areas within all subregions except within Central America and Caribbean, where Global Technology pathway could lead to a greater increase in natural areas. In comparison with business as usual scenario, under the Consumption Change pathways, natural area in the subregions is projected to increase 1.9% for North America; 10.1% for Mesoamerica; and 9.6% for South America, whilst Global Technology pathway would positively affect the extent of natural areas in Central America and the Caribbean by 11.2%.

In summary, according to future scenarios results presented above, it is clear that improvement of the future prospects to ensure biodiversity and NCP conservation requires rethinking the current orientation from common policies; and that change in societal options could lead to less pressure to nature and help moving towards a sustainable future. Scenarios are simplifications of complex futures, to build them several assumptions are made and these simplifying assumptions result in different limitations (Kubiszewski *et al.*, 2017b). However, they are not intended to be predictions of the future, but rather to lay out a set of plausible futures and help decision makers and society in general, rethink possible ways to move towards more desirable futures.

5.6 CONSTRUCTING A PATHWAY TO A SUSTAINABLE WORLD

Toward policy targets and Sustainable Development Goals in the face of "wicked problems"

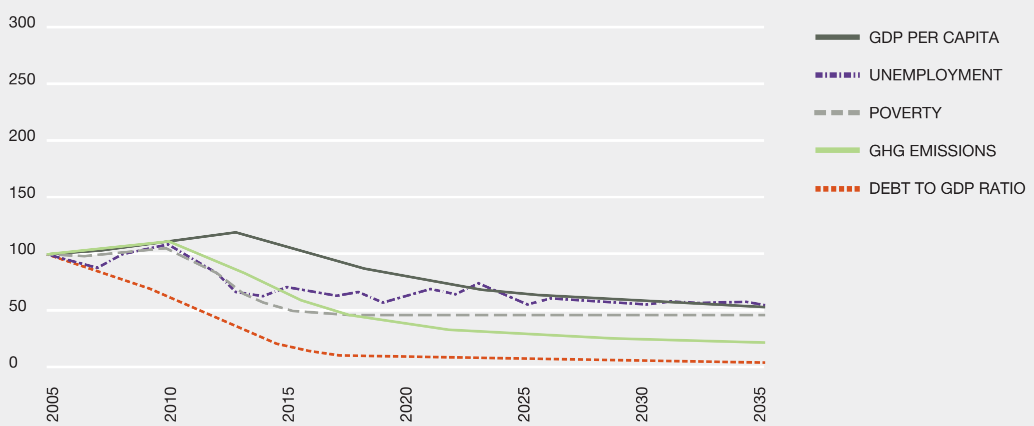
Some problems, while not necessarily easy, are relatively straightforward, like solving an algebra problem or determining a move in chess, in which standard approaches and strategies have long been established. Then there are problems that have resisted solutions for centuries or millennia, such as human rights violations across the globe and territorial disputes. Problems of the latter category are difficult to solve primarily because their root causes are varied and complex. In social planning and management science such problems have been termed "wicked problems", not in the strict sense that they are "evil", but that they are resistant to resolution, are complicated, tend to be fraught with interdependencies, and frequently the solution to one aspect of them creates, or simply reveals, a different challenge; environmental degradation and

Box 5 2 Novel considerations and questioning the assumptions: Is it possible to achieve environmental sustainability by reducing economic growth, while increasing human well-being?

Trends show a continuing decline in biodiversity even in the most optimistic scenarios (as observed in **Figure 5.22**, section 5.5). Most scenarios quantifying future trends in biodiversity and ecosystem services and showing their future decline have in common a continuous growth of the economy, commonly measured as GDP (Gross Domestic Product). For example, the shared socioeconomic pathways (O'Neill *et al.,* 2014) of the IPCC do not consider any alternative where environmental improvement goes together with low or no economic growth. In addition, evidence suggests that a decoupling of growth in both the economy (GDP) and environmental impacts is unrealistic (Ward *et al.,* 2016). This situation has motivated a line of thought and research arguing that environmental sustainability will not be possible without considering a significant slowdown or total halt of economic growth. This has been embraced by a group of narratives that could be classified within the Great Transitions scenario archetype. For example the eco-communalism type of scenarios (Makropoulos *et al.,* 2009), the degrowth movement (F. Schneider *et al.,* 2010), or specific to Latin America visions like "Buen Vivir" (Gudynas, 2011). These types of visions appear as alternative pathways to development and have one main aspect in common (for a comparison see Escobar, 2015); "an equitable downscaling of production and consumption that increases human well-being and enhances ecological conditions at the local and global level, in the short and long term (F. Schneider *et al.,* 2010)". By reducing production and consumption it is expected, indirectly, that GDP as a measure of economic growth would decline without affecting good quality of life, social equity and environmental sustainability.

There are no modeling exercises for the Americas that explicitly quantify trends into the future of NCP contemplating low economic growth. However, some modeling exercises have quantified future trends on economic and climate related aspects given energy constraints. Victor (2012) quantified a degrowth scenario for Canada in order to achieve a reduction in GDP per capita ($15,260) by 2035 **(Figure 5.28)**. Social indicators, compared with 2005, show a reduction in unemployment and the human poverty index. Environmentally, gas emissions are reduced almost 80% by 2035.

Figure 5 28 **A degrowth scenario for Canada. Source: Victor (2012).**



sustainability represent wicked problems. The focal analyses of section 5.4 give a good indication of the complexity of determining what "the best" use of the world's natural capital is; multiple drivers, teleconnections, telecoupling, differing socio-economic conditions, and differences in cultures and values are all considerations in trying to create a sustainable world. The Aichi targets and the SDG represent efforts to address, or at least frame, wicked problems related to the environment and human condition, towards which solutions should be aimed.

It is clear from this assessment that progress toward reaching the Aichi targets has been incremental at best and that no target has been fully reached; nevertheless they remain desirable goals. The SDG complement the Aichi targets, but the goals are still too new to expect significant progress since their promulgation. Each set of targets and goals establish guideposts on the paths to achieving the other set. Thus, solutions in one area should be designed to help provide solutions in the other. However, as both address suites of wicked problems, the question, of course, is how does policy and other decision makers actually develop solutions to meet the targets and goals? In the remainder of this section, we present a number of considerations that, based on this assessment are likely to prove helpful, if not critical, as the world goes forward in development of pathways to a sustainable future for humankind.

5.6.1 Integrated scenario building

IPBES has identified scenario building as a key approach in helping decision makers assess potential future impacts of different policy options they are considering on biodiversity and NCP in an uncertain world. This is a daunting task however as no human can provide a certain prediction of what lies ahead or anticipate how existing socio-economic and environmental trends will continue, or shift unexpectedly, and the implications for vulnerable ecosystems and people. Further complications are the associated inter-linkages to consider about what all of this may mean for individual countries, subregions, regions and at the global level. Hopefully, these considerations influence the decisions that societies take in shaping the future they want. Individuals though, appear to be more interested in how decisions affect them locally. A challenge in building scenarios in the Americas is therefore to develop scenarios that have local relevance to decision makers, and that make sense in the short term demanded by political considerations, and in the long-term context required to conserve regional biodiversity and NCP.

These considerations imply that the IPBES scenarios (IPBES, 2016), should not only be built from the ground-up to the regional level, but also simultaneously from the top-down global level to the regional level. The scenarios for the Americas could therefore be conceived as being primarily focused on issues at the regional level (section 5.3) with multi-scale links down to the local level (section 5.6.3) and links up to the global level (Rosa *et al.,* 2017) (sections 5.4 and 5.5). Although many scenario exercises have been done over time, several authors have noted that the diversity of scenarios commonly falls within predictable archetypes as outline in section 5.2. With the constraints of limited time and resources, three suggestions of how regional scenarios can be linked to typical global archetypes, such as those used by IPCC (adapted from Kok *et al.,* 2016) are shown in **Table 5.3**.

Table 5 3 **Strengths and weaknesses of the 3 options to develop new scenarios for biodiversity and ecosystem services as proposed by Kok *et al.* (2016).**

	Strengths	Weaknesses
Option 1 Use existing IPCC related shared socioeconomic pathways/ RCP archetype scenarios	• readily available global pathways • can be extended to biodiversity and ecosystem services • accepted by scientists and policy makers	• minimal involvement of stakeholders • lack of connection to ILK • only implicit connection to biodiversity and ecosystem services
Option 2 Develop new global biodiversity and ecosystem scenarios	• IPBES product and opportunity to involve IPBES stakeholders • Strongly linked to biodiversity and ecosystem services • Build on results & methods of Millennium Ecosystem Assessment	• Not available yet • Requires long process with high demand for time and funding • Risk of reinventing the wheel • Difficulty of incorporating cross-scale feedbacks
Option 3 Link bottom up local biodiversity scenarios to existing shared socioeconomic pathways	• Link IPBES to existing scenarios • Explicitly multi-scale, accounting for local variability and local issues • Relatively easy to develop and connect to IPBES stakeholders	• Potential lack of cross-scale consistency and comparability • Risk of focus on local, short-term issues that could be difficult to upscale

Kok *et al.* (2016) further recommend Option 3 for IPBES because it builds on existing global scenarios while accommodating the heterogeneous diversity of local and regional biodiversity and ecosystem services scenarios. This proposed multi-scale scenario approach should capture the diversity of local social-ecological processes and cross-scale global-to-local interactions that affect human well-being.

While there are clear advantages of building on existing scenario work, it should not preclude new or novel approaches as they arise. As pointed out in **Box 5.2**, all of the shared socioeconomic pathways assume global GDP to be at current or increasing levels. However, some researchers have questioned this basic assumption (see **Box 5.2**).

5.6.2 Inclusion of essential stakeholder groups

Scenarios are excellent thought-provoking exercises and can help to frame pathways to a sustainable world. However, to develop plausible scenarios, and ultimately to effectuate them, like those that will be required to achieve the Great Transition endpoint, will require solutions to multiple wicked problems through the concerted efforts of at least four categories of stakeholders operating at the global/regional and local levels: 1) policy makers; 2) local populations; 3) civil society; and 4) business community. The development of plausible scenarios that can successfully drive effective policy needs to take into consideration a great many factors. As outlined in the previous section, scenario development should proceed from a regional setting with region-to-global and regional-to-local integration, which includes participation by all four categories of stakeholders. Implementation of the policies that will be necessary to fulfill a vision of a future, in which the NCP stemming from the globe's natural capital are enjoyed by all, requires the buy-in by all four categories of stakeholder; all groups are necessary to assure the plausibility of any given scenario.

Civil society may fulfill various roles in scenario development, including provision of technical expertise through scientific and academic institutions; "grass roots" organizations (formal or informal collective groups centered on an issue), conservation organizations (e.g. The Nature Conservancy, The International Union for Conservation of Nature), the IPBES effort being an example itself. So, too, civil society may play an important role representing segments of the population; i.e. providing input, or even advocacy, for particular viewpoints and may be critical in assuring consideration of particular SDG such as: 3 – Healthcare; 4 – Education; and 5 – Gender equity.

Regarding SDG, it should be recognized that SDG 4 – Jobs and economic growth, and 5 – Industrialization, are directly linked and dependent on the business community. In addition, SDG 2 – Agriculture, 7 – Energy, 12 – Production patterns, 13 – Climate change, 14 – Sustainable use of oceans and marine resources, and 15 - Forest management, all involve the business community. We speak of "natural capital" for a good reason. Aside from a pure subsistence level, realization of NCP requires higher levels of activity such as municipal and regional governments, the local business community, and multi-national corporations. The business community, at all levels, has a very decided stake in perpetuation of our natural capital and it can play a significant role in its preservation. The primary goal of most corporations is to benefit its stockholders; scenarios that do not account for this are not plausible. Thus, bottom-up scenario building needs to include not only the lowest levels of organization (i.e. the individual), but also the higher levels, such as multinational corporations. There is a significant number of forward-looking corporations that take their environmental and social responsibilities seriously and dedicate resources to those efforts. Like-minded business leaders have banded together to form such organizations as the World Business Council on Sustainability, which is composed of high-level executives dedicated to environmentally sustainable business practices. Groups such as this hold great potential in furthering the efforts of the IPBES. So too, scenario building should incorporate developing business practices such as social and environmental accounting and reporting. Other emerging trends, such as formation of "B Corporations" which have a specific recognition of social responsibility and that maximization of returns to shareholders is not necessarily their primary goal; this deviates from a principle that has been operating for over a hundred years and could produce revolutionary results in transforming the business world. Thus, in scenario building, the business world should be viewed as a resource and a necessary partner. Incorporating the views of the business community, along with other sectors of society such as local and indigenous people, will allow considering the multiple and sometimes conflicting values that often determine the effectiveness, equity and legitimacy of management and policy actions.

5.6.3 Telecoupling - Recognizing interactions between distant socio-ecological systems profoundly affect nature and nature's contribution to people

In today's highly interconnected world, sustainability issues should be analyzed with attention to the impacts that consumption and production patterns in one part of the world can have on nature, NCP and quality of life elsewhere. To do this, several concepts and frameworks have been developed with the aim of better understanding and integrating the various distant interactions that often strongly influence the flow of NCP within and between social-ecological systems, e.g. trade and invasive species. Among these, the concept of telecoupling is useful to analyze cross-scale socio-economic and environmental interactions that influence local to regional sustainability trends and outcomes (Liu *et al.,* 2013).

Telecoupling refers to socio-economic and environmental interactions among social-ecological systems over distances and scales. The telecoupling framework takes a multilevel analytic approach. At the level of the telecoupled system, an interrelated set of social-ecological systems (sending, receiving and spillover systems) connect through flows among them. At the coupled-system level, each system consists of three interrelated components: agents, causes and effects. At the component level, each component includes many elements or dimensions, e.g. individuals, households, organizations, etc. The sustainable and equitable flow of nature contributions to people is strongly influenced by telecouplings in several socio-ecological systems of the Americas. Therefore, neglecting telecouplings and the resulting off-stage ecosystem burdens in model and scenario building, and in environmental decision-making, will jeopardize achieving SDG (Pascual *et al.,* 2017).

Nature in many rural landscapes of Latin America has been heavily transformed in order to produce raw materials that are exported to supply the increasing demand in emerging and developed countries. Conversely, rates of environmental degradation have been reduced in some developed countries as they displace land-use abroad by importing raw materials from developing countries (Meyfroidt *et al.,* 2013). The lower levels of environmental degradation for North America projected by the Global Biodiversity Model for policy support scenarios may be explained by the fact that the USA and Canada are large importers of food, have a large ecological footprint and thus export environmental degradation to food exporting regions such as Latin America (Moran & Kanemoto, 2017). Such telecoupling between exporting and importing regions of agricultural products means that trading decisions and policies in importing countries have a strong impact on the status of nature and its contributions to good quality of life in exporting countries.

Telecouplings can have negative or positive effects on sending and receiving systems. Many policy interventions proposed to improve sustainability outcomes in particular places (e.g. payments for ecosystem services, protected areas creation, etc.) are prone to have unintended effects on distant places, indicating that telecouplings must not be overlooked in the knowledge-policy interface (Pascual *et al.,* 2017). Next, the telecoupling framework will be used to illustrate how cause-effect interactions between distant places influence trends and outcomes of key sustainability issues in the Americas.

Case 1: Agricultural pest control

While it is difficult to estimate true losses, reduction in agricultural crop production due to insect feeding damage ranges from 10-20% and accounts for tens of billions of USA dollars in lost harvest worldwide on an annual basis (Maine & Boyles, 2015; Oerke, 2006; Oliveira *et al.,* 2014). It has been demonstrated that predators feeding on agricultural pests reduce feeding damage, resulting in increased yields. One such group of predators are migratory insectivorous bats.

Brazilian free-tailed bats *(Tadarida brasiliensis*) overwinter in central and southern Mexico, moving in the spring to northern Mexico and the southwestern USA, where they form large maternity colonies (aggregations of primarily female bats raising their young) and can number in the millions. They feed on a number of Lepidtopteran species (butterflies and mothes) in the family Noctuidae, including: fall armyworm *(Spodoptera frugiperda)*, cabbage looper *(Trichoplusia ni)*, tobacco budworm *(Heliothis virescens)*, and corn earworm/cotton bollworm *(Helicoverpa zea)* (Cleveland *et al.,* 2006). Studying the role of Brazilian free-tailed bats in a multi-county region of Texas, Cleveland *et al.* (2006) estimated that bats consuming 1.5 adult cotton bollworm moths per night will prevent about five moth larvae from damaging crop plants. Given that a single moth larva can destroy two to three bolls in its lifetime, they estimated that the bats reduce insect damage on cotton by 2-29%, depending on conditions.

Federico *et al.* (2008), in a follow-on study, calculated that Brazilian free-tailed bats not only contribute to more profitable agriculture by increasing yields, but also lower pesticide costs to farmers by delaying the build-up of cotton bollworms to critical levels, at which point pesticide applications become economical in terms of yield. Additionally, the modeling by Federico *et al.* (2008) indicates that predation by Brazilian free-tailed bats result in significant economic benefits even in the case of genetically modified cotton that is resistant to the moths; this has the ancillary contribution to society of lowering the amount of pesticides used.

Similar benefits from migratory, insectivorous bats for the corn crop have been shown in the Midwest of the USA. In areas where the eastern red bat *(Lasiurus borealis)*, believed to be the primary species of bat feeding on pests, was excluded from cornfields, Maine and Boyles (2015) found a 59% increase in the number of larvae of corn earworms. They calculate that for corn alone, bats reduce crop loss by over $10 billion per year worldwide. As with the Brazilian free-tailed bats, eastern red bats are migratory, overwintering in the southern USA and traveling northward to the Midwest in the spring.

There are several important points to note about these cases of telecoupling: 1) the bats spend a large portion of the year distant from where they provide benefit; 2) the beneficiaries of the cotton crop are, in essence, distributed worldwide; and; 3) being migratory, the bats are at risk not only in their summer habitat, but also during migration and in their winter habitat.

The risk to migratory bats can be substantial. Bat fatalities at wind turbines in North America have been documented at various rates, depending on the site and situation, with higher rates being reported in the Eastern USA (National Academy of Science, 2007). Strickland *et al.* (2011) reviewed fatality rates and found them to vary from 0.07-39.7 fatalities/MW/Year, with the highest rates associated with forested, mountain ridge tops. (Frick *et al.,* 2017) has estimated that deaths due to wind turbines pose an actual extinction threat for some species. Fatalities can result from either direct interaction with wind turbines, i.e. bats struck by turbine blades or colliding with monopoles (Kunz *et al.,* 2007), or from barotrauma, i.e. lung damage resulting from rapid decompression due to turbulence associated with wind turbines (Gorell *et al.,* 2004). Approximately 75% of bat mortality associated with wind turbines in North America is accounted for by three species: eastern red bat, hoary bat *(Lasiurus cinereus)*, and the silver-haired bat *(Lasionycteris noctivagans)*, all of which are long-distance migrators, wintering in the southern USA and migrating north to the Midwest each summer (National Academy of Sciences Agencies, 2007). Klatt and Gehring (2013) have shown that in an agricultural area in southern Michigan USA, these three species tended to be found over open agricultural fields as opposed to riparian areas, which are preferred by the cave-hibernating bats in the area. In the Midwest, most wind farms are located within agricultural fields. Thus, preservation of NCP in agro-ecosystems can be aided by conservation of migratory, insectivorous bat species, but, ironically, these species are threatened by alternative energy options.

Case 2: Amazon forest as provider of global services

The case of the Amazon forest may well illustrate cross-scale interaction where decisions on land use at the local level may influence the global wellbeing. There have been two (intertwined) ways to look at how this influence happens: by understanding the loss of a given ecosystem service (e.g. negative consequences of deforestation for biodiversity and ecosystem functioning, or, as put by Costanza *et al.* (1997) and Fearnside (2008), what it would cost to replicate the service in a technologically produced, artificial biosphere, or by assessing the value of a given ecosystem service to society (e.g. the willingness to pay for an ecosystem service). In any case, different time scale analysis plays an important role for decision-making. For example, land use change from forest to pasture could show advantages in the present time (and at the local scale) (Foley *et al.,* 2005); but be proven otherwise in the long run with implication ranging from local to regional or even global scales.

As the world's largest tropical forest (~5.4 million km^2), Amazonian forests, a myriad of biodiversity, have a substantial influence on regional and global climates (Malhi *et al.,* 2008; Ometto *et al.,* 2011; Schwartzman *et al.,* 2012). For instance, almost 1/3 of the global net primary productivity (photosynthesis minus plant respiration) interannual variation is associated with Amazonia carbon fluxes (Zhao & Running, 2010). The carbon stock, in living biomass, is considered to be on the order of 150–200 Pg C, being one of the largest ecosystem carbon pool (Brienen *et al.,* 2015; Feldpausch *et al.,* 2012; Nogueira *et al.,* 2015). The range of carbon pool estimate (Malhi *et al.,* 2009; Potter *et al.,* 2009; Saatchi *et al.,* 2007), as well as the differences representing the vegetation cover (Bustamante *et al.,* 2016; Ometto *et al.,* 2014), reflects the difficulty to estimate forest structure and vegetation biomass, in a large and highly diverse ecosystem.

The carbon budget and the regional hydrological dynamic are affected by direct anthropogenic actions, as land cover and land use changes (e.g. deforestation, forest fires, forest degradation associated to unplanned logging, expansion of pasturelands) and by climate-induced extreme events, such as extended droughts (Marengo *et al.,* 2004). Effects of these, independently or combined, increase the risk of disruption of these natural processes, as well the threat to biodiversity and ecosystem services (Aragão *et al.,* 2014; Poulter *et al.,* 2011). Climate feedback of these processes have also been shown through local observation and modelled at regional scale (Marengo *et al.,* 2004; Spracklen & Garcia-Carreras, 2015), as a strong indication of the importance of the natural vegetation as climate regulation. Therefore, deforestation can, itself, be a driver of climate change (Cardoso *et al.,* 2009; Malhi *et al.,* 2008; Sampaio *et al.,* 2007) at both local and global scale (Lawrence & Vandecar, 2014; Maeda *et al.,* 2015; Werth, 2002). Normally, climate change simulations consider deforestation in large areas, or even at biome scale, although, the effect on loss of ecosystem services at local scale can drive deep changes in subregion climate, possibly weakening the resilience of the whole region (Malhi *et al.,* 2008).

Despite the recent reduction in deforestation rates in the Brazilian Amazon, deforestation and forest degradation are still process of high concern; the region has lost about 19% of its natural cover and has about 40% of its area on conservation units and Indian reservation (Aguiar *et al.,* 2016). The Amazon monitoring systems of Brazilian Government, as Amazon Forest Degradation Monitoring System (INPE, 2014, www.inpe.br) and Amazon Deforestation Monitoring System (INPE, 2017) identified, in the period from 2007 to 2013, illegal logging and anthropogenic fire activities, degraded 103,000 km^2 of forests, whilst clear cut deforestation impacted 56,000 km^2. From the clear cut, about 60% turned into pasturelands, and 23% is abandoned, leading to the recovery of secondary vegetation (TerraClass, INPE, 2015, www.inpe.br). These systems, associated with the agricultural census, provided useful information on the major characteristic of the rural properties, which reflected in a better mapping of the deforestation paths and characteristics (Godar *et al.,* 2015). Those initiatives were associated to a Government act named (in Portuguese), *"Plano de Ação para Prevenção e Controle do Desmatamento na Amazônia Legal"*, Brazilian Ministry of Environment, 2004, important to reduce the rate of deforestation observed in 2004, at 27,772 km^2, to 4571 km^2 in 2012. Since then, deforestation has an increasing trend, reaching 7,893 km^2 in 2016 (INPE, 2017). However, the revision of the Brazilian forest code might threaten, under legal terms, forests from the biomes Amazon, Cerrado and Atlantic forest, mainly by the broad possibilities of reducing the requirement to preserve natural vegetation outside the farm boundaries and the relaxation of the rules for private farms established before 2008 (Brancalion *et al.,* 2016; Sparovek *et al.,* 2015). The dynamic of land cover change, implementation of agricultural production areas or, otherwise, further abandonment, defines important patterns of land use in the region, with similar patterns in other forests in Latin America (Boillat *et al.,* 2017).

Although, not advocating the maintenance of the replacement of natural vegetation, local societal needs ought to be in consideration. A deep analysis in the policies addressing environmental conservation and the relation to societal need, or poverty alleviation, shows a dichotomy (Pinho *et al.,* 2014), indicating the need of deeper action towards a sustainable future for the moist tropical forests. Boillat *et al.* (2017), on analysing land systems in Latin America, identified that the dynamic of land change process in the region tends to be persistent in the future. The identification of the high value services provided by the forest in comparison to what agriculture, or beef, production does goes back more than 20 years, as observed by Chomitz and Kumari (1998) and Fearnside (1997), however, the strong historical connections to the global market (Dalla-Nora *et al.,* 2014), the importance of commodities for the region's economies (Lapola *et al.,* 2013), land tenure and governance, with lack of socio-ecological inclusive strategy might lead to a persistence of depletion of natural vegetation in the region.

Aguiar *et al.* (2016) used several socio-economic scenarios approach to calculate future carbon emissions for the Amazon region and conclude that unless a "forest based transition economy evolves in the region the land use and forest sector in Brazil shall have a limited capacity of mitigating other sectors emissions in the next decades". Historically, for the countries in Latin America and, especially considering areas of moist and dry forests, both, deforestation and forest degradation, are important drivers of carbon dioxide emissions to the atmosphere, contributing significantly to the country emissions profiles (as observed in the past two National Communications that Brazil has submitted to the United Nations Framework Convention on Climate Change, http://sirene.mcti.gov.br).

For these reasons, Foley (2005) argues it is appropriate (in order to make more informed decisions) to balance the trade-offs between "the societal benefits (typically the short-term realization of ecosystem goods and commercially valuable commodities) against the long-term costs of ecological degradation (associated with the functioning of the ecosystem). Adding to this is the fact that, in large, NCP descend from common goods (such as clean air and water, soil formation, climate regulation, waste treatment, aesthetic values and good health), which are generally taken for granted, as they do not pass through the money economy (Costanza *et al.,* 1997).

Case 3: Urban Telecoupling

The world is increasingly urban and interconnected. This alone makes urban processes of fundamental importance to better understand global change (Huang *et al.,* 2010) and respond to it. Today's population of 7.6 billion is expected to reach 9.8 billion in 2050, when about two-thirds of the world's population is projected to be urban (UN, 2017). This unprecedented state is posing consequences regarding the balance between demand and supply of ecosystem services in order to assure human well-being. After all, urbanization should be understood not only as a demographic or socioeconomic phenomenon but also as a process of ecological transformation by humans, affecting land ecosystems from local to global (Huang *et al.,* 2010). This occurs for at least two intertwined reasons. First, because the increasing magnitude and pace of urbanization directly reshape land use locally in an accumulative fashion throughout the world (Seto *et al.,* 2012). More than 1.5 million square kilometers of global urban land area is expected to be added by 2030 (Seto *et al.,* 2011). This expansion is expected to occur at the cost of high quality agricultural land as well as high biodiversity sites (Fragkias *et al.,* 2012). Additionally, at a global scale, the physical expansion of urban areas is growing twice as fast as urban population (Seto & Ramankutty, 2016). New expansion is expected to increasingly take place close to biodiversity hotspots. By 2030, 1.8% additional area from biodiversity hotspots will be converted into urban use (Seto *et al.,* 2012). It is in South America where the most pronounced increase in the amount of urban land (forecasted at 100,000 km^2) in biodiversity hotspots will take place (Güneralp *et al.,* 2013) and in the Americas, in general, where the highest number of species already highly threatened will be impacted by urban expansion (Seto *et al.,* 2012).

The second reason, captured by the concept of telecoupling, is linked to trends in urban consumption patterns that unintentionally affect ecosystems at different spatial scales. However, despite conceptual advances, there is a gap in studies demonstrating these linkages. This is partially because telecoupling between places of consumption and places of production are largely unnoticed at subnational levels.

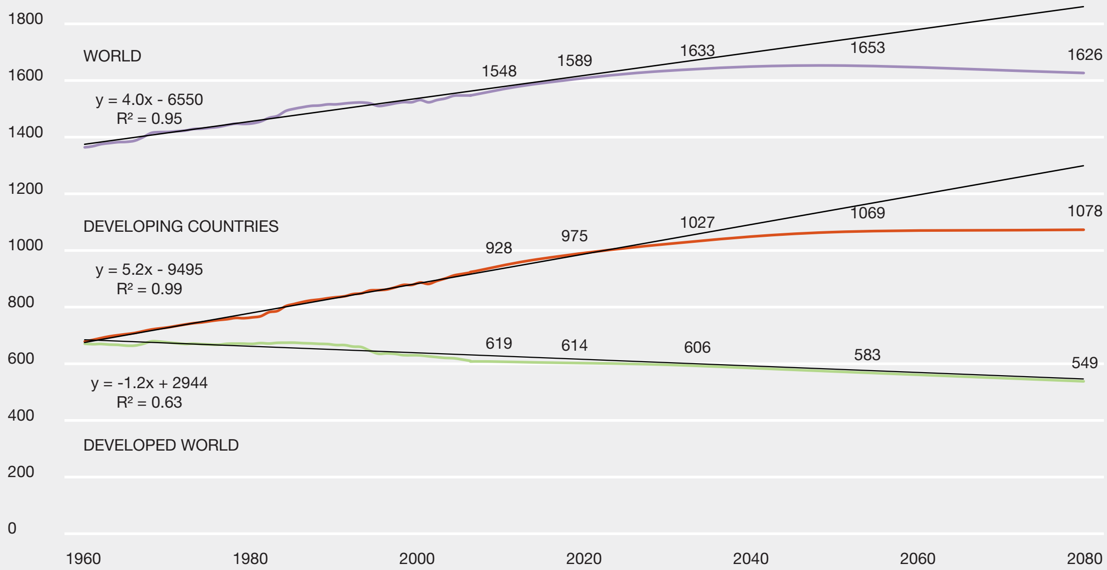
As opposed to non-urban, urban residents tend to consume differently (Gadda & Gasparatos, 2009; Rudel *et al.,* 2009; Yu *et al.,* 2013), artificially detached to the source of the ecosystem service. This means that urban residents, "appropriate" natural ecosystems, ecosystem goods and services, and natural capital from one or more "different elsewheres" and therefore indirectly affect land use at scales ranging from the hinterlands of the urban area to a single or multiple remote geographical unit(s) (Seitzinger *et al.,* 2012; Seto *et al.,* 2012). This is largely driven by economic complexities and dynamic interrelations among scales (local, regional, and global processes) and flows of goods and services. Along these lines, Seto *et al.* (2012) argue that since urban economies currently generate more than 90% of global gross value added, there may be few non-urban systems unaffected by urbanization. An outstanding example is the indirect impact that shifts in urban dietary preferences (Gadda & Gasparatos, 2009; Satterthwaite *et al.,* 2010) is having on new agricultural lands and which is expected to continue growing into the future (FAO, 2017b). This is well illustrated by the growing demand for animal protein expected to continue throughout the urban world, at least until 2050. After all, more land is needed to produce meat (and dairy-based foods) than vegetable and grain-based diet (Güneralp *et al.,* 2013). And, as demands for agricultural products grow, large remaining forest area is likely to experience increasing pressures (Defries *et al.,* 2010; FAO, 2017b) especially in developing countries (FAO, 2017b). Therefore, not only is there a strong connection between urbanization and economic growth but also between affluence (and urban preferences) and the global displacement of land use particularly from high-income to low-income countries (Weinzettel *et al.,* 2013). Despite increasing evidence of these trends, the underlying processes relevant to better manage the increasing telecoupled urban world are still not well captured (Liu *et al.,* 2013; Seto & Ramankutty, 2016).

While land-use and land-cover change have been well documented, its linkage with urbanization is less well studied. As land is a finite resource, the increasing competition for land globally (e.g. for agricultural products, energy production, biomass, infrastructure and settlements, conservation and recreation, as well as a large range of other ecosystem services) and the degree of global environmental change associated with it (embedded in the general phenomenon of the "Great Acceleration") makes the understanding between land-use and urbanization an urgent need. Most studies have focused on land-use changes driven by international food trade and its great influence on global food production and the environment. After all, agricultural products are an outstanding illustration of ecosystem services of global demand. Among studies, a particular emphasis has been around global demand for cash crops. One reported case is of continued deforestation in South America in general, and in the Amazon rainforest in particular, due to the demand for soybean (Graesser *et al.,* 2015) by urbanized and affluent European Union countries, USA, Japan and by increasingly urbanized China, (Rudel *et al.,* 2009; Sun *et al.,* 2017), among others. Yu *et al.* (2013) show that 47% and 88% of cropland in Brazil and Argentina, respectively, are used for consumption in other countries, mainly the European Union and China. China alone displaces 5 Mha pf cropland in Brazil, mainly for soybeans. China's appropriation of virtual water embodied in soybeans from Brazil nearly doubled between 2001 and 2007 (Liu *et al.,* 2015). Commoditization of agriculture in the South is, therefore, a key driver affecting land cover (Lapola *et al.,* 2013), well illustrating the interconnection and cross-scale issues of a globalized urban world. That is, telecoupling in the agriculture sector shows a very strong interaction among agri-social-ecological systems over long distances and scales.

These trends are expected to continue into the future. For example, it is expected that the demand for food between 2012 and 2050 will increase by 50%. The underlying factors will continue to be urbanization, population growth and increases in income. This increasing demand will happen as natural capacity for producing the needed food will be under increasing stress. This includes the need for additional land. It is expected that by 2050, 100 million ha of new land will be required (FAO, 2017), very likely at the expense of forested areas (e.g. natural ecosystems). This poses a threat to priority areas for biodiversity conservation in many places of Latin America, for example. In fact, the rising international demand for land embodied in food trade has been growing and is expected to continue rising throughout the coming decades, mostly at the cost of land cover conversion to new arable land in developing countries **(Figure 5.29)**. In other words, "doubling global food supply without extensive additional environmental degradation to non urban areas presents a major challenge" (Seitzinger *et al.,* 2012).

While cities are often solely perceived as a driver of environmental degradation, consequently affecting human well-being, they also offer important opportunities to reduce these impacts, if well managed. Therefore, urbanization has increasingly been recognized as a key element for a sustainable future, with impacts beyond urban borders. Urban environmental sustainability is now an important pillar of the new urban agenda (Habitat III, 2016). Included in the vision shared by signatories of the United

Figure 5 29 **Trend in arable land and land under permanent crops (million hectares) for food, feed and fibre production. Source: Bruinsma (2011).**



Nations Conference on Housing and Sustainable Urban Development is that urban food security and strengthening of urban-rural linkages will play a major role towards sustainable urban development. Moreover, governments are committed to ensuring environmental sustainability by several measures, including the protection and improvement of ecosystem services and biodiversity.

For this end, however, the sustainability of cities needs to be understood beyond place-based concepts that advocate for decisions that are local in scope (e.g. efforts of self-sufficiency at the local level) as these decisions do not account for critical consequences of telecouplings in distant places and people. Urban telecoupling (as an analytical tool) can assist in concentrating decisions concerning urban processes (flows of capital, information, people, goods, materials, energy, and services) that spill over large geographical areas with the advantage of having both well-being and equity issues more explicit (Seto *et al.,* 2012). Urbanization, after all, can be conceptualized as "a multidimensional, social and biophysical process driven by continuous changes across space and time in various subsystems including biophysical, built environment, and socio-institutional (e.g. economic, political, demographic, behavioral, and sociological)" (Marcotullio *et al.,* 2014). As such, urbanization with appropriate governance, incentives, and cultural capacities (Satterthwaite *et al.,* 2010) that adopt planetary stewardship (Seitzinger *et al.,* 2012) may well lead the path towards a desirable global future. For example, urban residents tend to have a higher willingness to pay for ecosystem services than non-urban counterparts do. Urban citizens from Italy and the United Kingdom were willing to pay almost $44 to protect 5% of the Brazilian Amazon rain forest and therefore protect an existence value; that is, protect an ecosystem that they may not ever visit or use directly (Güneralp *et al.,* 2013). Also, changes in urban consumption patterns can have far-reaching consequences that are less environmentally harmful. One example is the increasing European preference for organic food that has developed a new supply chain of these products in South America (Seto & Ramankutty, 2016). Moreover, urban citizens and organizations have the potential of self-organizing to ensure better decisions. The next couple of decades offer us the opportunity to showcase how cities can be responsible stewards of biodiversity and ecosystem services at all scales (Elmqvist *et al.,* 2013).

Case 4: Biomass burn

Despite the local effect of fire, especially the high frequency of fire events in the tropical ecosystems, in general affecting biodiversity, the process of atmospheric transfer of biomass burning plume takes material and chemicals to further distances. Until 2100, atmospheric deposition of reactive nitrogen shall be the third-largest determinant of biodiversity loss, behind land use and climate changes (Sala, 2000). Plant community composition is tightly related, at larger scale, to nutrient availability, and for several ecosystems low fertility is determinant of community process stability. Therefore, changes in nitrogen input may directly impact ecosystems and constitute a major ecological threat. Among the ecological disruption processes one can highlight, nitrophilous plant species are favored in a high nitrogen input systems resulting in declining species diversity

(Bobbink & Lamers, 2002); soil acidification, herbivory and susceptibly to drought, can lead to competitive exclusion and biodiversity loss.

Reactive nitrogen input in natural ecosystems, derived from atmospheric deposition is associated with several factors, such as use of fertilizer in agriculture, industrial gaseous waste/fossil fuel combustion and biomass burning. Austin *et al.* (2013) discuss the uneven use of nitrogen fertilizers among different countries in the Americas. In South America, especially Brazil, the use of fire is a common management practice in agricultural areas, which very often burns areas of natural vegetation marginal to the production areas. Amazonian fires contribute a flow of smoke following the jet streams associated to the Intertropical Convergence Zone, towards the southern area of the continent, including areas of Bolivia, Paraguay, Northern Argentina and substantial area of Brazil. In regions closer to highly urbanized areas, with strong industrialization, in southeastern Brazil, as well in the Central area of the Country, dominated by Cerrado biome, the nitrogen budget indicates an increase of anthropogenically derived nitrogen atmospheric deposition (Filoso *et al.,* 2006; Lara *et al.,* 2001).

Nitrogen deposition might affect biodiversity in priority areas for conservation in developing countries, especially in tropical and subtropical regions of the Americas. Despite the fact that the surface covered by hotspots for biodiversity conservation in these areas (2.1% of Earth's land surface), they host circa of 50% of the world's vascular plant diversity (Mittermeier *et al.,* 2005; PHOENIX *et al.,* 2006). Deposition rates for reactive nitrogen deposition, modeled for 2050, indicate values exceeding 15KgN ha^{-1} y^{-1} in areas of South America that are hot spots for endemic plants, as the tropical Andes and the Atlantic Forest in Brazil. Another aspect to highlight refers to the relation of nutrient availability (nitrogen and phosphorus) and carbon cycling, affecting the prediction of productivity responses of tropical ecosystems to climate changes (Cleveland & O'Connor, 2011).

Biomass burning in Southern and Eastern Brazilian Amazon, Central Brazil and Western Bolivia (www.inpe.br/queimadas) feed the atmosphere with a broad distribution of chemical compounds, including nitrogen oxides and organic substances; long-range transport of reactive nitrogen compounds are observed by smoke plume rise and transport modeling (Longo *et al.,* 2009). This transport takes the chemical compounds to the Southern portion of Brazil, Uruguay and Northern Argentina (Zunckel *et al.,* 2003). The photochemical reaction in the atmosphere my lead to the production of ozone, in lower altitudes, by the high nitrogen oxide presence. Ozone in lower atmosphere is phytotoxic, impacting plant communities, but also human health (Artaxo *et al.,* 2009; Butler *et al.,* 2008).

5.6.4 Recognition and inclusion of multiple values

Models and scenarios are powerful tools to assist in the identification of policy and management options. The arena for the design and implementation of these options is characterized by a diversity of values of nature and its contributions to people's good quality of life, associated with different cultural and institutional contexts. Stakeholders' values of nature and NCP conflict in most contexts of the Americas, affecting the way sustainability is conceived and policy and management decisions are made (Pascual *et al.,* 2017). Thus, the full range of values should be considered when building models and scenarios if they are to assist in the development of effective, legitimate, adaptive and equitable options towards sustainability. Value conflicts arise because stakeholders hold different identities and beliefs of their relationship with nature, which produces different and sometimes contrasting preferences over NCP and ways to manage these (Mastrangelo & Laterra, 2015). Most of the literature on value conflicts tends to emphasize the dichotomy between instrumental (i.e. values of living entities as means to achieve human ends, or satisfy human preferences) vs. intrinsic (i.e. values inherent to nature, independent of human judgement) dimensions of nature (Pascual *et al.,* 2017).

A pluralistic approach to the diversity of values underpinning nature–human relationships also recognizes that NCP can embody symbolic relationships with natural entities that define "relational values", i.e. values that do not directly emanate from nature but are derivative of our relationships with it and our responsibilities towards it (Chan *et al.,* 2016). Capturing this diversity of values in models and scenarios requires an integrated valuation approach. However, most valuation efforts to date have relied on unidimensional valuation approaches, by which, either economic, ecological or socio-cultural values are elicited separately. Ecological or biophysical values have been the most frequently incorporated in models and scenarios, with ecological values of multiple NCP being used in protocols for assessing and mapping NCP at regional scales such as InVEST (Nelson *et al.,* 2009) and ECOSER (Laterra *et al.,* 2012). Economic or monetary values have often been incorporated into models and scenarios, for example, to make global estimates of the value of ecosystems and their services (Kubiszewski *et al.,* 2017a) **(Box 5.3)**. In contrast, social and cultural values of nature and NCP have been rarely incorporated in models and scenarios. This represents a significant research gap as the knowledge and values of local stakeholders have been demonstrated to confer legitimacy, flexibility and adaptive capacity to policy and management actions (Pascual *et al.,* 2017).

Integrated valuation approaches that incorporate social and cultural values allow capturing the knowledge and

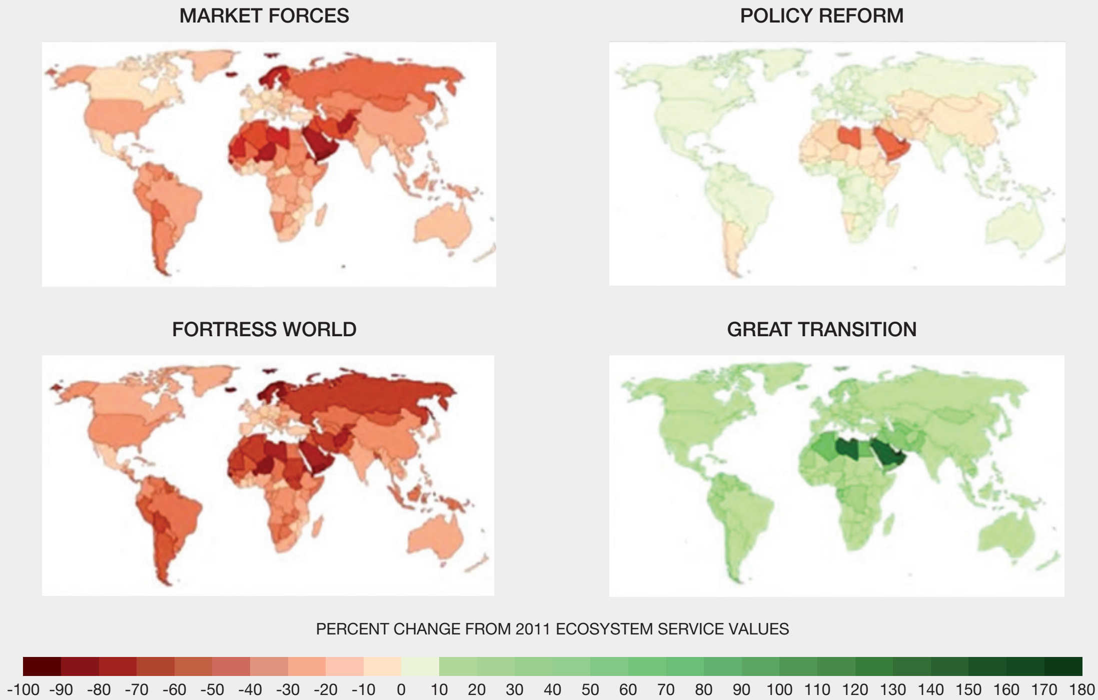
Box 5 3 Future changes in the monetary value of ecosystems services.

Kubiszewski *et al.* (2017a) evaluated scenarios for ecosystem services in the Anthropocene globally, assessing the future change of total ecosystem services values due to land-use change decisions. The study used four scenarios archetypes of the "Great Transition Initiative" (Raskin *et al.,* 2002) presented in section 5.2.

The change in the value of ecosystem services in each scenario was calculated considering two factors: 1) change in area covered by each ecosystem type; and 2) change in the "unit value" based on policy and management assumptions that are likely to happen in each scenario. The plausible estimates of the magnitude of change that may occur under each scenario are based roughly on the estimates from (Bateman *et al.,* 2013) of future scenarios for the United Kingdom:

- Market Forces: 10% reduction in unit values from their 2011 levels due to a decrease in environmental and non-market factors.
- Fortress World: 20% reduction in unit values from their 2011 levels due to a significant decrease in consideration of environmental and non-market factors.
- Policy Reform: no significant change in unit values from their 2011 estimates due to a slight improvement from 2011 policies and management.
- Great Transition: 20% increase in unit values from their 2011 levels due to a significant increase in consideration of environmental and non-market factors.

Figure 5 30 Global map showing the scale of percent change for each country in ecosystem services value in each of the four scenarios from the 2011 base map. Kubiszewski *et al.* (2017)



Under the Market Forces and the Fortress World scenarios all countries in the Americas show a decrease in ecosystem services value **(Figure 5.30)**, with an average negative change of 24% and 36% for Market Forces and Fortress World respectively. The highest negative percentage changes are particularly experience by islands in the Caribbean. For example, Saint Vincent and the Grenadines is expected to have a decrease in ecosystem services value of 79% under the Fortress World scenario. Within the inland countries, Bolivia shows the biggest loss (69%). In comparison, Brazil will show a decrease of 45%, equivalent to a loss of $3,717 billion/year due to losses of Tropical Forest, while USA will have a decrease of 38% ($3,279 billion/year). In the Policy Reform scenario most countries in the Americas experience an increase in ecosystem service values except for Argentina and Chile and the Caribbean islands but the magnitude of the changes are very small. In contrast, the increment in ecosystem services value is greater under the Great Transition scenario (23% average increment).

values of indigenous and local people. Indigenous and local knowledge can provide an important catalyst for scoping and developing management actions in response to larger-scale drivers of change (Folke *et al.,* 2005). Given the scale of environmental problems, most efforts at building models and scenarios have been done at subregional to global scales. Incorporating ILK into these broad-scale models and scenarios becomes important as most scenario archetypes, although considering a range of drivers and impacts, make implicit assumptions on underlying worldviews and values (Kubiszewski *et al.,* 2017a). Participatory scenario planning is one technique to incorporate multiple stakeholder values, including ILK, into models to explore plausible futures or support decisions to reach desirable futures. Participatory scenario planning is a process in which stakeholders, frequently guided by researchers, are engaged in a highly collaborative process and develop a leadership role within some or all stages of a scenario development process to investigate alternative futures (Oteros-Rozas *et al.,* 2015). Participatory scenario planning has been applied in some socio-ecological contexts of the Americas; however, the lack of systematic monitoring and evaluation to assess its impact on the promotion of collective action and social learning precludes us from determining the actual potential of participatory scenario planning for linking broad-scale models and scenarios and ILK (Brown *et al.,* 2016; Oteros-Rozas *et al.,* 2015). Nevertheless, participatory scenario planning holds promise as the use of intuitive stakeholder-based scenarios rather than more formal scenarios (e.g. quantitative model outputs) reportedly engendered a greater sense of ownership of the process because participants could modify and customize narratives that incorporated local knowledge (Brown *et al.,* 2016).

5.7 CONCLUSIONS REGARDING MODELING, SCENARIOS, AND PATHWAYS

Scenarios and models (both qualitative and quantitative) have formed a thread throughout this chapter and we believe that several conclusions regarding their utility, use, construction, and state-of-the-art with respect to the Americas can be stated.

- While the links between the various components of the IPBES framework are easy to conceptualize qualitatively, much work remains to be done to define the relationships quantitatively, as evidenced throughout this chapter. Yet, the utility of both qualitative and quantitative modeling is clearly demonstrated by use of the IPBES framework in section 5.4 and the Global Biodiversity Model for policy support considerations presented in section 5.5, respectively.

- From Chapters 3 and 4, it is clear that region-level datasets are lacking for many taxa and drivers and this will continue to be a challenge for regional and subregional modeling in the Americas.

- Scenarios and scenario building will provide only some of the process and raw intellectual material for development of solutions for the wicked problem of biodiversity conservation. Development of new approaches to governance and new policy tools will be necessary for those solutions. Modeling will help evaluate policy options that are inherent in scenarios and both will lend themselves to development of visions of achievable and desirable futures and the most efficacious pathways to those futures. This ex-ante modeling to evaluate the effectiveness of policies is critical; as some policies and efforts may have unintended consequences.

- Scenarios are descriptions of plausible futures, but the futures themselves need to be carefully defined with clear endpoints in mind and implemented at the national and international levels. Progress is being made on defining desireable endpoints through the Aichi targets, the Paris Accord, and the SDG, but consistent with Aichi target 2, critical to the effectiveness of both is mainstreaming of the targets and goals throughout governance systems at all scales. With well-defined goals, the development of target-seekiing scenarios would likely prove productive.

- A number of considerations have been identified throughout this chapter that are necessary to insuring effective and comprehensive scenarios and modeling efforts:

  - Making use of all sources of knowledge
  - Consideration of different value systems
  - Hundreds of scenarios already exist, more effort by practitioners should go towards integration of these scenarios rather than development new ones
  - Telecoupling
  - Feedback systems in nature, especially as related to tipping points and thresholds
  - Synergies among drivers

- As with the search for modeling studies that comprehensively address the IPBES framework, no regional level visions or pathways for the Americas Region were identified through this assessment. However, a number of studies have identified principles that have met with success in more limited situations. The following are emerging principles/efforts in this area specifically from studies for the Americas.

- Developing countries will be key factors in biodiversity conservation, as they are by definition expanding their economy, and hence, ecological footprint and have the potential to disproportionately influence progress towards biodiversity conservation by 2050 (Adenle *et al.,* 2014; Joshi *et al.,* 2015).

- Participatory approaches to scenario development are helpful in insuring their achievability and the lack of participatory mechanisms can be detrimental to resource management (Bohunovsky *et al.,* 2011; Gonzalez-Bernat & Clifton, 2017; Quinn *et al.,* 2013; Schmitt-Olabisi *et al.,* 2010; Seghezzo *et al.,* 2011).

- Refocusing and directing resources in direct support of biodiversity projects, especially in developing countries, may be a viable component of future pathways (Adenle *et al.,* 2014; Boit *et al.,* 2016).

- Environmental management would benefit from systematic and complete reviews of available evidence and data (Cooke *et al.,* 2016; Kremen, 2015); this concept is applicable to scenario-modeling development as well.

- Pathways, which by necessity must include socio-ecological-governance systems, can be more effective if adaptive capacity is designed into them via cooperative networks; conversely, lack of capacity can be a significant hindrance to even the best intended policies (Folke *et al.,* 2005; Gonzalez-Bernat & Clifton, 2017; Howes *et al.,* 2017; Joshi *et al.,* 2015; Young *et al.,* 2014)

- While funding plays a role in the implementation of the Convention on Biological Diversity, general awareness among policy makers also plays a significant role, whereas lack of awareness among those responsible for policy implementation can be detrimental (Gagnon-Legare & Prestre, 2014; Howes *et al.,* 2017).

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