Chapter **2.1**

STATUS AND TRENDS – DRIVERS OF CHANGE

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CHAPTER 2.1 STATUS AND TRENDS – DRIVERS OF CHANGE

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STATUS AND TRENDS – DRIVERS OF CHANGE

EXECUTIVE SUMMARY

Global transformation involved key trade-offs, and inequalities, as growing interactions drove economic growth but also degradation.

Accelerations in consumption and interconnection have had trade-offs.

i. Meeting basic material needs, and rising hopes of growing populations has had trade-offs. Nature has been degraded by the aggregated impacts of myriad actions (*well established*). Today, humans extract more from the earth than ever before (~60 billion tons of renewable and nonrenewable resources) {2.1.2} with population doubling over 50 years {2.1.4} and the per person consumption of materials up 15% since 1980. Since 1970, global extraction of biomass, fossil fuels, minerals, and metals increased sixfold {2.1.6, 2.1.11, 2.1.14}. Urban area doubled since 1992 and half of agricultural expansion (1980–2000) was into tropical forests {2.1.13}. Fishing now covers over half the ocean {2.1.11}. Since 1980, greenhouse gas emissions doubled {2.1.11, 2.1.12}, raising average global temperature by at least 0.7 degrees {2.1.12} and plastic pollution increased tenfold {2.1.15}. Over 80% of global wastewater is discharged into the environment without treatment, while 300–400 million tons of heavy metals, solvents, toxic sludge, and other wastes are dumped into the world's waters each year {2.1.15}. Fertilizers enter coastal ecosystems, producing more than 400 hypoxic zones and affecting a total area of more than 245,000 km^2 {2.1.15}. The number of recorded invasive alien species doubled over 50 years {2.1.16}. Today, a full 75% of the terrestrial environment, 40% of the marine environment, and 50% of streams manifest severe impacts of degradation {2.1.12}.

ii. Accomplishments and shortfalls in the past – and the futures that we will shape – follow from variations in values, demography, innovation, trade and governance *(well established)*. Over the last 50 years, utilitarian instrumental views framed nature chiefly as a source of inputs, although narrow views have been challenged by varied institutions {2.1.3}. Irrespective of values, our increasing numbers drive degradation. Urban concentration shifts the trade-offs that we face {2.1.4}, while education affects changes in populations and per-person degradation – potentially at the cost of losses of the knowledge held by IPLCs {2.1.4}. Scarcities in nature's contributions have driven innovations that shift trade-offs, from the Green Revolution to massive hydroelectric dams, with genetic engineering, fracking, wind power, and other trends all to be fiercely debated {2.1.5}. The diffusion of such innovations could lower total degradation, while globalization has shifted degradation far away from consumption {2.1.5, 2.1.6}. Local community governance has organized more sustainable production {2.1.8} while nations, as 'global community citizens', have initiated a range of governance agreements, which had a range of fates. Nations also have adopted domestic conservation policies and even adjusted economic policies for nature {2.1.9, 2.1.10}. Supply chains are challenging national governance yet also signaling citizens' environmental preferences {2.1.7}.

iii. Within and across countries, outcomes trajectories have been unequal – for nature, for basic individual human needs, and for aggregate economic growth rates (*well established*). Forest cover stabilized in high income countries but since 1990 fell 30% in low income countries {2.1.11} as agricultural area fell in the former but rose in the latter {2.1.11, 2.1.13}. Natural assets values fell 1% in low income countries, since 1995, yet rose 5% in middle and upper-middle income countries {2.1.2, 2.1.13}. While 860 million people face food insecurity in Africa and Asia, obesity is rising in high and middle income countries {2.1.2}. Per capita demand for materials from nature is four times higher in high and low income countries {2.1.2}. Per capita consumption of animal protein rose by 50% during 1960–2010, to ~55 g/capita/day within the US and the EU, and ~30 g/capita/day in Latin America, but only ~15 g/capita/day in Asia and sub-Saharan Africa {2.1.2}. Contrasts are clear in the satisfaction of basic needs and the maintenance of nature and the two are linked, e.g., 40% of the globe's population lacks access to clean and safe drinking water and the highest gaps drive up child mortality in Africa {2.1.2}. Environments-based health burdens (e.g., air or water pollution) are born by people with lower-income {2.1.2, 2.1.15}, while GDP per capita is 34 times larger in developed than in developing countries and still it is rising faster within the former {2.1.2}.

I. Indirect Drivers: The root causes of transformations – both pros and cons

Values, demography, innovation, trade and governance drive outcomes

I-A. INDIRECT DRIVERS – VALUES

1 **The ways in which nature is conceived of and valued have had enormous implications for different consumption and production choices that influence degradation (*well established*).** Values differ across people, and evolve over time, informed by cultures and experiences {2.1.2.3}. Values toward nature may be grounded in ethical principles, and relationships, or predominantly utilitarian, focused on immediate preferences or leaning toward consideration of the future {2.1.2.3}. Globalization, migration, urbanization, and climate change are disruptors that can catalyse shifts in values towards nature {2.1.3}. Relational worldviews and values with strong ties to the land are central in many cultures around the world, associated to self-imposed restriction based on norms {2.1.3}. Narrower utilitarian, instrumental views of nature as a source of economic inputs, though, underpinned a variety of actions that promote resource extraction, industrialization, urbanization, and global trade, which continue to intensify {2.1.3}. Such views have been challenged in the last fifty years by calls for other ethics to mediate the interactions among and between humans and nature {2.1.3}. Examples of such narratives are the "living in harmony with nature" principle of the Rio 1992 Summit of The Earth conference, the Mother Earth emphasis within "the future we want" vision from Rio+20, and Pope Francis' recent encyclical {2.1.3}. Such visions of well-being and links to nature clearly have evolved over time {2.1.3}. For instance, if nature is degraded over time, while economies grow, core values may shift from a narrower orientation toward economic development to an integration of other dimensions such as varied capacities, justice, security and equity – all linking with nature in different ways {2.1.3}. Yet, stepping back, while all these views contributed to conservation and restoration in some locations, at the global level degradation of nature has continued despite increasing high-level awareness of degradation and scarcity {2.1.3}.

I-B. INDIRECT DRIVERS – DEMOGRAPHY

2 **For any values, population size is a big factor in scales of degradation (*well established*).** Human population has been growing, globally, doubling since 1970 overall, and despite regional variations this growth is expected to continue – with implications for degradation {2.1.4, 2.1.13}. The largest current increases are in least developed countries and in Africa, where the total population doubled, yet countries are starting to experience decreases, as developed countries have experienced in the past {2.1.4}. That said, those decreases in fertility rates result not from an automatic 'demographic transition', based upon economic development alone, but instead from conditions including women's empowerment and their access to family planning methods {2.1.3}.

3 **Education causes and is caused by economic growth – which in turn degrades, lowering human capital – yet education also can influence the rates of degradation *(well established)*.** Education has increased globally, in particular for women, with implications for human capital accumulation and, thereby, use of nature {2.1.4}. Together, those capital assets form a large share of national wealth, in particular for lower-income countries, and support an ongoing investment in education {2.1.4}. Environmental education can support lower degradation per unit of economic growth, through shifts in both production and individual habits {2.1.4}. This has benefits for human capital, as for example pollution lowers human productivity {2.1.4, 2.1.13}.

4 **Appreciation of indigenous and local knowledge (ILK) for managing nature is rising yet, at the same time, these local knowledge systems continue to be degraded (*well established*).** Indigenous and local knowledge (ILK) generated within IPLCs increasingly is seen as relevant for sustainable production. It offers broadly applicable alternatives to centralized and technically oriented solutions, which often have not substantially improved prospects for smaller producers {2.1.4, 2.1.5, 2.1.11, 2.1.13}. Yet, at the very same time, values and knowledge change with exposures including formal education, which can erode local worldviews that prioritized nature {2.1.3, 2.1.4}.

5 **Migration is both a cause and an effect of nature's degradation. Links in both directions are connected to patterns of vulnerability, in rural as well as urban areas (*well established*).** Migration has increased greatly, with 264 million international migrants entering other countries since 1970: more to developed countries {2.1.4}. Environmental and economic factors contribute to this migration. Today, environmental migrants number several million {2.1.2, 2.1.4} given inequity across regions in conditions for well-being and in provisioning and regulating contributions from nature that are among the most important determinants {2.1.2, 2.1.4}. Immigrants are often among the most vulnerable groups in society, with low access to nature's contributions to basic needs (water, sanitation and nutrition), yet they can have impacts on how nature is managed, including due to differences in values {2.1.2, 2.1.4}.

6 **Urbanization has been rapid, with enormous consequences including spatial patterns of land use**

that affect nature and NCP provision in urban and rural areas (*well established*). Today, close to 60% of the world's population lives in cities, with the fastest increases in Asia and the Pacific (25% rise in urban share in 1980–2010) and Africa (37%). There are 2.8 billion people now in megacities, with the fastest growth in low- (45% since 1980) and lower-middle income (39%) countries {2.1.4}. In the developing world, many of those people live in slums, with a low quality of environment and life {2.1.4}. Cities are sources of innovations in transport, industry and medicine, however, their high densities affect spatial patterns of land use and, thereby, nature {2.1.4}. Urban consumers have huge impacts and thus the potential to drive global changes {2.1.4}.

I-C. INDIRECT DRIVERS – TECHNOLOGY

7 **By region, IPLC practices are expanding in their use or disappearing (*well established*).** Much of the globe's population appropriates natural resources via rural or primary management of terrestrial, marine and freshwater ecosystems {2.1.2, 2.1.4, 2.1.5}. Related IPLCs practices based on long-standing knowledge of complex local ecological systems are seen to be resilient in IPLCs and among small-holders who together are ~2 billion people with 25% of land {2.1.5}. For instance, the agroforestry systems in many tropical countries have common characteristics: highly diversified, productive, complex, and using rotations in agriculture – as well as grazing, hunting, and fishing {2.1.5}. Yet a combination of lifestyle change, adaptation to climate change, seasonal migration, enclosures, privatization, and degradation of resources is strongly affecting both the settlement patterns and the lifestyles of the peoples who manage directly these diverse systems {2.1.5}.

8 **Technological advances in agriculture brought new benefits and costs (*well established*).** The Green Revolution brought opportunities and risks – exemplifying the need to consider both social and environmental trade-offs of innovations that benefit aggregate economic output {2.1.5}. Yields of rice, maize and wheat all increased, steadily, through greater application of irrigation, fertilizers, machinery, and seed varieties with higher yields and resistance to disease {2.1.5}. Yet despite aggregate gains, there were losses for some groups and for the environment (all raising possible trade-offs in agricultural genetic engineering) {2.1.5}. Food security may have fallen, for some, as production shifted from subsistence approaches which had fed Indigenous Peoples and Local Communities to monocultures that offered lower nutrition and access to markets {2.1.2, 2.1.5}. Further, despite greater food availability famine continued given institutional failures {2.1.2, 2.1.5}.

9 **Transitions from biomass to other energy sources have large impacts (*well established*).** Innovations have also greatly shifted how energy is produced and used around the world {2.1.5}. More than in other regions, households in sub-Saharan Africa and East Africa in particular still depend on biomass for domestic energy supply (and some high income countries are promoting renewable woody biomass). By setting, this can adversely affect human health and provision of contributions such as climate regulation and species habitats {2.1.5}. Information constraints, costs of capital, cultural preferences, and slow development of market institutions inhibit adoptions of modern fuels (e.g., liquid petroleum gas or electricity) {2.1.5}. The resulting deforestation not only lowers multiple contributions from nature but also threatens local supplies of energy {2.1.5, 2.1.12}. Demands for energy are also increasingly met by hydroelectric dams, with projected expansions in Latin America, Africa and Asia – again changing the production-degradation trade-offs {2.1.5}.

10 **Scarcity of nature's contributions has motivated various adjustments (*well established*).** Scarcities due to the degradation of nature have motivated shifts towards methods of production with lower material or environmental intensities {2.1.2.1}. For instance, households invest in cleaner stoves when rising incomes raise food consumption and thus also fuels consumption for cooking, such that indoor air quality falls {2.1.5}. Information on water quality motivates purification efforts from village infrastructures to household filters and bottled water {2.1.5}. In irrigation, scarcity of water quantity drives societal innovation like upstream-downstream allocation committees {2.1.5}. High prices for fossil fuels inspire novelties from rural extensions of electric grids to solar lamps and wind energy as well as batteries to store the output {2.1.5}. Positive effects of such innovations include those from their diffusion {2.1.5}. Broader use allows low income countries to avoid more environmentally destructive stages of economic growth by 'leapfrogging ahead' to more modern technologies of production with less degradation per unit of output {2.1.2.1}. Policy innovations may seek to spur such private innovation and adoption in light of critical degradations of nature {2.1.5}. Concerns about climate change, for instance, have led to proposals for carbon taxes, so that fuel and other prices reflect degradation and spur innovation in both mitigation and adaptation {2.1.5}.

I-D. INDIRECT DRIVERS – ECONOMY

11 **Transitions across sectors greatly influence the degradation of nature (*well established*).** As economies have grown, since 1950, many have shifted from agriculture toward both industry and services {2.1.6}, resulting in far higher shares in agriculture for value added, and employment, for the low income countries {2.1.6}. This affects management of nature, given that industrialized economies are characterized by the lowest materials intensities {2.1.6} – although we must keep in mind that this is due in part to their imports of agriculture (see below). At 0.5 tons of

domestic material consumption per US$1000 GDP, Europe and North America had the lowest 2013 intensities (down from 0.8 and 1 in 1980, respectively) {2.1.6}, as influenced by the methods noted above as well as sectors characterized by lower material per unit of economic output {2.1.6}. Yet even material efficiency can be swamped by rising production {2.1.6} and, while Asia's intensity remained relatively constant at ~2.5 tons per $1000 US GDP between 1980 and 1992, since 2003 intensity rose again, reaching 3.1 tons in 2013 – with immense impact on average global intensity {2.1.6}. African economies still have the highest intensities but gains over 3 0 years have been significant, e.g., from 4.2 tons per $1000 US GDP in 1980 to 3.3 tons in 2013 {2.1.6}. Evidence is mixed for time paths as economies grow, with the scale of consumption potentially offset by the mix of what is consumed and the way in which it is produced. Forests show reversals from degradation to recovery, while different pollution types have mixed paths, including due to trade {2.1.6, 2.1.13}.

12 **Concentration of output and funds – sometimes associated with industrial innovation – influences what is produced and who benefits within and across countries (*well established*).** Today, a few corporations and/or financiers often control large shares of the flows in any market, as well as amounts of capital assets that rival total revenues for a vast majority of countries {2.1.6}. These concentrations and their locations can hamper nature governance efforts (see below) {2.1.6}. Related, increasing shares of relevant sectors (e.g., coffee, fruits & vegetables, textiles & apparel, furniture) are supplied through value chains featuring considerable power at the retail ends {2.1.6}. This affects bargaining in exchanges of labor, and goods made with natural resources, including in the agricultural, fisheries and forestry sectors {2.1.6}. The location of power additionally affects regulatory oversight, with respect to environmental and social issues {2.1.6} – e.g., infrastructure development is known for its murky oversight and for its impacts upon nature. Funding via tax havens provided 68% of foreign capital for Amazonian soy and beef production and supported 70% of the vessels that are implicated in illegal, unreported and unregulated fishing {2.1.6, 2.1.11}.

13 **Expanding trade means consumption affects degradation elsewhere (*well established*).** Domestic material consumption per capita is highest for the developed countries and rapidly increasing for developing countries {2.1.2, 2.1.6}. Net goods flows vary, with some countries exporting more and others importing more {6}. Generally, developed countries reduced agricultural outputs over the last 50 years {2.1.6, 2.1.12}, and domestic water footprints, while importing crops from low income countries {2.1.6}. Environmental degradation from the production of those traded goods should be taken into account in assessing importing countries' net impacts, as total impacts can rise as domestic degradation falls {2.1.6}. This all influences equity too, e.g., whether in current market institutions suppliers of resources get 'equitable' compensation {2.1.6}. Different trade-offs arise when forest in low income countries is conserved by importing from high income countries, which can occur when efficient uses of capital lower the total areas in production – a phenomenon that may lower local incomes in that sector or spur other local sectors {2.1.6, 2.1.13}.

I-E. INDIRECT DRIVERS – GOVERNANCE

14 **Pro-environmental signaling from consumers has grown, within multiple supply chains, yet the documentation of significant impacts on nature has been limited *(well established)*.** Consumers at the ends of supply chains increasingly request information about the practices and the degradation linked with production. It can be facilitated by civil society, even across borders, as third parties collaborate with all of the private actors engaged in varied exchanges {2.1.6, 2.1.7}. Sustainable production certifications, terrestrial or marine, have risen greatly – for practices both environmental and social – yet despite some positive anecdotes, large impacts remain rare {2.1.6}.

15 **Community governance has reduced or reversed degradation *(well established)*.** Local actors have often conserved nature in common property systems – using local information, social norms, and abilities to impose cost {2.1.2, 2.1.8}. For centuries, IPLCs have contributed in this way to regional economies. In recent decades, the share of resources such as forests governed by Indigenous Peoples and Local Communities has grown {2.1.8}. Governance of shared resources can be facilitated by access to resources and information sharing; for instance, the unassessed smaller fisheries have fared worse {2.1.8}. Lacking comprehensive global data, we have sufficient cases of both successes and failures to have learned that community governance can be effective, yet it is not always {2.1.8}, and successes may rely in part on the roles of formal governments – e.g., without the public defense of local rights to manage resource and to exclude others, community areas of terrestrial and aquatic resources can be invaded and local efforts thus undermined {2.1.8}.

16 **Public clarifications of rights influence investments that affect nature *(well established)*.** Allocating private rights may generate conflicts concerning fairness or equity – yet clear rights can improve the efficiency of both investment and management by, e.g., smallholders who are incentivized to monitor nature locally, as for terrestrial multiple-use protected areas {2.1.8, 2.1.9}. Clear examples of the importance of rights also exist for large- and small-scale fisheries which used rights-based governance to maintain fish stocks {2.1.8}. Successes in management have been more frequent when such local

rights were established in ways that respected local procedures. When government ignores local governance, public interventions can be destructive {2.1.8, 2.1.9}.

17 **Public facilitation of sustainable land-use practices – such as agroforestry, agroecology – shows promise and perhaps potential for upscaling *(well established).*** With appropriate support, both financial and non-financial, sustainable agroecological practices have restored nature and its contributions. At varied scales, these have been observed in multiple locations across the globe from farmer-managed regeneration in dry parkland forests in Africa to a variety of Indigenous Peoples and Local Communities forests which function under forestry certifications {2.1.8}. Yet there can also be spillovers from such intervention – e.g., raising forest cover within a country may be facilitated by degradation elsewhere, as forest clearing simply shifts (see Asian examples) {2.1.8}.

18 **Leading economic policies (e.g., roads, credit, private rights) can be adjusted to lower degradation of nature and potentially at a low cost to affected economies *(well established).*** One way governments stimulate economies is by investing in infrastructures for transport {2.1.9}. An obvious option to reduce its degradation is planning the routes for economic corridors {9}. With good local information, and processes, this can lower the costs of satisfying all stakeholder safeguards. Another core policy is establishing and enforcing clear tenure {2.1.8, 2.1.9}. Clarifying smallholder rights, including around customary tenure, can lower natural degradation {2.1.8, 2.1.9}. Further, it can spur greater investment in productivity, including within sustainable approaches.

19 **Popular economic subsidies to degrading behaviours can be adjusted *(well established).*** Subsidies to various forms of energy (gasoline, electricity, etc.) are common and popular {2.1.9}. Possible adjustments include maintaining income transfers while removing price distortions that have raised environmentally damaging behaviours {2.1.9}. Alternatively, such credits, or transfers, can be made conditional on environmental metrics (just as in conservation policies below) {2.1.9}.

20 **Public conservation policies like protected areas (PAs) and payments for ecosystem services (PES) reduce degradation if pressure was confronted and local actors engaged *(well established).*** A growing set 'payments for ecosystem services' (PES) compensate local actors for restrictions on uses of nature {2.1.9}. States also directly restrict production or extraction as in protected areas, the most extensive conservation measures, and undertaken costly actions to restore nature {2.1.9}. The gains for nature from such interventions have ranged from none to quite significant, based on whether and how pressures were confronted and if that included engaging with locals {2.1.9}. Impacts have been more common in high income countries, although funding transfers support interventions in low income countries that provide global public goods (e.g., carbon storage and habitats) {2.1.9}. Restrictions in low income countries can have positive local outcomes if support is provided yet unless local actors are a focus, economic costs can be higher than local benefits {2.1.9}. Generally, equity considerations can shift the choices and implementation of such policy. Policies' benefits and costs often are not equally distributed across either income levels or other dimensions, including race, though who bears the burden varies greatly with varied use patterns. Rights allocations and subsidies affect disparities, in either direction – again varying by context.

21 **Governments have coordinated to reduce some types of degradation *(well established).*** National borders limit governance of transboundary resources. While various global 'commons' are judged to be worth conserving, including outside of national jurisdictions, accountability for failures of sustainable management there has been, at the least, uneven {2.1.10}. Like individuals in communities, nations can agree upon self-regulations that aid global 'commons' by mutually limiting degradation, even when facing high costs of organizing restrictions, as well as threats to their stability based on nations' political shifts over time {2.1.10}. For global coordination such as about biodiversity, the ozone layer, the climate system, the oceans, and poles, the coordination of actors can be even more difficult than for local communities {2.1.10}. Still, even if some policies have not had short-run impact, efforts are ongoing. For example, a relatively recent endorsement by 170 states of FAO's Code of Conduct for Responsible Fisheries (CCRF) in 1995, as well as a growing endorsement of The Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing, which came into force in June 2016 (now with 54 countries), have contributed to a lowering of illegal, unreported, and unregulated fishing {2.1.10}.

II. Direct Drivers

Demands have led to varied actions with multiple impacts upon nature

II-A. DIRECT DRIVERS – SECTORS (actions that link indirect drivers to aggregated impacts)

22 **Fisheries have the largest footprint – with all of industrial extraction, aquaculture and mariculture, and the small fisheries critical for the livelihoods of millions *(well established).*** Today, industrial fishing has a footprint four times larger than agriculture, in which more than the 70,000 reported industrial fishing vessels cover at

least 55% of the oceans – with hotspots for fishing in the northeast Atlantic, northwest Pacific, and upwelling regions off South America and West Africa {2.1.11}. Smaller fisheries account for over 90% of the commercial fishers (over 100 million people), as well as nearly half (46%) of the total global fish catch, yet the rest of global fish production is quite concentrated, within a few countries and a few corporations. Knowledge of inland fisheries is limited, despite their societal and ecological significance (accounting for up to 12% of global fisheries production). The contribution of aquaculture and mariculture to global fish production is increasing (6–9% growth in 1990–2012), with mixed effects upon coastal and marine ecosystems. While nearly 75% of the major marine fish stocks are currently depleted, or overexploited, since 1992 the global fishery community has incrementally adopted sustainable development principles created under the umbrella of mainstreaming biodiversity in fisheries.

23 **Agriculture, including grazing, has immense impacts upon terrestrial ecosystems, with important differences depending upon enterprise's intensity and size *(well established)*.** Agricultural systems remain quite varied, with plant- and animal-based systems, monocultures and mixed farming, plus newly emerging systems including organic, precision, and peri-urban approaches to production. Today, over a third of the world's land surface and ~3/4 of freshwater resources are devoted to agropastoral production {2.1.11}. Grazing occurs on ~50% of agricultural lands and ~70% of drylands {2.1.11}. About 25% of greenhouse gas (GHG) emissions come from land clearing, crop production, and fertilization, with animal-based food contributing 75% of it. Intensive agriculture has led to increases in food production at a cost of multiple regulating and non-tangible contributions from nature and even overall decreases in well-being in cases {2.1.11}. Small land holders (< 2 ha) contribute ~30% of global crop production and ~30% of the global food supply – using 24% of agricultural land and with the largest agrobiodiversity levels {2.1.11}. Their diverse agricultural systems, developed over centuries, have reduced negative impacts on nature, providing a wide range of material and regulating and non-material contributions, while generating the basis for sustainable agriculture intensification, soil management and integrated pest management {2.1.11}. Organic agriculture has developed rapidly, with variable outcomes: in general, it has contributed to higher biodiversity, improved soil or water quality, and nutritional values, although often at the expense of lowering yields and/or raising consumer prices {2.1.11}.

24 **Industrial roundwood harvests have risen, while bioenergy use rose dramatically in the rural areas of poorer regions, with some sustainable forest management (*well established*).** Reductions in forest cover during 1990 to 2015 totaled 290 million ha (~6%), although the areas of planted forests rose by 110 million ha (51%) {2.1.11}. Industrial roundwood made up half of the global harvest (3.9 billion m^3 in 2017), with fuelwood the other half {2.1.11}. Industrial harvest is falling in high income countries but rising in upper-middle and lower-middle income countries {2.1.11}. Global bioenergy uses almost tripled, largely in Africa, although bioenergy fell as a share – from 15% to 10% – with 30% of global fuelwood deemed unsustainable and over 200 million people facing rural fuelwood scarcities, mostly in South Asia and East Africa {2.1.11}. Sustainable forestry has been tried in many countries, over some time, including for forest certification, with some positive impacts upon forest cover and biodiversity, although mixed social impacts {2.1.11}.

25 **Harvesting wild plants and animals from land- and seascapes supports the livelihoods of a large share of the globe's population, raising sustainability concerns *(well established)*.** Over 350 million people – mostly lower-income households in Africa, Asia, Latin America – depend on non-timber forest products (NTFPs) for subsistence and income. Over six million tons of medium-to-large-sized mammals, birds, and reptiles are harvested in the tropics, annually, for bushmeat. Also, ~6 million wild ungulates are harvested in the Northern Hemisphere every year, by game hunters {2.1.11}. Evidence on sustainability is sparse, yet a well-managed harvesting of resources with strong local involvement could benefit both livelihoods and conservation {2.1.11}.

26 **Mining has risen dramatically, with big impacts on terrestrial biodiversity hotspots and global oceans, mostly in developing areas with weaker regulation *(established but incomplete)*.** Hundreds of mined products serve quite diverse purposes, globally, contributing more than 60% of 2014 GDP for 81 countries, with 17,000 large-scale sites in 171 countries. Most minerals are produced by large international corporations {2.1.11}. Still, small-scale mining is important in the livelihoods of many rural poor in the developing world – where many corporations have now located, given weaker environmental and social regulations (Africa is estimated to have 40% of global gold, 60% of cobalt, and 90% of platinum reserves) {2.1.9, 2.1.11}. Such impacts of mining are a growing concern, including per conflicts and illegality – although systematic quantitative data are unavailable {2.1.9, 2.1.11, 2.1.13}. Mining utilizes under 1% of global land but its negative impact on biodiversity, availability and quality of water, and human health may be larger than from agriculture {2.1.11}. Gold mining is of particular concern, given the rising demands and big impacts on biodiversity hotspots (despite protected areas) {2.1.11}. Ocean mining has been increasing, with ~6,500 offshore oil and gas installations, worldwide, in 53 countries (60% in the Gulf of Mexico) and possible expansion in the Artic and Antarctic regions as ice melts {2.1.11}.

27 Dams, roads, and cities have strong local negative impacts on nature, yet they also can have positive spillovers associated to increased efficiency and innovation (*well established*). While new infrastructure tends to have negative local consequences for nature, it can also have significant positive and negative spillovers {2.1.11}. The total number of dams has escalated in 50 years, with ~50,000 large dams (> 15 m height), and ~17 million reservoirs (> 0.01 ha) holding ~8,070 km^3 of water {2.1.11}. Urban area, while accounting less than 3% of the total land area, is rising faster than urban population and is associated with large effects beyond cities, which affect regional climates, hydrology and pollution {2.1.11}. Yet urban areas can excel in stewardship, e.g., raising flood resilience, reducing emissions, and constructing biodiversity friendly spaces {2.1.11}. New transport infrastructure tends to raise forest losses on frontiers, with direct negative impacts on biodiversity, plus exacerbate the environmental impacts of other developments, such as large mining operations {2.1.11}. Yet within more developed settings, shifts in transport costs can help forests {2.1.11}. Increasing human encroachment, land reclamation, and coastal development have strong impacts on coastal environments {2.1.11}. More and better planned infrastructure is found in higher income countries while fast, ill-planned expansion of infrastructure is found in rapidly growing urban and peri-urban settlements, especially in Africa and South and East Asia {2.1.11}.

28 Tourism has risen dramatically with huge impacts on nature overall, higher impacts for the higher-end options, and mixed outcomes from nature-based options (*well established*). Tourism grew dramatically in the last 20 years both domestically and internationally, especially from high and upper-middle income countries, with international travel levels tripling {2.1.11}. During 2009–2013, tourism's carbon footprint rose 40% to 4.5 Gt of carbon dioxide (8% of the total greenhouse gas emissions involved in transport and food consumption related to tourism) {2.1.11}. Most of those emissions are in, or from, high income countries. The impacts of a trip vary 1000-fold in terms of energy use, being higher for luxury accommodations and selected transportation types for the globally growing class of wealthy travelers {2.1.11}. The demand for nature-based or eco-tourism also has risen, with mixed effects on nature and societies {2.1.11}.

29 Both airborne and seaborne transportation of goods and people has risen dramatically, causing both increased pollution and a significant rise in invasive alien species (*well established*). Transport of goods and people has risen drastically over the last few decades, with the number of air flights doubling globally (1980–2010) and tripling for high income countries {2.1.11}. Seaborne carriage has doubled for oil, quadrupled for general cargo, and quintupled for grain and minerals over this period, while the voyage lengths have also increased {2.1.11}. The transport of goods and people have direct, indirect, and cumulative impacts upon nature including pollution (of air, water and soil), greenhouse gas emissions (contributing 15% of the global CO_2 emissions) and varied durable consequences along trade routes including introductions of invasive alien species {2.1.11}.

30 Restoration can offset current degradation levels, with varied intensities and outcomes, although global initiatives have focused mostly on our forests (*established but incomplete*). Restoration increasingly is required, given the ongoing degradation of various ecosystem types. It offers direct and indirect benefits through material, regulating and non-material NCP {2.1.11}. Approaches range from passive to active – with distinct costs, limitations, extents, and outcomes – though no global data are available on its current extent and outcomes {2.1.11}. One large-scale initiative is the Bonn Challenge aiming to restore 350 M ha of degraded forestland worldwide by 2030, yet no similar global challenges have been proposed for any non-forest ecosystems {2.1.11}.

31 Illegal extraction – including fishing, forestry and poaching – adds to unsustainability, yet is fostered by markets (local, global) and poor governance (*established but incomplete*). Illegal, unreported or unregulated (IUU) fishing made up 33% of the world's total catch in 2011, being highest off the coast of West Africa and in the Southwest Atlantic {2.1.11}. Illegal forestry supplies 10–15% of global timber, going up to 50% in some areas, worsening both revenues (for private or state owners) and livelihoods for poor rural inhabitants. Illegal pressures also increase the costs of trying sustainable forest management {2.1.11}. Illegal production of biofuels is large, especially for small, poor, informal actors in Africa {2.1.11}. Poaching is rising, pushing species (e.g., rhinos, tigers) toward extinction despite considerable international efforts {2.1.11}. Illegality is incentivized by high prices of species in demand and, for the low prices often received by the poor, driven by weak regulation and enforcement, with corruption and poor management {2.1.11}.

II-B. DIRECT DRIVERS – AGGREGATED IMPACTS OF ALL ACTIONS ON NATURE

32 The largest transformations in the last 30 years have been from increases in urban area, expansions of the areas fished, and the transformations of tropical forests (*well established*). Today, 75 per cent of the total land surface and 40 per cent of the ocean area are severely altered {2.1.12}. The total area of cities has doubled from 1992 to 2015, with the most severe impacts in tropical and subtropical savannas and grasslands {2.1.13}. Agriculture area in the tropics expanded mostly at the expense of tropical forests, with large expansions (~35 million ha) associated with cattle ranching in Latin America, linked to diets, and plantations, including for oil palm {2.1.13}. Land-cover changes have led to increasing fragmentation of the remaining forest as well {2.1.13}. Technological advance in agriculture, fisheries and aquaculture, and forestry has yielded at times irreversible shifts in ecosystems and in nature's contributions. These are exacerbated by greater livestock densities, changes in fire regimes, and intensifications leading to accelerated pollution of soils and water {2.1.13}. Soil degradation – including erosion, acidification, and salinity – has increased globally, although further systematic and reliable information will be required {2.1.13}.

33 **Demands for materials for nature have escalated, especially in developing countries and the Asia and the Pacific region, accounting for unprecedented global impacts *(well established)*.** The total demands for living and nonliving materials increased sixfold from 1970 to 2010, while the demand for materials used in construction and industry quadrupled during that time. The most drastic increases in demands for construction materials – on the order of ten times – occurred within developing countries and the Asia and the Pacific region. The extraction of living biomass from agriculture, forestry, fishing, hunting, and other activities has nearly tripled, globally – with the rapidly growing developing countries having the highest current levels for the rates of extraction for all living and nonliving materials {2.1.12, 2.1.14}.

34 **Pollution has been increasing at least as fast as total population, with key differences by region and by type of pollution – with more monitoring needed *(established but incomplete)*.** While quantitative assessment of pollution is limited in terms of the amount and quality of data in many countries, current data show pollution rising at least as fast as is the human population. Untreated urban sewage, industrial and agriculture run-offs, as well as oil spills, and dumping of toxic compounds, have had strong negative effects on freshwater and marine water quality {2.1.15}. Non-greenhouse gas atmospheric pollution, such particulate matter, is highest in countries with low or no regulation standards and poor enforcement, often at lower income. Fertilizer use rose fourfold in only 13 years, in Asia and the Pacific, and doubled in developing countries {2.1.11, 2.1.15}.

35 **Alien species increasingly are recorded across continents, although less in Africa, given variable rates of species 'invasibility' and monitoring capacity *(established but incomplete)*.** Current cumulative records of alien species are ~40 times larger in developed than in least developed countries. Though comparable across Europe and Central Asia, the Americas and Asia and the Pacific, they are ~4 times lower in Africa {2.1.12, 2.1.16}. This has resulted from increased trade and population densities but also large differences in detection capacities and 'invasibility' across alien species.

36 **Climate has changed since pre-industrial times due to anthropogenic activities and has influenced impacts, on nature and society, of many other critical drivers *(well established)*.** Anthropogenic activities – in particular those raising greenhouse gas emissions – are estimated to have caused approximately a 1.0°C warming by 2017, versus pre-industrial times, with ~0.2°C (±0.1°C) rises per decade. The fastest changes are observed in flat landscapes at higher latitudes {2.1.17}. The frequency and the magnitude of extreme weather events both have increased across the last five decades, while the global average sea level rose at a rate of over 3 mm yr^{-1} over the last decades {2.1.12, 2.1.17}. Greenhouse gas emissions per capita are highest for developed countries, though are decreasing there; they are followed by those in developing countries where they have increased by 10% since 1970. Decreases are associated to changes in behaviour, due to perceived threats, plus responses in governance and innovation – as well as some shifts in emissions to other countries {2.1.17}.

III. Development Pathways

Dominant development dynamics involved complex interactions across countries and regions, leading to inequalities in nature and trade-offs

37 **Rising interactions via global trade shifted consumption's footprints *(well established)*.** The consumption footprint per capita of each country, measured as the amount of land needed to support consumption, rises with per capita income or per capita GDP. Thus, it is far from equal. It rises even more rapidly for elements beyond the consuming country's borders that can reflect stronger governance of nature within the consuming countries. That affects nature more in low income countries with weaker governance {2.1.18}. Alternatively, production might shift to more efficient locations and reduce total degradation as efficient production lowers market incentives for supply. Strategies in international governance also affect nature beyond countries' borders. For instance, protected areas can block inefficient production in forest habitats in low income tropical countries that are highly prized, shifting production to less prized locations elsewhere. On net, though, trade-based degradation has flowed toward those countries with lower income.

38 **The trade-offs between economic growth and degradation have shifted (*well established*).** Even for higher-income countries, earlier economic development during the last 50 years mostly occurred at the expense of local nature. When trade and governance increased imports

of nature from low income countries, economic aid (perhaps compensating global public goods as above) could provide those countries with local net benefits {2.1.2, 2.1.18}. In contrast, concentrating power in global supply chains lowers economic returns in lower-income countries from appropriations of nature – sometimes with net local environmental and economic costs. These interactions helped high income countries to protect their nature while continuing to have economic growth {2.1.2, 2.1.18}, although the relative rates of growth, based on such exchanges, depend on the bargaining power.

39 **Economic and environmental inequality evolved, across income levels (*well established)*.** Globally, GDP per capita has increased relatively steadily over time {2.1.2}. Increases have been unequal over space, however. Globally, economic inequalities have steadily increased (note that within countries, the evolutions of inequalities have been uneven, averaging out to little change). That in turn can shift bargaining power, yielding unequal divisions of the gains from interactions, though dynamics can include convergence, with more rapid GDP growth in emerging economies (more generally, developing countries are intermediate between the developed and least developed countries' pathways). Inequalities within and among countries can make collective actions (coordination, cooperation) that are needed for conserving and restoring nature's contributions even harder to achieve {2.1.2, 2.1.18}.

40 **Social instabilities linked to scarcities in nature are part of current and future threats to nature based upon economic, social, and geopolitical conflicts (*established but incomplete)*.** Conflicts result from interactions concerning availability and control over nature's contributions {2.1.18}. More than 2,500 conflicts over fossil fuels, water, food and land are currently occurring. Lower-income countries that tend to be rich in natural resources have experienced more conflict – exacerbating environmental degradation, lowering GDP growth, and raising migration {2.1.18}. Communities expelled from lands or threatened by degradation (e.g., deforestation, mining or the expansion of industrial logging) have been associated with related violence (e.g., ~1,000 activists and journalists killed during 2002 to 2013) {2.1.11, 2.1.18}. Armed conflicts have direct physical impacts on ecosystems, beyond their destabilizing effects on resource uses and productivity {2.1.18}. The ecosystems relatively untouched by human activities can be particularly vulnerable to intrusions of this type, because remote ecosystems with few humans have harbored illegal activities {2.1.11, 2.1.18}.

41 **Social-ecological dynamics yield balances and regime shifts (*established but incomplete)*.** Interactions among drivers can generate iterative dynamics that raise outcomes variability {2.1.18}. Some systems equilibrate, e.g., if scarcities are perceived then prices and governance initiatives may rise as responses, then recede {2.1.18}. Other systemic interactions have led to rapid changes and extreme outcomes including 'regime shifts' for ecosystem functions: marine hypoxic zones; species invasions; or desertification {2.1.18}. Some collapses have arisen in high income settings, as challenges for rulemaking and enforcement confounded local regulations, despite capacities. Some dysfunctions have resulted in conflicts, in and across societies, which extend dysfunction: e.g., food shortages due to climate shifts, and unequal access, have generated 'food riots' {2.1.18}. Serious conflicts and societal shifts have arisen within mining, water, biodiversity, and land – sometimes financed by resource extraction and exacerbating environmental degradation {2.1.18}.

42 **Dynamics include (nonlinear) recoveries to good balances (*established but incomplete)*.** Systemic interactions have led some settings towards a positive 'equilibrium', with a reduction of degradation or a restoration of nature {2.1.18}. For example: policies that affect a fishery stock by shifting some behaviours may 'tip' the setting into sustainable harvesting, in which individual actors shift into making choices consistent with stock preservation; or, conservation sometimes spreads if one group observes benefits to earlier adopters and, so, chooses to mimic their actions. Further, individual nations' participation in some global collective agreements has spread when payoffs from joining rise with the participation of other countries – so leadership matters {2.1.18}.

2.1.1 INTRODUCTION

The globe's diverse citizens strive to achieve a good quality of life, with diverse perspectives on what is needed to achieve that, as a result of varied relationships with each other and with nature. Nature supports all these individual and collective pursuits, through contributions detailed in this volume (see chapter 2.3): provisioning or material contributions, such as food and timber; regulating contributions, such as climate regulation and protection of soils; and cultural and non-material contributions, such as learning and inspiration. Meeting the individual and societal demands for nature has posed severe and heterogeneous challenges. Some groups still do not have their basic needs met from nature's contributions yet increasing demands upon nature are exceeding rates at which contributions can be sustained (IPBES, 2018b, 2018e, 2018c, 2018d). At current trends, we risk drastic degradation, with drops in contributions critical for societies and uneven distributions of losses.

Basic needs and luxuries depend on nature, i.e., on land, plants and animals, minerals, and water whose supplies depend upon myriad functions of ecosystems, such as nutrient cycling and water purification. How nature is manipulated, including within markets, depends upon socioeconomic factors: values, incomes, technologies and power (i.e., who determines which development ideas are implemented and how). Scarcities drive human responses, including governance institutions, from norms to national policies. Yet markets' prices often fail to reflect scarcities in nature, thus degradation remains invisible in local and global economic systems, for rural and urban settings. Likewise, individuals and society often fail to fully recognize and to incorporate the value from nature's contributions, despite their immense importance for multiple dimensions of well-being.

For this global assessment of nature, and its contributions to people, we are concerned with all of these pursuits. Every one of the Sustainable Development Goals (SDGs), for instance, is critical. Yet we focus on the consequences for nature from economic and social development trajectories, over the past 50 years, that centrally involve interactions across local, national and global scales. Those consequences, in turn, enable or constrain potential for future development, sustainable or otherwise. Our focus in this chapter is on understanding the indirect and direct drivers affecting past and present, and influencing possible trajectories for nature, and people, at different scales.

To broadly describe the interactions between society and nature that underpin trajectories within development, we analyze the evolution of different categories of drivers that affect nature and its contributions to people. First, we cover **indirect drivers**, i.e., factors behind human choices that affect nature. This starts with values, as goals affect choices. We next consider 'demographic' (population, migration, education) and then 'technological' (innovation) factors. Next come the 'economic' factors: structural transition, i.e., shifts across economic sectors such as agriculture, manufacturing, and services; concentrated production, i.e., shifts in output shares for big actors; and trade as well as financial flows that continue to increase within and across national borders.

Finally, we consider 'governance', an overarching sub-category of **indirect drivers** that includes all types of governance. They respond to scarcities in nature's capacity to generate contributions: scarcities increase the likelihoods of responses although many other factors also determine them.

Within governance, we distinguish different forms, while emphasizing their many interactions. We start with efforts by private actors within supply chains, e.g., the certification of production processes for environmentally beneficial features for which at least some consumers would pay. Moving outside markets, we consider coordination at local levels within community governance. We then consider the governance by formal states, i.e. policies from local scale to national scale, and their interaction with community governance which can either enhance or worsen outcomes. Finally, we consider coordination across governments – i.e., 'global community governance' – that must address challenges similar to those which face smaller-scale community governance.

We then move to the **direct drivers**, i.e., direct human influences upon nature – in seven sections. The first section (2.1.11) covers human actions, e.g., farming, fishing, logging, and mining, that respond to indirect drivers and directly affect nature. Interventions often aim to shift such actions, based on theory and evidence about dominant dynamics. Section 2.1.12 gives an overview of all the influences on nature from those actions for aggregate influences upon nature, which are detailed in the following sections These include land/seascape change (2.1.13), resource extraction (2.1.14), pollution (2.1.15), invasive alien species (2.1.16) and climate change (2.1.17). Both sections consider efforts to reduce degradation and recover nature, i.e., restoration efforts and outcomes.

Following chapter 1, our final section (2.1.18) "closes the loop". Direct drivers feed processes in nature that, in turn, feed into the process of co-production of all nature's contributions to people (NCP). In turn, NCP abundance and scarcities affect the quality of life of everyone within a society and, thereby, spur shifts in indirect drivers such as values, market prices and other institutions. Thus, we can work through cases of drivers' consequences coming around to shape drivers' evolutions. We consider the implications of such iterations for future (perhaps sustainable) development pathways.

Understanding development trajectories with global interconnections.

Intensified global interconnections have been a defining feature of the last 50 years. Any global perspective includes how regional, national, and subnational trajectories – for nature, economic development and governance – have interacted at a global level. Figures below articulate how as a consequence, the trajectories observed across the last 50 years, while related to each other, have differed considerably across space and time, e.g., as experienced by different groups of countries in terms of nature **(Figure 2.1.1)**, economic growth, and environmental governance **(Figures 2.1.2-2.1.3)**. The figures aim to illustrate how least developed, developing, and developed countries followed distinct but interconnected trajectories, given differing and interacting bundles of indirect and direct drivers in and across regions with cumulative and/or cascading effects over time. In many cases, varied trajectories are present in single countries. An example for forests, in **Box 2.1.1**, illustrates how various interconnections of multiple drivers across and within regions shaped forest landscapes.

Observed historical trajectories for important elements of nature can be summarized using a few possible steps: degradation to start, almost surely; then possibly also stabilization, and recovery **(Figure 2.1.1)**. The trajectories for different societies are not necessarily independent, however, and we explore how they could be the result of interacting trajectories of indirect and direct drivers – due to individuals' and societal choices. For instance, if one society recovered certain capacities of nature after degrading them (as is observed in various regions especially in the 'Global North'), how could that transition have occurred within a world in which other societies did not choose or were not able to reverse related negative trends within nature? Looking across 50 years, were the observed transitions simply independent choices by heterogeneous societies to regulate more, or invest more in sustainability, or consume less? Or did recoveries rely upon degradation in other countries? And, going forward, what are the implications of those interactions for trajectories?

Next, we wish to consider whether multiple dynamics could generate each trajectory in **Figure 2.1.1** because exactly how a country or region managed to stabilize or to improve elements of nature affects not only the sustainability of those changes but also the implied consequences for others. For instance, some societies enjoyed greater initial endowments of particular natural resources – such as minerals, land, climate, and ecosystem productivity on many dimensions (Scheffer *et al.*, 2017) – which in general could improve those trajectories.

However, natural wealth alone has proven not to be sufficient for ongoing positive trajectories, independent of society's institutions and choices. In fact, many distinct evolutions of different bundles of indirect drivers could affect nature similarly – i.e., generate the same trajectories in **Figure 2.1.1** – yet differ greatly in trade, governance,

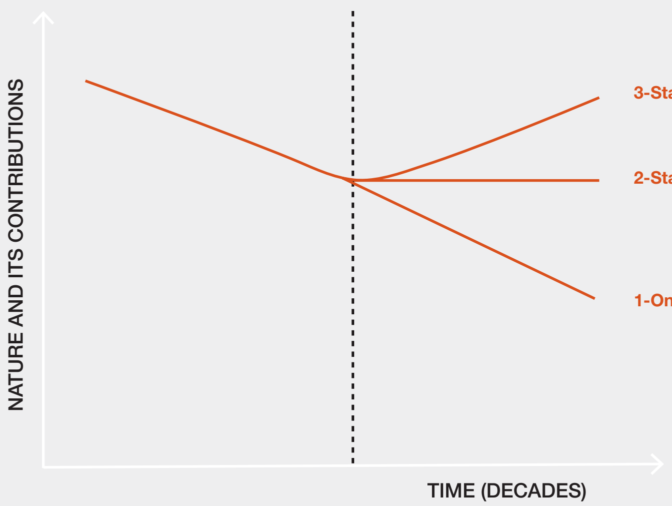


Figure 2 1 1 **Illustrative trajectories along differing development pathways for 'nature', i.e., its productive stocks or its capacity to generate valued contributions, at the time scale of decades.**

The first trajectory is ongoing degradation, the second is stabilization after degradation, and the third is not only stabilization but also a reversal or recovery. The vertical line is a point of transition, whose timing depends upon many factors, including scarcities in nature.

Box 2 1 1 Multiple dynamics driving forest cover can underlie stabilization or recovery.

Forests provide examples for such dynamics (IPBES, 2018a). Global forest cover has been close to stable in recent years, yet forest cover decreased in some regions while stabilizing or even recovering in others. Existing theories about processes underlying such trajectories (Meyfroidt *et al.*, 2018) propose dynamics that have similar forest trajectories but differ on other dimensions in **Figure 2.1.2**. Forest degradation often results from agricultural expansion, for which there are many examples, including within the tropics, where that remains a significant phenomenon (Barlow *et al.*, 2018; Curtis *et al.*, 2018; Hansen *et al.*, 2013). This is common enough that it could explain initial and continuing downward slopes within a version of **Figure 2.1.1** for forest.

'Forest transitions' (**Figure 2.1.1**, Trajectory #2/#3) were observed in Western Europe and North America (Mather & Needle, 1998; Rudel, 1998), then East and South Asia (Foster & Rosenzweig, 2003; Kauppi *et al.*, 2006), and parts of Latin America. Different dynamics underlying transitions have been highlighted in varied literatures (Caldas *et al.*, 2007; Geist *et al.*, 2006; Gutman *et al.*, 2004; Rindfuss *et al.*, 2004). We consider some below.

Intensification. For a fixed area, outputs can rise via changing knowledge and practices, inputs and tools to promote 'intensification' – such as double cropping or higher-yield crop varieties (Thaler, 2017). Incorporating trees is an agropastoral option which also aids biodiversity (Pagiola *et al.*, 2016; Perfecto & Vandermeer, 2010). If adoption of any of the above alternatives were to be universal, then forests might stabilize or even recover in all countries, while across-country inequality would depend upon biophysical and societal constraints on yield.

Transition to manufacturing/services. A distinct dynamic is sectoral transition from agriculture to manufacturing and services, within processes of both urban and industrial growth – often along with rural depopulation and a spatial contraction of increasingly intensive agricultural production. This may raise affluence and the demand for improving ecosystem health and ensuing regulating and cultural contributions (e.g., Mather & Needle, 1998; Rudel, 1998) that affect both governance and trade (see, e.g., Mather, 2007; Rudel *et al.*, 2005; Viña *et al.*, 2016).

Substitution by imports. Countries also have stabilized forest cover by importing wood or food, grown at the expense of forests elsewhere (Meyfroidt *et al.*, 2010). In this dynamic, recoveries rely on others' degradation. Some countries follow Trajectory #1, as still occurs in the tropics. With increasing global trade, sources of inequalities between countries include differences in who gained from these trades, given differences in power across firms and countries, including in abilities to increase value in forest and agricultural products through transformation processes.

economic outputs, and various inequalities. Further, within many of those dynamics, outcomes differ as a function of countries' development level (those additional dimensions plus broad differences across development levels motivate **Figure 2.1.2**).

Box 2.1.1 lists varied interconnections that shaped forest landscapes, both illustrating **Figure 2.1.1**'s trajectories, and their interconnections at the global level, and illustrating that there is a suite of different implications of the achievement of **Figure 2.1.1**'s trajectories. In and beyond forest cover, these differing and interrelated possible trajectories for nature involve some countries being able to 'transition' from the degradation of nature to a stabilization or a recovery within their borders, while others incur the costs of degradation. In other settings, the stabilization or the recovery of nature in one country is not dependent on degradation elsewhere, so reversal is possible for all.

Again, then, for forest cover, and beyond, the trajectories of countries can be highly contrasting (motivating **Figure 2.1.2**). In general, provisioning contributions from nature raised gross domestic product (GDP), even in per capita terms despite rising populations, during initial degradation of nature via transformations of ecosystems for agriculture (i.e., to the left of **Figure 2.1.2**'s transition). Further, between-country economic inequality rose – while falling or rising in different countries – since scales of economic activity differed. Output per unit of natural degradation also differed, as countries with higher income could combine more physical, financial, educational and social capital with their natural capital in production. They also could have had different past histories, e.g., longer periods of depending on nature beyond their borders, through colonization or trade. Thus, many countries' periods of early economic development had similar impacts on nature but differed in economic trajectories, including in trade and in (relatively rare) governance of nature.

Nonetheless, each trajectory involves particular trade-offs in meeting the society's diverse needs, through both production and conservation. Yet, since countries' trajectories are not independent, given rising global interconnections, which mechanisms or settings facilitate or drive transitions has significant implications for who reaps gains or bears the costs of degradation and recoveries. Some possible inequalities in trade-offs between gains and losses in nature and economic output, looking both within and across countries, are illustrated by contrasting trajectories in **Figure 2.1.3**.

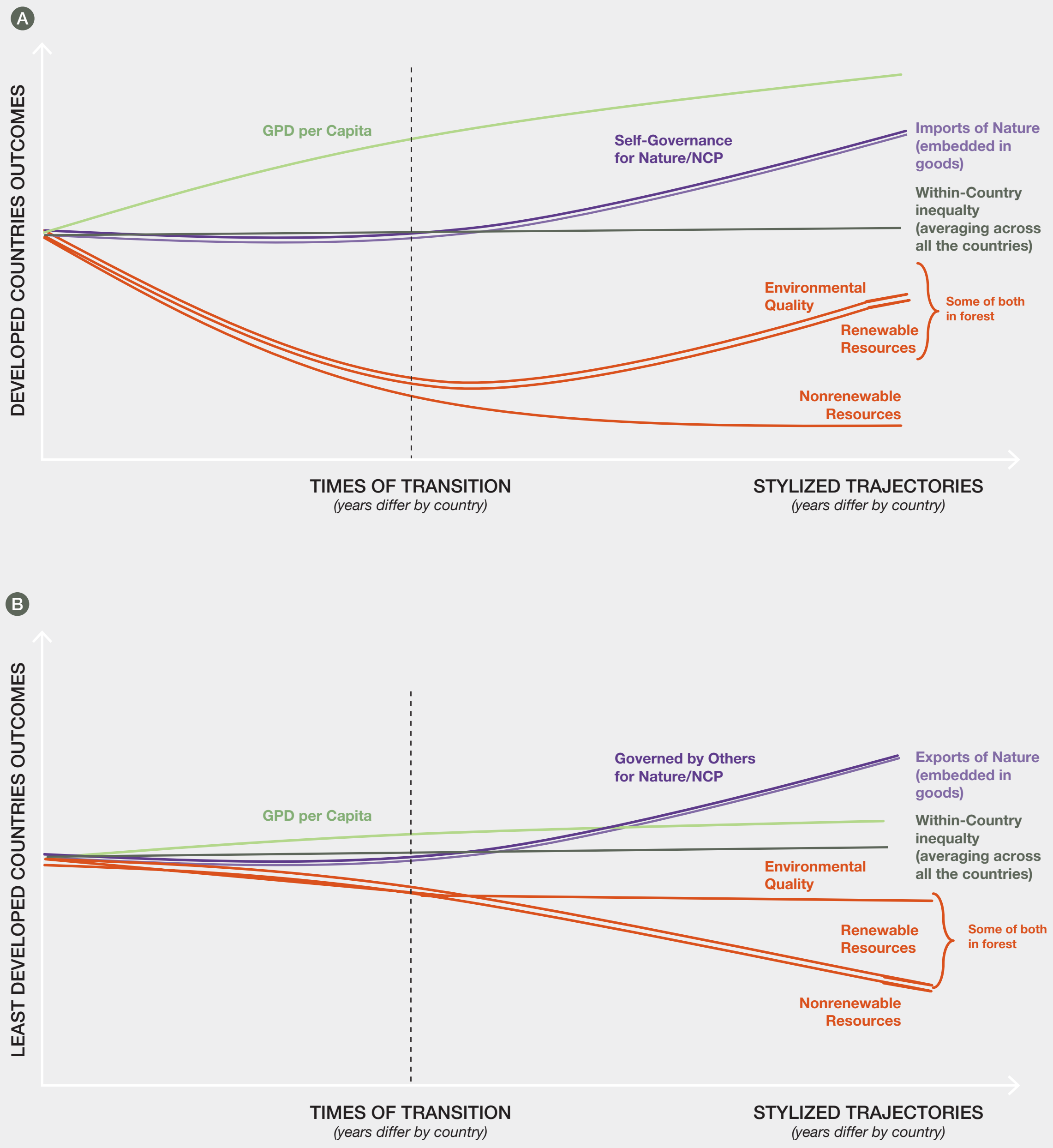


Figure 2 1 2 **Stylized sketches of average trajectories in developed countries outcomes A and least developed countries outcomes B.**

From bottom to top: quality of environment and natural resources ('renewable' like fish or trees, which regrow, or 'non-renewable' like oil or ores); institutional features of economies (i.e., trade) and societies (i.e., governance); gross domestic product (GDP) per capita; and inequality in GDP per capita. This figure builds upon **Figure 2.1.1**, with vertical lines indicating times for transitions that, in reality, happen at different times in different countries.

Consider, for instance, the degradation of nature as well as the other outcomes from expansion and intensification dynamics of economic activities. Regulations can limit the areas affected by those activities (e.g., agriculture), and a country also can invest to raise its outputs per unit area and, further, even to lower total 'environmental footprint' (e.g., abandon activities and reforest); which can produce the Self-Governing trajectory: recovery for nature, slower GDP growth **(Figure 2.1.3)**. Whether all this occurs depends on whether the society places a sufficiently high value on forest.

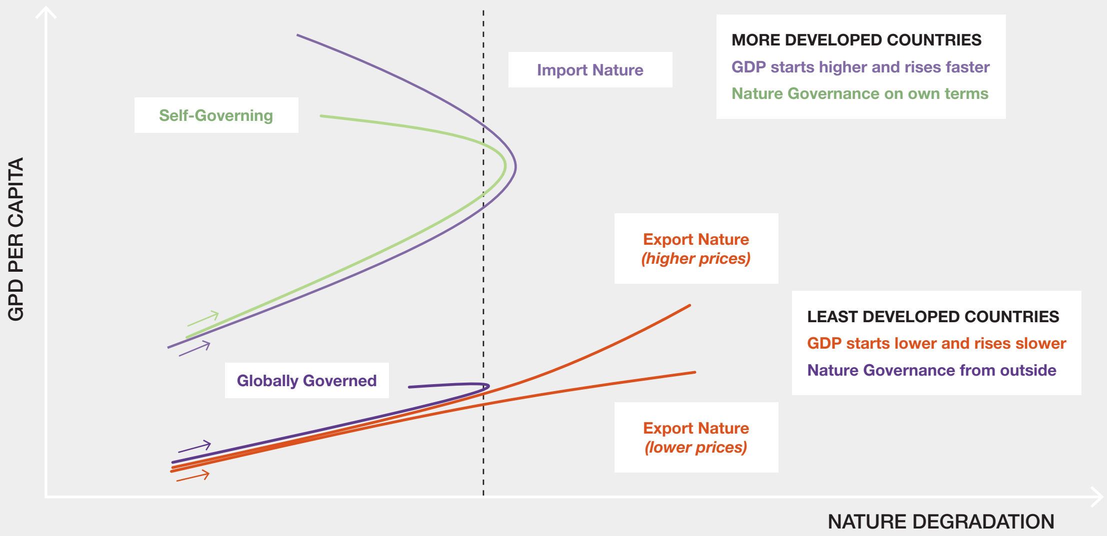


Figure 2 1 3 **Stylized sketches of cross-country interactions in trajectories for material contributions of nature.**

y-axis = GDP per capita and capacity for future material, regulating and non-material contributions, x-axis = nature. Imports and exports of nature are embodied in goods, e.g., water in food or trees in timber decrease for exporters and increase for importers. As in Figures 2.1.1 and 2.1.2, a vertical line indicates a point of possible societal transitions.

Instead, developed countries may conserve nature (e.g., forest cover) by importing forest and agricultural goods from least developed countries, albeit at the expense of nature for the exporters. For importers, an 'Import Nature' trajectory may be better than meeting needs by self-governing, though whether this occurs depends on whether exporters put a sufficiently low value on forests. The trade-offs depend on export prices, as illustrated in two Export Nature trajectories **(Figure 2.1.3)**.

Alternatively, developed countries may advocate – and cover the costs of – nature governance in least developed countries such as strict protected areas that make some local uses of forest illegal. That may provide global public goods – yet sometimes by imposing net costs on the local actors. A rise in nature could raise welfare for developed countries, yet lower GDP for least developed countries, if the latter cannot shift into other activities that support economies (Globally Governed trajectory). This motivates a quest for actions to help nature and local economies. For instance, forests might also increase if enforced protected areas flanked new railway links that facilitated urban growth.

2.1.2 PAST TRAJECTORIES, THEIR TRADE-OFFS AND INEQUALITIES

2.1.2.1 Maintain nature or meet society's many and diverse short-run goals?

Compared with pre-1980 realities, the world has changed rapidly **(Figure 2.1.4)**. Population, urban areas and international migration have risen greatly. Overall, quality of life has improved, in the senses of, e.g., lower child mortality, or higher caloric intake, and varied summaries such as the Human Development Index. Economic development generally has advanced, in terms of per capita GDP and per capita consumption, while the value of merchandise being exported has also increased. Yet, these improvements have come at a real cost: increasing impact upon nature. Since 1980, food production systems have intensified and, although the overall areas covered by cities and agriculture have not drastically increased, more fertilizer and pesticides are being used while total pollution (including greenhouse gas emissions), the number of invasive alien species, and temperature anomalies are increasing, and biodiversity intactness is decreasing (see chapter 2.2 for more on this variable) – despite increasing efforts to protect key

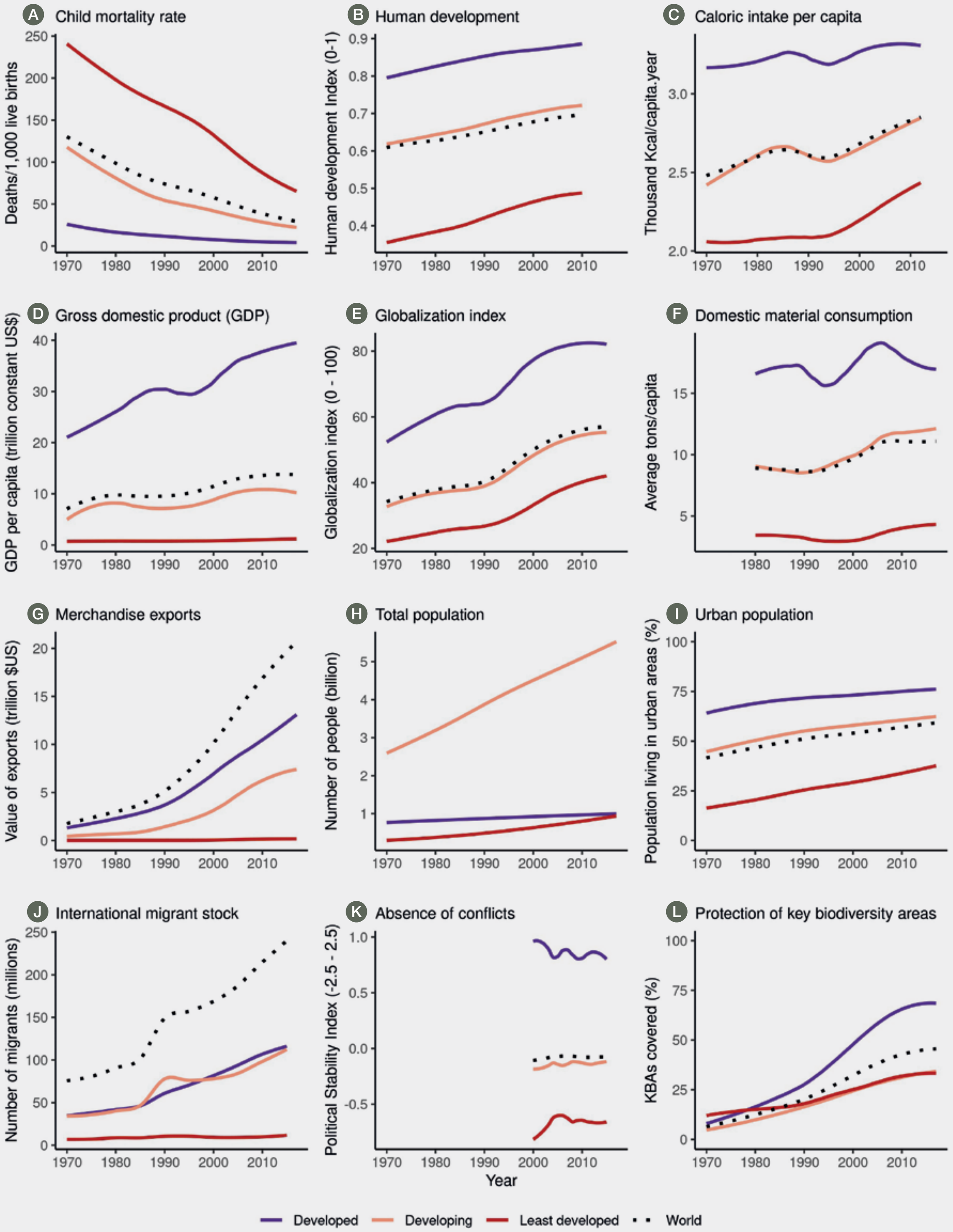


Figure 2 1 4 **Trends in indirect drivers for countries with different development levels.**

The data shown are trends, per country, averaged (A, B, C, D, E, F, H, I, and K) or totaled (G, J) for each of the three UN development categories: developed, developing, and least developed. Panels shown are: A **Child mortality rate:** Mortality rate, under-5 (per 1,000 live births); B **Human Development Index:** a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard of living; C **Calorie intake:** Kilocalories consumed per person per day; D **GDP per capita** (gross domestic product divided by midyear population) in constant 2010 U.S. dollars; E **Globalization index:** The KOF Globalization Index measures the

economic, social and political dimensions of globalization; F **Domestic material consumption per capita:** all materials used by the economy, either extracted from the domestic territory or imported from other countries; G **Merchandise exports:** value of goods provided to the rest of the world per country valued in current U.S. dollars; H **Total population**; I **Proportion of urban population:** Proportion of the total population that is urban, which refers to people living in urban areas; J **International Migrant Stock:** the number of people born in a country other than that in which they live (includes refugees); K **Absence of conflict as an indicator of political stability:** Index that measures perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically-motivated violence as well as terrorism; L **Protection of key biodiversity areas (KBA):** measures progress towards protecting the most important sites for biodiversity in % of such sites per country (including Alliance for Zero Extinction sites).
Sources: BirdLife International (2018); FAO (2016a); KOF Swiss Economic Institute (2018); UNDP (2016b); UNEP-WCMC & IUCN (2018); World Bank (2018l, 2018i, 2018q, 2018k, 2018n); WU & Dittrich (2014).

biodiversity areas (KBAs). These global patterns will be described in detail in each of the sections of this chapter.

The trends differ widely, though, across countries, global regions, and regions within countries. To highlight some differences, we use a typology that divides all countries into three development level categories **(Figure 2.1.4)**: developed, developing, and least developed, based on Gross Domestic Product (GDP)[1]. We also use the four World Bank categories of income: lower, lower-middle, upper-middle and high income (World Bank, 2018r), that can be aggregated (lower-middle and upper-middle into middle) or disaggregated (high income OECD and high income oil and high income other) as needed (Figure S2). Additionally, we refer to the IPBES regions (Figure S2): Africa, Americas, Europe and Central Asia, Asia and the Pacific (see Supplementary Materials: Table 2 for a comparison of typologies).

2.1.2.2 Inequalities

2.1.2.2.1 Poverty and inequalities with respect to basic needs

There have been some marked advances in terms of poverty reduction over the past few decades (Figure S5), though many people around the world still remain in poverty. Per the "international poverty line" established by the World Bank in 2008, equivalent to a daily income below $1.90 US dollars/person (in 2015 prices) (Ravallion *et al.*, 2008), ~1.2 billion people still live in poverty (UN, 2016a). According to the Multidimensional Poverty Index (MPI), introduced in 2010 in the Human Development Report (UNDP) using metrics for health, education, and standard of living, still ~1.5 billion people are living in extreme poverty.

Further, even while overall income has risen on average to above the international poverty line, clearly many other basic needs have not been met, despite significant global stresses on nature. Globally, food security (i.e., security in food supply, with elimination of caloric and nutritional deficiencies) has been increasing but remains low within least developed countries. Currently, despite average gains over time at the global level, close to 860 million people still suffer severe food insecurity across the globe, of which 48% are in Africa (particularly in sub-Saharan Africa) and 45% in Latin America (Figure S3) (WFP, 2017). Conflicts, refugee crises, droughts, floods, pandemics, and inadequate social institutions all have contributed to shortfalls both in aggregate food production, or food availability, and in the effective food supply, with 37 countries (28 in Africa) having received emergency food aid in 2016 (WFP, 2017).

In addition, while the child mortality rate – largely associated with a lack of water sanitation and food deficiencies – has decreased overall, this threat remains prevalent in low income countries, in which as many as 10% of the children born alive die before age 5 (World Bank, 2018l). Regionally, Africa and the Americas show highest mortality (Figure S3). While access to improved water resources has increased, on average, 40% of the world's population still is lacking access to safe drinking water, most of them in least developed countries, especially within sub-Saharan Africa (WHO & UNICEF, 2017). Furthermore, almost all maternal deaths during childbirth (99%) occur in developing countries, over half in sub-Saharan Africa (Wang *et al.*, 2011), as a result of water scarcity, poor management, and governance failures.

In terms of broader measures of well-being, the Human Development Index (HDI) that includes income, health (life expectancy at birth), and education (average number of years of schooling) (UN, 2016a) also illustrates great contrasts across the planet. Least developed and developing countries have much lower HDI values than do the developed countries (**Figure 2.1.4**; UNDP, 2016a). Africa has the lowest HDI values among IPBES regions, followed by Asia (Figure S3). Across regions, Indigenous Peoples and Local Communities (IPLCs) are among the poorest groups, by income but also in access to basic needs, services, and opportunities (Hall & Patrinos, 2012).

Countries differ in many other well-being metrics too (**Figure 2.1.4**, Figure S4), such as material conditions for life – frequently assessed from an economic perspective with economic indicators (see section 2.1.3). Higher-income countries rank higher for indicators associated with societal

1. https://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf

development and for sustainability (Figure S4) (Eira *et al.*, 2013; Inuit Circumpolar Council, 2015; Raymond-Yakoubian & Angnaboogok, 2017), including for various indicators of the options citizens have, also called 'freedoms', that are included in the World Happiness Index (WHI, 2017) (Figure S4). These countries also have better conditions than low income countries for access, equality, tolerance, and inclusion of minorities, as shown by the Social Progress Index (SPI, 2017) (Figure S4). With respect to metrics for the management of ecosystem services and environmental policies such as Environmental Performance Index (EPI, 2018), low income countries rank lower. Yet they rank higher in terms of indicators for diversity, environmental degradation, and ecological footprint, including consumption of renewable water resources. Low income countries exhibit higher rankings in the Environmental Component of the Social Sustainability Index (SSI.EV; Figure S4) which includes linguistic diversity (Maffi, 2005), cultural identity, and the retention over time of indigenous ecological knowledge as well as practices (Sterling *et al.*, 2017).

2.1.2.2.2 Inequalities in Income

Economic inequality across all countries has been rising since 1820 (Bourguignon & Morrisson, 2002; World Bank, 2018r), and also has escalated since 1980 (**Figure 2.1.4**; Figure S2; Figure S3; Figure S5; World Bank, 2018o), with the highest-income countries increasing their incomes faster (OECD, 2015). In 2017, the GDP per capita was nearly four times higher in developed than in developing countries and nearly 34 times higher than in least developed countries (**Figure 2.1.4**; World Bank, 2018i). In terms of growth, GDP per capita is rising fastest for developed and developing countries, but slower in least developed countries, making the gap among these particular groups larger every year.

Within-country inequality also shifted over time in many countries. However, the changes went in both positive and negative directions, and so on average, within-country inequality remained fairly constant (Bourguignon & Morrisson, 2002; World Bank, 2018o). Still, quite a few countries experienced rising within-country income inequality, as expressed by metrics such as the Gini coefficient (Figure S5) or the Palma ratio (Palma, 2006), with cases in which lower incomes fell while higher incomes rose – particularly in the Americas and Africa.

2.1.2.2.3 Lifestyles and Inequalities in Consumption

Consumption too has been escalating, across the last few decades, albeit with differences among countries and global regions. Energy consumption has been rising since the industrial revolution. Wood and oil from whales were replaced in the early 1900s by coal, petroleum and natural gas (Smil, 2004). By the middle of the 20th Century, the "Green Revolution" boosted agricultural yields through the application of fertilizers, pesticides, fungicides and herbicides, together with irrigation, all of which increased energy demands (Dzioubinski & Chipman, 1999). Total energy use has doubled in the last 40 years (World Bank, 2018g) (Figure S6), while substantial transitions to modern gridded clean fuels occurred between 1990 and 2010 (Pachauri *et al.*, 2012), allowing ~1.7 billion people access to electricity and about ~1.6 billion people access to non-solid fuels for household cooking. The greatest increases have occurred in middle income countries, while low income countries exhibited lower increases (Figure S6; World Bank, 2018a) with real variations in rates of technological development and in the initial endowments of energy resources (Burke, 2010; Toman & Jemelkova, 2017). For instance, high income non-oil-producing countries have been gradually reducing their use of fossil fuels and increasing the use of nuclear and other non-fossil-fuel sources (Figure S7). Among the highest energy consumers, in total as well as per capita, are high income countries where intensive agriculture is more prevalent (Figure S9).

Global patterns of food consumption have also changed over the past fifty years, with important differences by country (Figure S6). As nations urbanize, urban dwellers get wealthier, food supplies increase, and eating habits change. Diets are rising in refined carbohydrates, added sugars, fats, and animal-based foods (e.g., meats, dairy) but falling in pulses, vegetables, coarse grains, fruits, complex carbohydrates and fiber, in tandem with the diversity of food sources (Keats & Wiggins, 2014; Khoury *et al.*, 2014; Popkin *et al.*, 2012; Tilman & Clark, 2014). Again, the variations across regions are significant. From 1970 to 2015, global average caloric intake per capita rose by 15% – yet developed countries have the highest levels **(Figure 2.1.4)**, particularly in Europe (Figure S3), while the lowest levels are found in least developed countries **(Figure 2.1.4)**, particularly in sub-Saharan Africa (Figure S3). Likewise, by 2009 while the average per capita consumption of protein exceeded the average estimated daily requirements in all the regions of the globe, it is the highest in high income countries (FAO, 2011b, 2016a; Paul, 1989; Walpole *et al.*, 2012).

With those changes in diet, the number of obese and overweight people has grown (Figure S6), to 2.1 billion in 2013 (Ng *et al.*, 2014). This too differs by region, with six times more obese people in high income than low income countries today (Figure S6). Furthermore, there are large variations across regions in the amount of fats (e.g., fats in foods and oils) for human consumption. The lowest quantities consumed are in Africa, while the highest are in parts of North America and Europe. Both the quantities and qualities (animal-based versus vegetable oils) of fats are key features of the nutritional transitions in national diets (Ranganathan *et al.*, 2016). Fast-food options are rising in low income countries, as exemplified by the higher numbers of chain restaurants (e.g., McDonald's restaurants[2]).

New 'needs' have also emerged with economic development. For instance, after mobile phones first became accessible, their number quickly "exploded" to one for every five people in the world (Figure S6). In addition to providing useful services, phones cause important environmental impacts associated with mining of precious metals for components and with both the manufacture of electronics and their careless disposal (Babu *et al.*, 2007; Fehske *et al.*, 2011; Wanger, 2011; Widmer *et al.*, 2005).

2.1.2.2.4 Inequalities in Environmental Footprints

With changes in lifestyle, per capita demand for natural resources has increased – unevenly (**Figure 2.1.4**, Figure S1). For instance, domestic material consumption (DMC) – the total amount of material directly used in an economy, including domestic extraction and imports (Wiedmann *et al.*, 2015; WU, 2017) varies greatly. DMC per capita is ~5 times larger in high income countries than low income. As DMC per capita rose by 15% globally since 1980 (18% since 1970), the largest increases are in developing countries (73% since 1970), followed by least developed (18% since 1970; **Figure 2.1.4**). By IPBES region, since 1980, DMC rose most in Asia and the Pacific (20%), followed by Africa (18%), and rose least in Europe and Central Asia (7%) (Figure S3).

Such demands upon nature scale with both the total population and demand per person. As such, since 1970, global material consumption has risen over 1.4 times faster than has total population (**Figure 2.1.4**, Figure S1). With every 10% increase in GDP, the average material footprint of nations – raw material extraction in the final demand of an economy – has risen by 6% (Wiedmann *et al.*, 2015; WU, 2017). Once again, growth rates for absolute and for per capita material consumption are unequal. For example, from 1980 to 2008 they increased in all regions except Central Asia (due to the collapse of the former Soviet Union) and most rapidly in Northeast Asia (Wiedmann *et al.*, 2015; WU, 2017). The global amount of material extraction was approximately 70 billion tons in 2008 (Wiedmann *et al.*, 2015; WU, 2017). Asia has the highest material extraction of all the regions, while 2008's per capita consumption in North America was ten times higher, at 30 to 35 tons of raw materials, than in Central Africa (Figure S18). Total material extraction (living and nonliving) in developing countries is rising the fastest, due to rapid increases in total population and GDP and DMC per capita (**Figure 2.1.12**, Figure S17, Figure S18, Figure S25).

All of this has impacts upon ecosystems. Estimates of ecological footprints, based on demands for both material and regulating contributions to people from nature, suggest sustained increases of footprints that are beyond the biological capacity to supply them (Borucke *et al.*, 2013; Galli *et al.*, 2016, 2014; Lazarus *et al.*, 2015; Lin *et al.*, 2015; Wackernagel *et al.*, 2014). This is especially true for the developing countries that are growing fastest in people, per capita demand, and globalization **(Figure 2.1.4)**.

Critically, environmental footprints of country consumption increasingly stretch beyond borders (as discussed in the introduction, see **Figures 2.1.2 and 2.1.3**). The world is ever more global, in economic, social, and political terms (Figure S1). Globalization metrics are highest for developed countries and lowest for least developed countries **(Figure 2.1.4)**. Such indices of increased resource flows include a 12-fold rise in the value of exports from 1970 to 2017, with fastest increases in developing countries (20-fold), followed by least developed ones (15-fold) **(Figure 2.1.4)**. Footprints associated with exports can be larger than is indicated by these trade values, though, because the usage of resources is, on average, larger than physical quantities of traded goods (Wiedmann *et al.*, 2015).

2.1.2.2.5 Inequalities in Social, Environmental, and Historical Constraints

Differences in current conditions and trends among countries are associated partly with different natural endowments. High income OECD countries and upper-middle income countries have the largest fractions of renewable freshwater resources and agricultural lands, for instance, while oil-producing high income countries have the smallest such fractions (Figure S7), although the largest for nonrenewable resources (e.g., petroleum, natural gas). Forest cover is similar for countries with rather different income levels, except for oil-producing countries that have little (S7). Globally, natural assets represent about one tenth of total wealth, with produced capital three times and human capital six times as large. Yet for some countries with lower income levels, the natural capital constitutes most of their wealth (World Bank, 2018o). The contribution of natural capital to total wealth for high income countries is relatively small, roughly half the magnitude of the shares for low income countries (Lange *et al.*, 2018a). Thus, degradation of nature should have the strongest detrimental impacts on low income countries' future economic development.

Beyond the roles natural conditions play in divergent development pathways among countries – which are debated (Diamond, 1997; Gallup *et al.*, 1999) – countries also differ in institutions, e.g., in governance, culture, religion, philosophies, and past development. The colonial period was characterized by natural resource flows from the South to the North that often were linked with

2. https://stage-corporate.mcdonalds.com/content/dam/gwscorp/investor-relations-content/supplemental-information/2016%20Restaurants%20by%20Country.pdf

ecological damage and social oppression (Goeminne & Paredis, 2010; Nagendra, 2018). As a result, tropical civilizations whose total wealth was closer to their European counterparts in the precolonial era are now far poorer (Acemoglu *et al.*, 2005). Patterns of poverty in the tropics have been linked to a variety of institutions, such as some arrangements that enable inclusive economic growth that lowers poverty (Acemoglu *et al.*, 2001; Easterly & Levine, 2003; Rodrik *et al.*, 2004). The current patterns of poverty and the environmental conditions in the Americas, Asia and the Pacific, and Africa are still strongly influenced by the pervasive experience of past colonialism (16^{th} to 19^{th} centuries). Its continuing influences upon resource flows and trade arrangements contribute to persistent social inequality as well as weak governance institutions which perpetuate inequalities (IPBES, 2018b).

For instance, most economic growth in the last 50 years occurred in countries not experiencing civil conflict and with strong state institutions. Additionally, 70% of today's poor live in "fragile states" with cycles of violence, weak institutions, inequality, and low growth. All are obstacles to overcoming poverty (Sachs, 2005; Smith, 2007; World Bank, 2015a). Developed countries are more politically stable **(Figure 2.1.4)**, e.g., with European countries more stable than African (Figure S3).

All these inequalities have important societal and environmental consequences – for instance, differential conservation practices, depending on governance contexts. Inequality is associated with less protected land for relatively democratic countries, yet the reverse is true for relatively undemocratic countries (Kashwan, 2017). Some suggest nonlinear linkages between inequality and both economic and environmental outcomes (Dorling, 2010, 2012; Holland *et al.*, 2009; Mikkelson *et al.*, 2007). Equality has generally facilitated collective efforts to protect natural resources under common and public ownership or control (Baland & Platteau, 1999, 2007; Bromley & Feeny, 1992; Colchester, 1994; Dayton-Johnson & Bardhan, 2002; Itaya *et al.*, 1997; Ostrom, 2015; Ostrom *et al.*, 1999; Scruggs, 1998; Templet, 1995). Inequality may yield social and environmental vulnerabilities, including through the distribution of risk (Bolin & Kurtz, 2018). Inequality may also lead to conflict and, if both become self-sustaining by limiting opportunities and mobility – yielding hopelessness and a lack of a vision – that can fundamentally undermine the motivation to invest in nature for sustainability (Stiglitz, 2013; Wilkinson & Pickett, 2010).

2.1.3 INDIRECT DRIVERS: VALUES

2.1.3.1 Different social groups hold different values

The different values people hold concerning nature, nature's contributions to people, and their relationship to the quality of life affect people's attitudes toward nature and, thus, the policies, norms, and technologies which modulate people's interactions with nature. Values encompass principles or moral judgments that can lead to responsibility concerning, and stewardship towards, nature. They also encompass varied views about the importance or significance of something or a particular course of action. For instance, as highlighted within 'the water-diamond paradox', even though water is necessary for life, while diamonds clearly are not at all, the market prices for diamonds usually are far higher due to (at times intentional) market scarcities (Chan *et al.*, 2016; IPBES, 2015; Pascual *et al.*, 2017a; see chapter 1).

Values concerning nature can be relational, instrumental or intrinsic (chapter 1). Individuals and social groups who hold in high regard their relationships with nature often hold moral principles for living in harmony with nature. Such relational values are central for Indigenous cultures in many parts of the world. This is the case, for instance, of the Eeyouch of the Eastern Subarctic in Canada, who traditionally view humans, other animals, plants, some aspects of the natural world, and spiritual beings as all having conscious agency in a world that is dependent on relationships and on an ethic of mutual respect (Berkes, 2012; Descola, 2013; Motte-Florac *et al.*, 2012; Pascual *et al.*, 2017a). Also, some groups in the Tibetan plateau hold that intangible and mythical creatures or deities inhabit soils, water, air, rocks and mountains, and have different qualities and identities with whom humans need to find a balanced mode of interaction (Dorje, 2011). Aymara and Quechua communities in the Andes, as groups elsewhere using this or other terms, conceptualize Mother Earth as a self-regulatory organism representing the totality of time and space and integrating the many relationships among all the living beings. Such conceptualization is used by many Indigenous organizations to re-establish cultural links to ancestral practices and to contest forms of environmental degradation that are imposed on them (Medina, 2006, 2010; Ogutu, 1992; Posey, 1999; Rist, 2002). Relational views such as these examples support approaches to governance that reaffirm important points of interconnection and virtues (e.g., respect, humility, gratitude) and often lead to self-imposed restrictions on use of nature (Mosha, 1999; Spiller *et al.*, 2011; Verbos & Humphries, 2014).

Instrumental values, in contrast, reflect the importance of an entity in terms of its contribution to an end, or its utility. Entities can provide instrumental value for consumptive (e.g., use of water, energy, biomass, food) and nonconsumptive (e.g., nutrient cycling) uses. Utilitarian paradigms viewing nature as a resource for economic development have intensified over the last centuries, especially in industrialized regions. In this anthropocentric, materialist worldview nature is seen as a pool of material goods and energies to be mastered and employed (Merchant, 1980; Nash, 1989; Pepper, 1996; Plumwood, 1991), supporting the extraction of biodiversity and resources (Dietz & Engels, 2017) and both substitutability and discounting perspectives. Substitutability implies that ecosystems or their functions could be lost as long as their contributions to quality of life are provided in other ways (Traeger, 2011). Discounting gives less importance in decisions to future benefits or costs (Dobson, 1999; Padilla, 2002) – following the assumption that future generations will be better off (much as current generations are better off than the past (above)).

In practice, values can be simultaneously instrumental and relational. Many Indigenous Peoples and Local Communities in varied rural settings, for instance – indeed across the IPBES regions – relate to nature with deep respect not only due to their conceptualizations of key relational values but also because their livelihoods depend upon the food and other materials that nature provides.

Intrinsic values are an inherent property of the entity (e.g., an organism), not ascribed by external valuing agents (such as human beings). Because of this independence from humans' experiences, intrinsic values are beyond the scope of anthropocentric valuation approaches (Díaz *et al.*, 2015). Intrinsic values can be particularly relevant in nature for non-human and even nonliving entities (Krebs, 1999). In the face of environmental degradation, environmental movements in the 1970s advocated for the intrinsic value of natural entities (Hay, 2002), regardless of their usefulness to humans. These included sentient animals (Singer, 1975), all living beings (Taylor, 1981) or ecosystems with living and nonliving components (Devall & Sessions, 1985). Intrinsic values have been presented as a basis for laws and regulations or other governance to implement conservation agendas that minimize humans' interactions with nature (Purser & Park, 1995) while ensuring the well-being of future human generations by maintaining nature's contributions to people (Mace, 2014). Some argue that the intrinsic value of non-human entities and its implications for biodiversity conservation could be considered as part of a wide instrumental perspective (Justus *et al.*, 2009; Maguire & Justus, 2008).

Nature is also valued today for its contributions into the future (Faith, 2016; UNEP, 2015), from a number of perspectives. Bequest values consider present-day satisfaction of protecting nature for future generations, for instance, involving a principle of intergenerational equity. Insurance values pertain to resilience, in the face of change, while option values facing uncertainty focus on retaining the potential to access nature's benefits in future (Gómez-Baggethun *et al.*, 2014).

Access to food, water, shelter, health, education, good social relationships, livelihoods, security, equality, identity, prosperity, spirituality, as well as freedoms of choice, action and participation, are valued in different ways by people in a society and across different societies (Díaz *et al.*, 2015). Some of these values may be expressed through the use of a standard of exchange used by a community, such as money. Monetary value is considered a proxy for how people may perceive the worth of an entity. Multiple considerations influence the estimation of an entity's monetary value – or the amount that people are willing to pay – which complicates the identification of its full significance. Due to the diverse ways of conceiving and experiencing the relationships between humans and the rest of nature, people also often value nature and nature's contributions to people, including many ecosystem services, in ways that are incompatible with the reasoning in monetary exchanges (Pascual *et al.*, 2017b; UNEP, 2015).

2.1.3.2 Values of nature are rapidly changing

The values at the core of individual and social priorities and behaviours also can evolve over time, informed by awareness, experience, culture and society. Pressures associated with globalization, climate change, and population migration over the last century have been catalysts for social and cultural changes – including changes in the human perceptions of and relationships with nature. While urbanization may separate people from nature, there is a trend towards greater awareness of the importance of nature to human well-being in the scientific community and across society.

Long-standing values held by communities with strong ties to the land are increasingly disrupted, however, by economic globalization (Beng-Huat, 1998; Brosi *et al.*, 2007; Jameson & Miyoshi, 1998). Varied global influences can challenge local practices, including in the implementation of conservation. Local conceptualizations of conservation may differ from external conservation paradigms (Miura, 2005), although perhaps even more from consumptive views on exploiting remote ecosystems. Changes in values and lifestyle include the abandonment of indigenous and local knowledge, and traditional practices (Halmy, 2016), the erosion of traditional knowledge (Youn, 2009), and changes in institutions and community organizations (Mburu

& Kaguna, 2016; Ole Kaunga, 2017), as documented by IPBES assessments (IPBES, 2018b).

Migration, domestic and international, can disrupt relationships between communities and lands if arriving attitudes are not adapted to local socioecological conditions. Migration (resulting from conflict, lack of livelihood, urbanization, industrialization of agriculture, and changes in climate, among other reasons) can lead to local and also global losses of local environmental knowledge, governance and management practices that sustained local livelihoods (Merino, 2012; Robson & Lichtenstein, 2013). Significant numbers of people changing locations has driven changes in the worldviews, values, and practices of populations that migrate as well as those that receive them.

Climate change itself can also lead to changes in practices and the values associated with them (beyond effects through migration). For instance, both farmers and fishermen have been forced to shift daily and seasonal practices that affect not only their livelihood outcomes but also their long-standing senses of place, community structure, and cultural tradition (Breslow *et al.*, 2014).

A new ethic regarding nature has been called ‘environmental activism’ to explicitly challenge the dominance of the instrumental values (Callicott, 1989; Dunlap & Van Liere, 1978; Guthrie, 1971; Leach *et al.*, 1999; Leopold, 2014; Levins *et al.*, 1998; Meadows *et al.*, 1972; Naess, 1973). Recent examples include Pope Francis’ encyclical address (2015), reassessing Christianity’s vision of humanity’s relation with Earth (Buck, 2016; Marshall, 2009). Relational values also enter into conservation dialogues (Chan *et al.*, 2016; Mace, 2014). More holistic approaches to sustainable use of nature by humans inspired in part from indigenous worldviews are stated in international agendas, e.g., living in harmony with nature is a principle of the Rio 1992 “Summit of the Earth” (Mebratu, 1998; UN, 1992) and Rio 2012 Conference on Sustainable Development (UN, 2012) and the vision of the Convention on Biological Diversity up to 2050. An International Day of Mother Earth is recognized in the Rio+20 “The future we want” document, linked to rights of nature (UN, 2009, 2012). Recognition of Mother Earth appears in recent climate change agreements (UNFCCC, 2015), in the Convention on Biological Diversity (CBD, 2014) and in the United Nations Environment Assembly of the United Nations Environment Programme (UNEA, 2014).

More generally, Indigenous groups are actively trying to protect their rights while strengthening the recognition of the legitimacy of their relational worldviews and related governance practices in the face of economic, political, social and environmental pressures (Baer, 2014; Blaser *et al.*, 2004). For instance, viewing nature as part of social life, not property to exploit, is suggested by the inclusion of intrinsic rights of the natural world in the constitutions of Bolivia and Ecuador (Lalander, 2015). Yet placing the rights of nature on par with those of Indigenous communities may support or undermine indigenous control and raise questions about how rights are linked with responsibilities. In Bolivia, for instance, rights of nature have been given equal standing to the rights of ethnic groups, while in New Zealand, some native (Māori) communities have successfully fought to gain political and legal power over land-use planning (Menzies & Ruru, 2011) in ways that lead to new laws that recognize the spiritual connection of an Iwi (tribe) to their ancestral place and the legal personality of national parks and rivers (Salmond, 2014).

Views of what constitutes a good quality of life are also changing. A vision welfare based upon economic development and material well-being prevailed in academic literature until the 1980s (Agarwala *et al.*, 2014), yet concepts of well-being have integrated additional dimensions and focused more on experiences of people (Gasper, 2004; King *et al.*, 2014; McGregor *et al.*, 2015) and include their capacities and connections with nature (Sterling *et al.*, 2017), together with education and health, knowledge and skills, happiness and satisfaction. Equity, justice, security and resilience lenses are also increasingly being integrated in definitions of well-being, alongside the recognition of different types of knowledge about life and cultural identities (Sterling *et al.*, 2017). Evolutions of values can have important consequences for nature and its contributions, modifying not only material consumption patterns and but also governance.

2.1.4 INDIRECT DRIVERS: DEMOGRAPHIC

2.1.4.1 Population dynamics

The world's population has doubled over the last 50 years (**Figure 2.1.4**; Figure S1), and is still growing, although the growth rate has peaked (Roser *et al.*, 2017). There are over 7 billion humans today (PRB, 2014). Important reductions in growth rates have been observed in developed countries, while the fastest increases are in the least developed countries **(Figure 2.1.4)**, and in Asia and the Pacific (Figure S3). These differences in growth rates are consistent with a 'demographic transition': population growth rates increase as child mortality decreases, leading to increased life expectancy; then fertility and growth decrease, leading to falling population growth rates, as has already been observed within some regions (Fogel, 1986; Hirschman, 1994; Thompson, 2003). The demographic transition occurred over centuries in Europe but more quickly in some developing countries over the last few decades in a context of poverty and overexploited natural resources.

Demographic patterns have been linked with urbanization and with improvements in women's education, rights, and health that tend to reduce child mortality and to improve family planning (Caldwell, 2006; Galor, 2012). Developed countries have lower growth rates than developing countries. While convergence is expected, large differences may still remain for at least one century as some countries, mainly in Africa, may maintain high growth rates if current slow decreases in fertility continue (Clarke & Low, 2001; UN, 2004). Further, different 'demographic transitions' have been suggested, relating to shifts in partnership formation (cohabiting instead of marriage), values associated with childbearing decisions (ethics, politics, sex relations, education), and the postponement of parenthood. Their environmental impacts bear exploration (Lesthaeghe, 2014).

The world's population is aging, with consequences for resource consumption and management. The number of seniors – 60 years and above – is growing fast, while those above 80 are increasing even faster (McNicoll, 2002). Seniors are growing faster in urban than rural areas (McNicoll, 2002). Aging in rural areas has implications for the composition of rural labor forces and thus agricultural production patterns, land tenure, social organization in rural communities, and rural socioeconomic development. Such shifts over several decades in developed countries are now taking place in developing and least developed countries, challenging generational replacement that has been central for governance, environmental protection and sustainable use in rural areas. Shifts also highlight poor environmental quality, plus limited access to employment and services – especially for young people – within the rapidly growing urban areas of the developing world.

2.1.4.2 Migration

The amount of people who migrate to a new country has more than tripled in the last five decades **(Figure 2.1.4)**, with about 240 million people living today within a country where they were not born. The number of international immigrants currently is largest for developed countries **(Figure 2.1.4)**, as well as for Europe and Central Asia (Figure S3). The number is increasing fastest, however, within developing countries **(Figure 2.1.4)**, and also in Europe and Central Asia (Figure S3), where the number of migrants has increased fourfold between 1980 to 2010, in both regions.

International and within-nation migration has multiple drivers (Arango, 2017). Large contrasts in political stability, satisfied basic needs, and larger incomes are among some of these key drivers, particularly within the Middle East, South America and Asia. Migration may also be triggered by environmental conditions, with estimates of several million 'environmental migrants' today and with orders of magnitude increases in that group expected in the future (Laczko & Aghazarm, 2009).

Scarcities of resources (Hunter, 2005; Hunter *et al.*, 2005) and unfavourable conditions (Hunter, 2005) can shift populations (Lee, 1966; Todaro, 1969). Such degradation can interact with extreme events, such as those which caused the severe dust storms that occurred in American and Canadian prairies during the 1930s (Cook *et al.*, 2009), leading to the suggestion that migration could be one adaptive strategy for households facing environmental pressure. Rising temperatures have increased internal migration strategies in Brazil, Uruguay and South Africa (Mastrorillo *et al.*, 2016; Thiede *et al.*, 2016). Periods of low rainfall drove both internal and international migration in rural Mexico, particularly from municipalities with rain-fed agriculture (Leyk *et al.*, 2017). Crop failures driven by low rainfall also have fueled migration in Bangladesh (Gray & Mueller, 2012b).

Complex social-ecological interactions also underpin migration across different contexts (Black *et al.*, 2011). Villages and families with more resources (e.g., higher agricultural production) are more likely to engage in costly long-distance migration, as observed in rural Ecuador (Gray, 2009a, 2010), and northeastern South Africa (Hunter *et al.*, 2014). The role of gender is context-dependent (Gray & Mueller, 2012b), with: women's marriage-related migration falling by half during a recent drought in Ethiopia (Gray & Mueller, 2012a); while rural-urban migration increased due to deforestation in Ghana's central region particularly for young men more likely to find urban employment (Carr, 2005). Household characteristics are also important. In the Brazilian Amazon and in Southern Mexico, circular or iterative rural-urban migration is more likely for young adults, whose remittances often help to expand agricultural production (VanWey *et al.*, 2007). Community characteristics also matter, in particular social networks. In the context of Mexico-US migration, for instance, the impacts of environmental and resource risks, such as droughts, on migration are different for communities with expanded social networks due to migration histories (Hunter *et al.*, 2013).

While migration can be a strategy to reduce risks, much environmental migration is involuntary (Hunter *et al.*, 2015). Acute events, such as disasters (Fussell *et al.*, 2014; Lu *et al.*, 2016) and chronic events, such as regular droughts (Bates, 2002; Hugo, 1996; Renaud *et al.*, 2007), lead to involuntary migration. For instance, the disappearance of Lake Chad over the last few decades has been a crisis unfolding over the long term that has both internally displaced people (IPCC, 2007) and generated migrations to other countries (Fah, 2007). In Egypt, water pollution and desertification, with other resource scarcity, has driven migration (UN, 2016b).

The degree to which migration aids household adaptation depends upon specific vulnerabilities, such as the sensitivity of one's livelihood to climate (Warner & Afifi, 2014). Poorest households may be trapped by environmental change, lacking capital and increasingly unable to support even the sending of a migrant to provide remittances (Black *et al.*, 2011). For Bangladesh in 1994–2010, for instance, the poorest households were unable to use migration in response to flooding (Gray & Mueller, 2012b). The poorer also suffer higher exposures to environmental hazards (including climate-related), with fewer alternatives for settling in safer places. Thus, they endure more severe and long-lasting consequences (Blaikie *et al.*, 1994; Gray, 2009b; Gray & Mueller, 2012a; Gutmann & Field, 2010; IPCC, 2007).

Migration can have positive or negative environmental implications for receiving or for sending areas (Adamo & Curran, 2012; Curran, 2002; Fussell *et al.*, 2014; Unruh *et al.*, 2004). In areas sending migrants, depopulation may improve environmental outcomes such as regrowth of forests on abandoned land (Aide & Grau, 2004). Remittances back to sending areas may have positive environmental effects, if they reduce resource dependence by substituting bought goods for local production. However, this often can increase food vulnerability for those who remained. Alternatively, funds could have deleterious environmental effects, if used to expand investments in environmentally damaging practices, such as transformation of agricultural lands into urban and peri-urban parcels for real estate development (de Sherbinin *et al.*, 2008; Meyerson *et al.*, 2007). Migration may also hinder local generational replacement, weakening local environmental governance and resource management initiatives, particularly within the contexts in which global climate change poses strong local pressures upon natural resources (e.g., greater exposure of forests to pests and wildfires) that require local protection capacities (Merino, 2012).

In areas receiving migrants, mixed effects on nature are observed. For instance, migration to destinations with high-value amenities can raise resource and environmental degradation. In frontier mining, agriculture and ranching settlements, populations rise in ecologically sensitive areas (Joppa *et al.*, 2009; Wittemyer *et al.*, 2008), e.g., relocation of farm workers to cassava fields in Thailand (Curran & Cooke, 2008) or settlements of displaced individuals in northern Darfur, Sudan that are associated with lower vegetation due to the expansion of small farming (Hagenlocher *et al.*, 2012). Migration may also shift behaviour in receiving areas if individuals adopt attitudes from migrants. Recent immigrants to the U.S. exhibited greater concern for environmental issues than longer-term immigrants or native-born citizens (Hunter, 2000). Yet it has also been found that immigrants' perspectives about the environment can be at odds with resource management practices in receiving areas, as migrants are not very familiar with local realities and practices (Merino, 2012; Robson & Berkes, 2011).

2.1.4.3 Urbanization

Urbanization has been a significant trend in human settlement and development (**Figure 2.1.4**, Figure S1, Figure S3), driven by many factors and with significant environmental impacts. Globally, urban population rose from ~200 million in 1900 to ~4 billion in 2014 (UN, 2014), at which point over half of the world's population was urban. That share is expected to reach two thirds by 2050, as another 2.5 billion are expected to join urban areas, most in developing countries (CBD, 2012; Elmqvist *et al.*, 2004; UN, 2014). While the percentage of urban population is the highest in developed countries (~75%), it is growing the fastest in least developed and developing countries that rose 2.3 and 1.4 times respectively, respectively, between 1970 and 2017 **(Figure 2.1.4)**. Europe and Central Asia, and America have highest shares of urban population (~ 65% in each) but shares are growing the fastest within Africa (~40% between 1980 and 2010) and within Asia and the Pacific (~25%) (Figure S3).

Megacities with populations over 10 million people continue to arise and are projected to reach 41 by 2030. Small to medium-sized cities are growing the fastest and will be the home for the vast majority of future urban populations (UN, 2014). On the other hand, there are 300–400 shrinking cities in the world, about two-thirds in developed countries, in particular the United States, the United Kingdom and Germany (Kabisch & Haase, 2011; UN, 2014). Comparing IPBES regions, Africa, and Asia and the Pacific are urbanizing fastest, with future expansions in Asia and the Pacific expected to occur mostly in China and India (CBD, 2012; Seto *et al.*, 2011; Sui & Zeng, 2001). By 2050, up to 3 billion people will be living in slum areas within cities, mostly in developing countries (Nagendra, 2018).

Currently, urban areas cover under 3% of lands (Grimm *et al.*, 2008; McGranahan *et al.*, 2005; Potere & Schneider, 2007). Their extent is, however, expected to triple by 2030 (Seto *et al.*, 2012), rising faster than urban population. Much of the growth in urban extents has been observed in coastal regions, with 11% of all urban land in low-elevation coastal zones (i.e., less than 10m above sea level), where people and property are particularly vulnerable to floods and sea-level rise (Güneralp *et al.*, 2015; McGranahan *et al.*, 2007). In China, over 44% of urban land use is within floodplains, contributing to increasingly severe flood hazards (Du *et al.*, 2018). Rapid urban expansion is driven by positive feedbacks between urbanization and economic growth (Bai *et al.*, 2012), which generate further socioeconomic disparities between the coastal and inland regions (Bai *et al.*, 2012).

Urbanization is influenced by both ‘push’ and ‘pull’ factors (Hare, 1999), with job opportunities and services ‘pulling’ migrants while rural poverty, labor surplus, changing values (induced at times by the media and education), and civil conflicts acting ‘pushing’ people out of rural areas. ‘Push’ factors are often stronger, leading to many rural-urban migrants with poor employment and public services, including environmental. Poor neighborhoods in megacities of developing countries typically have poor environmental quality, with precarious access to safe drinking water and sanitation (Nagendra et al 2018). Yet the drivers of urbanization are quite variable (Bloom *et al.*, 2008; Fay & Opal, 2000), with important roles of national policies (Bai *et al.*, 2014). For instance, developed countries typically have higher levels of urbanization, with a strong correlation to productivity and income (Cohen & Simet, 2018). This forms a basis for some countries to promote urbanization as part of a strategy for economic growth, but there are large regional disparities, as well as quite mixed results (Bai *et al.*, 2012; Bloom *et al.*, 2008).

2.1.4.4 Human Capital

Human capital – including education, knowledge, health, capabilities and skills – is a significant component of development, one judged by many to be the largest share of the total wealth of all nations (World Bank, 2018o). That share varies by income level: within the low income countries, ‘produced and natural capital’ are the largest share; while in the high income countries, human capital dominates (World Bank, 2018o). Within that human capital, the levels and types of education influence economic development, including the scale of output, sectoral mix, and techniques used. Yet the relation between education, economic performance, environmental attitudes and sustainability is multifactorial – with factors such as economic and development policies, consumption patterns, and integration within the global economy playing major roles.

Human capital can be strongly affected, for instance, by the roles of women within a labor force. This societal factor can have a strong influence not only on the use of natural capital but also on other forms of human capital (World Bank, 2018o), beyond yielding more total human capital. Between 1995 and 2014, the estimated female share of human capital, globally, rose to ~40% – albeit with regional variations (from 18 to 44%; Credit Suisse, 2018).

2.1.4.4.1 Less Agricultural Extension

Meeting the world’s increasing demand for food while still reducing agriculture’s environmental impacts is one of the defining challenges of our times. Agricultural extension services constitute an important approach, as they may foster more productive uses of our limited natural resources, as in precision agriculture (Bongiovanni & Lowenberg-DeBoer, 2004). On the other hand, they can catalyse degrading shifts in production systems that lead to many losses of diverse traditional farming systems (IPBES, 2018b), or widespread harmful removal of tree cover (IPBES, 2018a).

During the 1960s and up to mid-1970s, rural support via agricultural extension was quite strong, particularly as associated with the Green Revolution. During the 1970s, extension was included explicitly within approaches to integrated rural development. However, public-sector extension became more limited after the 1980s, with its emphasis upon participatory approaches alongside drastic decreases in governmental expenditure on agricultural credits. In Latin America, between 1991 and 2007 such extension expenditures were reduced to below 10% (Figure S8). In addition, private support for such agricultural extension also started to decline around the 1980s, leading to underfinancing, staffing shortages, and the contraction of extension services (FAO, 2017b).

2.1.4.4.2 Indigenous and Local Knowledge

Indigenous Peoples and Local Communities (IPLCs) constitute a significant fraction of the world’s population and occupy a large fraction of the land area of the planet. Between 1 and 1.5 billion people are considered as members of Indigenous Peoples and Local Communities (see chapter 1), whiles estimates about smallholders range from 2 to 2.5 billion people (Zimmerer *et al.*, 2015). IPLCs manage or have tenure rights within ~38 million km^2, in 87 countries (or politically distinct areas), on all inhabited continents, covering over 25% of the land surface (Garnett *et al.*, 2018; Oxfam *et al.*, 2016). Their territories intersect with key areas for biodiversity conservation, including ~40% of all terrestrial protected areas and ecologically intact landscapes (Bhagwat & Rutte, 2006; Foltz *et al.*, 2003; Sobrevila, 2008). Traditional occupations are a key source of livelihoods and income for many IPLCs, thus recognizing their rights to land, benefit sharing, and the corresponding local institutions are crucial for supporting local to global biodiversity conservation goals (Garnett *et al.*, 2018).

Today, indigenous and local knowledge (ILK) is increasingly seen as relevant for sustainable resource use, not only for IPLCs but also more broadly. This reflects a shift from centralized, technically oriented solutions, which have not substantially improved the livelihood prospects for many small farmers (even if helping others). While there do exist multiple differences between indigenous and modern/contemporary knowledge, they still have some substantial overlaps, and ways to leverage the two sources of knowledge – e.g., for optimizing agricultural systems around agroforestry, multiple tree-cropping systems, and soil management targeted at smallholders – are being increasingly sought and further developed (Barrios & Trejo, 2003; Cash *et al.*, 2003).

Yet, the traditional practices stemming from ILK clearly are also declining at the very same time, and across multiple communities (Forest Peoples Programme, 2016; chapters 2.3 and 3). For instance, changes in both values and knowledge can be driven by contemporary education, in which prestige and progress might be associated to the replacement of traditional knowledge, which plays a key role in either the maintenance or the erosion of local worldviews and knowledge (Godoy *et al.*, 2009; Reyes-García *et al.*, 2007). More generally, schooling can loosen people's direct personal interactions with nature and lower traditional knowledge, while also potentially hindering the traditional transmission of knowledge based on direct learning from practice guided by local adults and elders. This occurs by creating cross-generational language barriers and changing cultural values (Godoy *et al.*, 2009; Pearce *et al.*, 2011; Reyes-García *et al.*, 2014, 2007). For instance, formal education can remove children from the everyday lives of families during the periods crucial for learning traditional knowledge (Ohmagari & Berkes, 1997; Ruiz-Mallén *et al.*, 2013), effective transmission of which relies upon observation, participation, and imitation in families and wider local communities. As formal education focuses on abstract and general knowledge, often alien to everyday life and local contexts, it may serve to overwrite elements of traditional knowledge. Thus, different ways of learning (i.e., traditional/local vs. formal) may result in multiple cultural identities (Pearce *et al.*, 2011). Yet, nonetheless, there are cases in which traditional knowledge and formal education have been successfully integrated, e.g., using local language and culture in implementing education and by also motivating traditional knowledge transmission (Barnnhardt & Kawagley, 2005; McCarter & Gavin, 2011; Michie, 2002; Ruiz-Mallén *et al.*, 2013).

2.1.4.4.3 Environmental Education

The patterns and relationships within human behaviours which are related to actions that affect nature started to be more closely assessed in the 1970s and 1980s (Hungerford & Volk, 1990). Results from systematic meta-analyses confirm that while environmental awareness is important, knowledge alone is not enough to motivate pro-environmental action (Bamberg & Möser, 2007; Klöckner, 2013). Also, pro-conservation and environmental attitudes tend to be insufficient for inspiring significant behaviours (Ajzen & Fishbein, 1980; Monroe, 2003; Schwartz, 1977; Stern, 2000). Instead, meaningful childhood experiences regarding nature, in particular in the context of family members who model care for nature, have been linked to adult conservation behaviours (Children and Nature Network, 2018; Clayton *et al.*, 2012; Tanner, 1980).

While a childhood's time in nature is clearly instrumental in developing a lifelong commitment to care for the Earth, a positive and meaningful connection to nature can also be facilitated and enhanced throughout our lives, though, and may start at any time. Nature-based activities have been shown to have instrumental influences on adult behaviour (Chawla, 1998; Wells & Lekies, 2006). Opportunities to cultivate that sense of connection can emerge within rural as well as in urban environments – not only promoting environment-supporting behaviours but also leading to increased health and well-being (Richardson *et al.*, 2016). Several studies have demonstrated a positive relationship between the level of involvement in nature-based activities as diverse as fishing (Oh & Ditton, 2006, 2008), SCUBA diving (Thapa *et al.*, 2006) and bird watching (Cheung *et al.*, 2017; Hvenegaard, 2002; McFarlane & Boxall, 1996), and individuals' concerns for the resources upon which their activities depend. People also grow attached to the specific places where they interact with nature, where they are more likely to engage in conservation actions (Halpenny, 2010; Ramkissoon *et al.*, 2013; Stedman, 2002; Tonge *et al.*, 2014; Vaske & Kobrin, 2001). For those already positive toward the environment, regular time in nature may play an affirming role by keeping nature "top of mind" and increasing the likelihood of taking action to benefit the environment (Manfredo *et al.*, 1992; Tarrant & Green, 1999; Thapa, 2010), all highlighting the importance of regular or even frequent experiences outdoors in nature (Kellert *et al.*, 2017).

2.1.5 INDIRECT DRIVERS: TECHNOLOGICAL

2.1.5.1 Traditional Technologies (Indigenous and Local Knowledge)

Both archaeological and contemporary evidence suggest that humans have used and continue to use a wide variety of deliberate means to manage species within habitats rich in biotic resources (Hoffmann *et al.*, 2016). Indigenous Peoples continue to interact with the planet's ecosystems in many and varied ways: forest managers in the tropical lowlands or in the mountains; pastoralists in savannas and other grasslands; and nomadic or semi-nomadic hunters and gatherers in forests, prairies and deserts (Toledo, 2013). Large groups of Indigenous Peoples are also just small-scale producers, not always easily distinguishable from the non-Indigenous Peoples producing nearby. Within the Andean and Mesoamerican countries of Latin America, the Indigenous Peoples farm much like surrounding small-scale farmers (Bellon *et al.*, 2018), with technology and knowledge flowing between the groups. Similarly, in India, distinctions between scheduled tribes and non-tribal peoples cannot be made solely upon the basis of productive activities. In these and other many cases, non-indigenous and indigenous producers plant crops using similar farming methods (Toledo, 2013), while also broadly contributing to dissemination of technologies and knowledge, such as in cases of agroforestry and other tree-cropping systems that are increasingly important within many regions (Agrawal, 2014). Together, IPLCs and a wide range of smallholder producers contribute a significant share of our global food production.

ILK and related practices are increasingly seen as relevant for sustainable use. This is part of a shift from centralized, technically-oriented resource management solutions that, in many cases, adapt poorly or are even harmful to local quality of life and environment. Beyond ecological knowledge and production technologies, there is increasing appreciation for the importance of local institutions that underlie the local access to, use of, and management of natural resources.

Indigenous Peoples and Local Communities' practices usually are based on a broad knowledge of the complex ecological systems in their own localities (Gadgil *et al.*, 1993). A wide range of outcomes emerge from these relationships, with cases illustrating sustainable resource and others with heavy ecosystem impacts via inappropriate management by local populations. For example, water use within Indian communities has proven to be highly efficient, for storage and distribution. Communities located close to the mountains with abundant precipitation have extensive knowledge about canals, dams, pools in hard rocks, and systems known as *kul*, *naula*, *Khatri* (Bansil, 2004). Indigenous Australians have demonstrated detailed technical knowledge of fire and have used it effectively to improve habitat for game and assist with the hunt itself (Lewis, 1989). Indigenous fire management has been documented across the world for agricultural and pastoral use, hunting, gathering, fishing, vegetation growth and abundance, clearing vegetation, habitat protection, domestic use, medicine/healing and spiritual use (Mistry *et al.*, 2016; Sletto & Rodriguez, 2013). In Brazil, the practice of Mayú, a mutual cooperation in the elaboration of large-scale tasks within traditional farming, e.g., cutting of trees and burning the felled biomass, is one social institution which has facilitated the formation and establishment of social bonding as well as important intergenerational knowledge transfer (Mistry *et al.*, 2016).

In tropical countries, IPLC agroforestry systems are based on ancestral practices with common characteristics. These systems are highly diversified, productive and complex. Producers manipulate species but also vegetation and ecological processes (Toledo & Barrera-Bassols, 2008). As within many regions of the world, in these countries the rotation of harvesting contributes to landscape heterogeneity – and while such rotation in agriculture is well known, less well known is rotation for grazing and hunting and fishing. In semiarid regions such as the fringe of Sahel, for instance, seasonal patterns of rainfall drive migration by larger herbivores and by traditional herding peoples. This can allow for the recovery of grazed lands – which can be disrupted by settlement. Throughout arid and semiarid Africa, traditional herders followed migratory cycles, rotating grazing land seasonally and, in cases, rotating adjacent grazing areas within a season (Gadgil *et al.*, 1993).

Yet, indigenous and local knowledge and practices are being lost, even as they come to the fore. One indication is reduced linguistic diversity. The Ethnologue (Lewis, 2009) identified 6,909 languages – of which half are at risk of extinction**.** Linguistic diversity can be correlated with biological diversity in regions including Taiwan and the Philippines, the Amazon Basin and Papua New Guinea and Eastern Indonesia, Northern and Central Australia, Eastern Siberia, and Mesoamerica. Extinction risks for these elements of linguistic diversity are high in Australia, the Amazon and Eastern Siberia. In many cases, these losses also correlate with the abandonment or transformation of local production systems, with implications for land cover change (involving reforestation and/or deforestation), local food self-sufficiency, and the loss of agrobiodiversity.

2.1.5.2 Technological changes in primary sectors (with direct uses of nature)

2.1.5.2.1 Significant Transitions in Agriculture

Agriculture has expanded significantly, in response to increasing demands – a trend not likely to decline in the near future, given the increases in livestock, human populations, and incomes. Yet such expansions can be either extensive, via increased area, or intensive, via increased yield (output per unit area, often increased through increases in the levels of inputs). At a global scale, intensification can imply greater shares of agriculture in some regions yet reductions elsewhere. Areas can fall while outputs hold steady, with increases in yields, as in high income countries in Latin America and the Caribbean (Figure S9). Illustrating regional variation, agricultural yields and areas rose concurrently in middle income countries, as well as in low- and middle income sub-Saharan Africa. For instance, there was a rise in both land area allocated to cereals and the cereals yield in sub-Saharan Africa, while other areas focused on raising yield without any significant increase in their farming areas. Most of the agricultural producers in this region are smallholders – including those farmers who practice slash-and-burn agriculture, which in some areas has contributed significantly to the losses of forest ecosystems and biodiversity.

Historically, the Green Revolution brought important changes with both opportunities and risks. During the 1960s, 1970s and 1980s, yields of rice, maize and wheat all increased steadily via the application of innovations in seed development, irrigation and fertilizer use. With billions added to the world population, since these practices began, many believe that without gains in outputs, famine and malnutrition would have been much greater. A nutrition expert who led the FAO, Lord Boyd Orr, was awarded a Nobel Peace Prize in 1949. The 'father' of the Green Revolution, Norman Borlaug, was also awarded a Nobel Peace Prize, in 1970, for 'providing bread'. Borlaug promoted the aggressive use of all advances in traditional methods – and then later championed genetic engineering – to develop varieties with greater yields, as well as resistance to diseases.

Yet, the Green Revolution highlights both the immense potential and significant trade-offs from innovations (Abramczyk *et al.*, 2017). Chemicals uses caused environment and health issues (Singh & Singh, 2000; WHO & UNEP, 1989; WRI *et al.*, 1992). Also, intensive fossil-fuel agricultural practices have negatively affected the water table in many regions. Food security fell for some, as production shifted out of the subsistence approaches which had been feeding many peasants in India. Also, monocultures have yielded poorer diets than traditional farming and agrobiodiversity. Looking globally, such practices also can lower food security through greater control of food systems by corporations upon whose inputs small- and middle-scale producers become dependent (Berlanga, 2017) and who may promote diets yielding poorer nutrition. Some practices may be subsidized by national governments, in the favour of large firms (FAO, 2009a). Also, despite food availability, famine has continued to come about, given societal failures (Drèze & Sen, 1991).

For nature, a gain from yields can be 'sparing' of land, i.e., less need for land for a given output (Stevenson *et al.*, 2013). Yet, evidence of land sparing is mixed across scales (local, national and global), intensification types (technology-driven versus market driven) and contexts (governance). Technology-driven increases in the outputs per unit area can reduce the pressure on land (Byerlee & Deininger, 2013) when intensification is far from frontier areas, so demands pull labor away from frontier areas. It can increase pressure by raising frontier productivity – increasing returns to lands (ibid). The market dynamics matter (DeFries *et al.*, 2013; Meyfroidt *et al.*, 2013; Rudel *et al.*, 2009b). For the IPBES regions, Africa responded to such increases in demands by increasing areas, while Asia and the Pacific responded mainly by increasing yields, using investments in both infrastructure and governance (IPBES, 2018b).

Potential adjustments to improve trajectories include applying IPLCs' agroecological innovations. Additional potential adjustments include various uses of biotechnology that, in traditional forms, have contributed for millennia. Providing foods and medicines via farmer selection and breeding of crops and animals has deep roots in local and traditional knowledge. Ongoing uses include a large number of plant varieties (for agrobiodiversity) and livestock breeds adapted to extremely varied soil, climate, disease, predation, and management contexts with specific qualities. These varieties and breeds constitute an asset to preserve for all of humanity, while modern agriculture has tended to homogenize the genetic diversity of crops and herds (see also chapter 2.2).

Further potential adjustments are genetically engineered seeds (genetically modified organisms -GMO) commercialized in 1996 and planted on ~185 million ha, across 26 countries, by 2016 (ISAAA, 2016) to increase insect resistance (IR) and herbicide tolerance (HT) in maize, soybean, cotton and rapeseed, thus lowering damages and crop losses (Lichtenberg & Zilberman, 1986). Hundreds of studies of farm-level impacts of HT and IR including field trials in many countries reveal substantial but not universal yield gain (Carpenter, 2010; Finger *et al.*, 2011; Qaim, 2009). Yet by increasing cotton yields 34%, corn yields 12% and soybean yields 3% such seeds are estimated to have spared 13 million ha of land from agriculture in 2010 (Barrows *et al.*, 2014b). Yield gains should be greatest in developing countries (Qaim & Zilberman, 2003), where pest pressures are higher, but smaller where pest damage is effectively controlled by conventional means (Carpenter, 2010; National Research Council, 2016; Qaim, 2009).

Evidence about lower pesticide and herbicide use due to such seeds is mixed. National Research Council (2000b) reported resistance in only three pest species in the first 14 years of commercial IR cropping, yet the cases have increased over time (Bennett *et al.*, 2004). The NRC (National Research Council, 2016) determined that damaging levels of resistance evolved in some insects targeted by IR crops where resistance-management practices were not followed. For instance, at least 10 species of weeds have evolved a resistance to glyphosate within the United States due to a nearly exclusive reliance on it for weed control (Duke & Powles, 2009). The situation may be improved by uses of varied weed control mechanisms (Barrows *et al.*, 2014a). Overall, as for other innovations, trade-offs emerged for genetically engineered seeds – including increasing costs, though control costs can decline sufficiently to improve farms' margins (Carpenter, 2010).

Trade-offs for GMO seeds might also include environmental concerns, such as impacts on crop genetic diversity, people's health and farmers' livelihoods. Gene flows across GMO and non-GMO seed can result from cross-pollination between GMO and non-GMO plants from different fields, as confirmed for the case of some landraces of maize in Mexico by a board of scientists (Commission for Environmental Cooperation, 2004), thus suggesting more attention is needed (National Research Council, 2010). Genes can also be transferred to wild plant species belonging to the same genus, which may have unpredictable effects. In terms of health, use of the herbicide glyphosate has been linked to an increase in cancer rates and teratogenesis in Argentina (Pengue, 2005) and some data suggest accumulations within the animal and human food chains (Krüger *et al.*, 2014) – yet the US NRC did not find evidence that consumption of GMO foods is riskier than non-GMO counterparts (FAO, 2000; National Research Council, 2000a, 2000b; WHO, 2005). Economic benefits and costs have been documented in varied contexts (Brookes & Barfoot, 2012; Kathage & Qaim, 2012; Qaim & de Janvry, 2003; Qaim & De Janvry, 2005; Zambrano *et al.*, 2009) yet there can exist concerns even about the economic and political pressure upon such science itself.

2.1.5.2.2 Limited Transitions in Biomass Energy

Innovation has also occurred in how energy is produced and used. More than in any other region, though, households in sub-Saharan Africa still depend upon biomass for domestic energy supply – with effects on health and nature (Arnold *et al.*, 2006; Bailis *et al.*, 2015, 2005; Foley, 2001; Ramanathan & Carmichael, 2008; Vlosky & Smithhart, 2011), particularly within East Africa. Approximately 95% of the people in Burundi, Ethiopia, Rwanda, Tanzania and Uganda use solid fuels to cook and to heat (GACC, 2017). Persistence within such behaviours is due in part to societal values of fuelwood, the slow development of markets for modern fuels (e.g., liquid petroleum gas) and clean cookstoves, with little information on personal or social benefits of switching fuels and stoves (Masera *et al.*, 2000; Schlag & Zuzarte, 2008). High capital costs and poor infrastructure have both also further inhibited the household adoption of modern fuels and technologies (e.g., electricity). In western Uganda, fuelwood consumption has contributed to deforestation (Dovie *et al.*, 2004; Ndangalasi *et al.*, 2007; Nkambwe & Sekhwela, 2006)though small-scale agriculture and timber remain the primary drivers (Geist & Lambin, 2002; Jagger *et al.*, 2012; Mwavu & Witkowski, 2008). Outside parks, half of tropical forest on private land is degraded (Nsita, 2005) in part to gain *de facto* property rights (Jagger, 2010).

Land-use change has greatly lowered the standing biomass over quite a short period of time (e.g., 26% in 2003-11). This can induce the planting of trees, as a response to scarcity of biomass. Yet it is only at small scale. Greater responses by rural households are in quantity and source of fuels – with significant shifts away from fuelwood from the forests to fuelwood from non-forest areas, which are larger where significant conversions have lowered biomass (Jagger & Kittner, 2017). More use of crop residues is consistent with this sort of shift. Shifting fuel types and sources has at least two direct impacts, at the level of a household: an increase in the use of low quality fuels, which raising exposures to household air pollution (Forouzanfar *et al.*, 2015); and an increase in the time required to collect fuel, with women primarily bearing the cost (Jagger & Kittner, 2017).

2.1.5.3 Technological changes, and trade-offs, within urbanization and industry

Transport investment and other innovations facilitated urbanization, generating both productivity – as economies diversified into manufacturing and services – and many other consequences. At the landscape level, transport investments also improved market access for peripheral areas. Still, most gains may go to urban areas and the linkages can further raise concentrations (Scott, 2009).

Within cities, transport costs again are critical. Given relatively fixed land areas, scale economies with high density eventually can be offset by congestion, i.e., traffic with time costs, so another urban investment has been in subways (Scott, 2009, chapter 4). Densities also raise the challenges of disease (Scott, 2009, pp. 140–141). Innovations such as vaccines address many threats, including in low income settings today, as do investments in sanitation that still affect choices of locations.

For direct uses of nature, scarcities have motivated innovations, including reductions in material or pollution intensities per unit production. Changes are due to both purely private motivations or regulations (see governance below) and, as consumptions rises, are needed to meet basic needs without raising consequent degradation. As consumers and as citizens, people may be willing to incur costs for cleaner production. For instance, households might on their own invest in stoves (Chaudhuri & Pfaff, 2003; Pfaff *et al.*, 2004a, 2004b; and many studies cited in World Bank, 2007) to produce cooking, heating and lighting services with far less pollution. This applies in rural areas but also has significant spillovers to ambient air quality within cities.

Scarcities of water quality and quantity clearly have motivated innovations, e.g., to purify water (Jalan & Somanathan, 2004) or to find safer sources (Madajewicz *et al.*, 2007). Understanding risk is critical for investments in both piped water (Jalan & Ravallion, 2003) and bottled (Fetter *et al.*, 2017). For water quantity, as for irrigation, at the local and community levels water shortages lead to social innovations such as local upstream-downstream groups to allocate water, as in Sri Lanka (Uphoff, 1996). Analogously, Ostrom (1990) documents a Spanish community's innovations to make water-use reductions physically and socially feasible, despite outputs goals.

Enormous shifts in energy efficiency are occurring, including in renewable energy. High prices for fossil fuels motivate such investments – just as recent lower prices for fossil fuels reduced the intensities of both conservation and exploration. Higher costs such as for extensions of electricity grids on rural frontiers also motivate investments in substitutes, such as solar, that degrade less. The diffusion or spreading of such innovations during industrial development can help nature (Popp *et al.*, 2010) and motivate further investments into research and development (Chuang, 1998; Golombek & Hoel, 2004). Broader use of such innovations could avoid the most environmentally destructive elements of economic development (Carson, 2009; Munasinghe, 1999), allowing 'leapfrogging' to modern technologies, e.g., grid or solar electricity, to furnish urban centers (Liu *et al.*, 2016a). Such diffusion may require regulation (Popp *et al.*, 2010) or subsidies to flourish (Fu *et al.*, 2011; Goldemberg, 1998; Murphy, 2001) yet in cases diffusion could even facilitate economic development (Munasinghe, 1999; Popp *et al.*, 2010) – including within fast-growing economies (Jayanthakumaran *et al.*, 2012).

Yet, as for other innovations, there are trade-offs including for nature – e.g., fossil fuel emissions from cars to windmills that hit birds. Replacing fuelwood with hydropower clearly aids forests and indoor air quality (Liu *et al.*, 2016a) but shifts water flows and flooding, with negative effects on biodiversity and more (Bunn & Arthington, 2002). While antibiotics have saved lives for over a century, and long been used in animal production, aquaculture, and high-value fruits and vegetables (McManus *et al.*, 2002) as well as feeds (Holmstrom *et al.*, 2003; Kumar *et al.*, 2005), they enter the soils plus surface and ground water and drain to coastal bodies of water where they do not readily degrade (Holmstrom *et al.*, 2003). Their widespread overuse also has led to a proliferation of antibiotic-resistant bacteria (Holmstrom *et al.*, 2003; Kumar *et al.*, 2005; McManus *et al.*, 2002) to the point of being recognized by the World Health Organization as a major, global public-health problem.

2.1.6 INDIRECT DRIVERS: ECONOMIC

2.1.6.1 Structural Transition

2.1.6.1.1 Economic Composition (shifts across sectors)

Since 1950, economies have shifted out of agriculture and towards both industry and services, in varied mixes. It is clear **(Figure 2.1.5)** that agriculture's share of value added is higher for low- than for high income countries, while the opposite ranking of shares holds in manufacturing and services.

For low income countries, employment shares across sectors were stable between 1990 to 2016 at ~65% in agriculture, ~9% in industry and ~26% in services. Across the same time period, however, the share of employment in agriculture fell 10% for all the middle income countries (down from ~46% in the lower-middle income and ~27% in upper-middle income countries), while the employment share in industry was relatively stable, rising about 4% during this period. Thus, employment went into services, which rose to ~37% in lower-middle and ~61% in upper-middle income countries, while also rising about 10%, to 73.1%, within high income countries.

Shares of GDP had similar trends, with agriculture falling for all country groups – albeit earlier for the high income but more smoothly for the middle income countries, stabilizing near 9% for upper-middle- and 16% for lower-middle income countries. From the 1960s, industry shares of GDP rose more steeply in high income countries, peaking at about 50% in 1974 while stabilizing at around 20% in low income and ~30% in middle income countries. Service shares increased steadily as well, reaching ~50% in low income and 63% in middle income countries by 2016. For high income countries, after fluctuating, they rose steadily until stabilizing around 68%.

According to the Vienna University of Economics and Business (WU, 2017), industrialized economies in Europe and North America have lowest material intensities (at 0.5 tons of material consumption per US$1000 of GDP in 2013, down from 0.8 and 1 in 1980, respectively). While this can be driven by technology shifts mentioned above, and by increased trade mentioned below, it **(Figure 2.1.6)** is partially due to the shift towards services.

Yet, scale still matters. Since 1950, world population grew by a factor of 2.7 and global material consumption by a factor of 3.7 (Schaffartzik *et al.*, 2014). Furthermore, resource use is unequal, linked to poverty. Western industrial countries that shared 44% of global GDP and 15% of world population in 2010 have been responsible for almost half of the global material consumption. In recent decades, there has been a shift toward China (Muradian *et al.*, 2012).

That shift in relative scales interacts with unequal intensities **(Figure 2.1.6)** to modify global intensities. Expansion in Asia raised average material extraction intensity for the global economy **(Figure 2.1.6)**, although without 'decoupling' the degradation of nature from economic growth (WU, 2017): while Asia's material intensity remained relatively constant for almost two decades after 1980 (at around 2.5 tons per $1000 US GDP), that measure rose (to 3.1 tons in 2013). African economies still have highest intensities but their improvement since 1980 (from 4.2 to 3.3 tons) has also been significant.

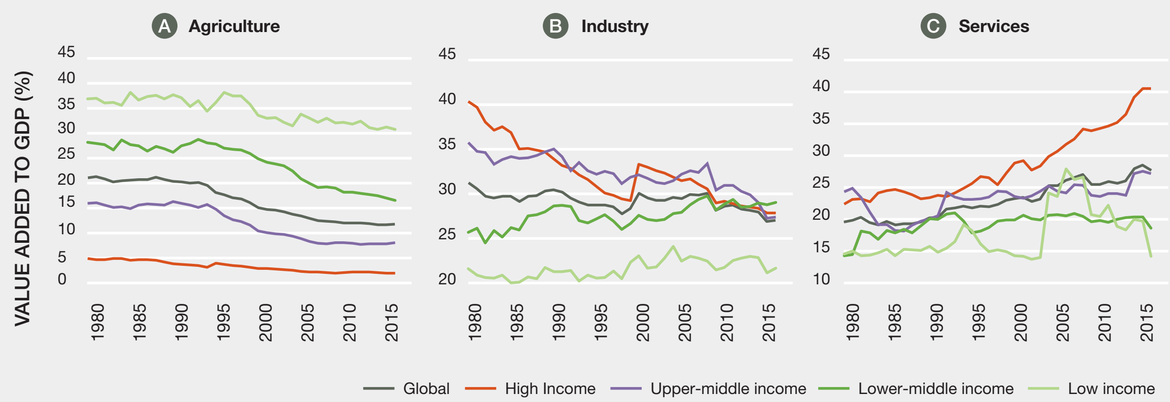


Figure 2 1 5 **Changes in economic composition: Value Added in Agriculture A versus Industry B and Services C.**

Values per country are averaged for World Bank income categories. Services sum service exports and imports then are divided by GDP, all in current U.S. dollars. Sources: (World Bank, 2018a, 2018b, 2018c, 2018d, 2018e)

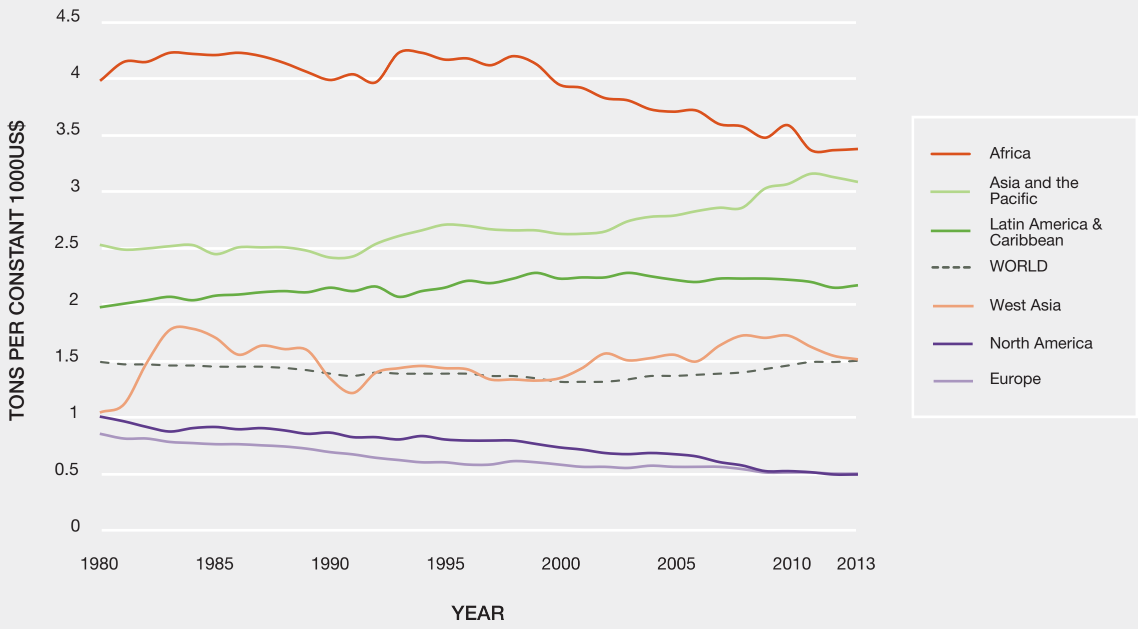


Figure 2 1 6 **Trend of material intensity (domestic material consumption in tons per constant 2005 US$1000 of GDP) by world region (1980~2013).**

Average values for six world regions and the world average for the tons of extracted materials necessary to produce economic output (in 1000 constant US $). Source: UN Environment Programme International Resource Panel Global Material Flows Database (https://www.resourcepanel.org/global-material-flows-database).

2.1.6.1.2 Factors Supporting Sectoral Shifts

Concerns about degradation are one motivation for individuals to put resources into transitions, such as across sectors. Such concerns or values are suggested when people take costly actions to maintain or to improve natural assets (e.g., Atkinson *et al.*, 2012; Freeman *et al.*, 2013; Merino & Martínez, 2014; Smith, 1996), e.g., treat water or use improved cooking technologies (Alberini *et al.*, 2010; Pattanayak & Pfaff, 2009), conserve ecosystems (Ferraro *et al.*, 2012; Kramer, 2007; Majuru *et al.*, 2016) and forests (Merino & Martínez, 2014). Scarcity of nature shifts the value placed on nature, as in the 'diamond-water paradox' (Farber & Griner, 2000; Heal, 2000): water is essential to sustain life yet, when perceived as plentiful, is used in non-conserving ways (Barnett & Morse, 1963; Pratt & Zeckhauser, 1996). Willingness to incur costs to shift behaviours also depends upon the belief that costs will be shared among interested parties and have positive outcomes. For instance, if families perceive that others free-ride on their actions, not engaging in contributions but benefiting, they too might free ride (Graves, 2009; Matta & Alavalapati, 2006; Starrett, 2003). Still, given a chance they may vote for rules that bind behaviours (Álvarez-Farizo *et al.*, 2007; Starrett, 2003; Wilson & Howarth, 2002; Wiser, 2007).

Beliefs about or perceptions of risk across sectors can help to drive such economic transitions (Lubell *et al.*, 2007; Whitehead, 2006). It can be hard to ascertain environmental quality, resulting in misaligned perceptions of safety and incorrectly low demand for actions that support nature (Orgill *et al.*, 2013). Salient information about the lack of environmental quality can spur demands for adjustments (Brown *et al.*, 2015; Hamoudi *et al.*, 2012; Madajewicz *et al.*, 2007). Within the provision of such information, one key issue is the multidimensionality of environmental amenities or, more generally, nature. For example, dimensions of drinking water that can affect behaviour include: price, convenience, reliability, taste, turbidity, and more (Farber & Griner, 2000; Jeuland *et al.*, 2016, 2014; Ma & Swinton, 2011). As a result, offering information on water's reliability alone may achieve little if other features affect decision trends.

When markets perceive scarcities, price rises, providing incentives to invest, as in forests (Foster & Rosenzweig, 2003), while countries may respond with policy (Mather, 2004; Mather & Fairbairn, 2000; Mather *et al.*, 1999a); for example, Bae *et al.* (2012) argue that South Korea's forest transition was due in some measure to reforestation policies. A different dynamic is a buildup of human capital that facilitates a switch to industry (Choumert *et al.*, 2013; Mather *et al.*, 1999a). Hecht *et al.* (2015) highlight the roles of urbanization and remittances in behavioural shifts (e.g., farmers migrate to the cities), while if populations stabilize, implying less growth in demands for crops, and in labor supply for agriculture, that can result in reduced pressure for new deforestation (Angelsen, 2007; Wolfersberger *et al.*, 2015). For instance, Rudel *et al.* (2000) found that for Puerto Rico, non-farm jobs pulled labor out of agriculture; agricultural production could then become more intensive, which could reduce the pressures on forests, while some agricultural lands could revert to forest (Rudel *et al.*, 2005). This lower pressure on forests can also result from a reduction of fuelwood collection (DeFries & Pandey, 2010).

2.1.6.1.3 Implications for Nature of Sectoral Shifts ('composition effects')

Sectoral shifts affect nature. A substantial literature during the 1990s found relationships between pollution concentrations and GDP per capita using data since World War II: as GDP per capita increases, pollution concentrations rise then fall (Gale & Mendez, 1996; Grossman & Krueger, 1991, 1995; Hilton & Levinson, 1998; Selden & Song, 1994; Shafik & Bandyopadhyay, 1992). In general, however, it appears that the specific relationships between pollution and economic growth can be quite different across the many types of pollutants, including in that they can be sensitive to the period of study and the quality of the data (Carson, 2009; Harbaugh *et al.*, 2002; Stern, 2004; Stern *et al.*, 1996). This speculative relationship was labeled the 'Environmental Kuznets Curve' (EKC, as a reference to Simon Kuznets' ideas in the 1950s about patterns of economic inequality for economic growth).

Parsing such patterns, Copeland and Taylor (2013) distinguish a few underlying changes that occur with the growth of an economy. Thus, when considering policies to shift outcomes, one might focus on any of these dimensions. The 'scale effect' refers to effects of the amount of production. The 'composition effect' refers to a change in the mix across types of economic activity – recalling that such changes in the sectoral mix could occur in part as a result of international trade. Last is the 'technique effect' that can apply to any type of economic activity, in which for private reasons and due to public policies innovations, as discussed above, there are lower damages per unit output for any sector (Brunel, 2017; Grether *et al.*, 2009; Shapiro & Walker, 2015). Some studies evaluate whether international trade induces such effects (Cherniwchan *et al.*, 2017; after Antweiler *et al.*, 2001; Cole & Elliott, 2003; Levinson, 2009; and Managi *et al.*, 2009).

These three effects can sum up to reverse trends for nature. One example of nonlinear and trend-reversing behaviour during economic development has been forest cover, i.e., 'forest transitions' (Mather, 1992). Various such sequences have been observed across the globe (Belay *et al.*, 2015; He *et al.*, 2014; Mather, 2007; Mather *et al.*, 1999b; Meyfroidt & Lambin, 2011; Rudel, 1998; Rudel *et al.*, 2002). While these forest cases do differ, their commonality is that in each case the trend in land use has been reversed (Barbier *et al.*, 2017) due to shifts in human choices, given changes in decision conditions. **Box 2.1.1** highlights the importance of understanding these dynamics well.

2.1.6.2 Concentrated Production

Corporations and financial agencies now control amounts of financial capital, which rival the revenues of the vast majority of countries. The top nine largest economies are countries but at least one company on its own could be the next largest, with larger revenues than the economies of India, South Korea or Australia (Anderson & Cavanagh, 2000). Another five corporations are, then, among the 22 largest 'economies' using these measures of size. One oil company, for instance, has a larger 'economy' than Mexico, India or Sweden. This size can affect the bargaining over any number of exchanges, from contracts with laborers to the exchanges of varied goods in which nature is embedded.

Box 2 1 2 Examples of supply chain concentrations relevant for uses of natural resources.

Coffee Despite variations, coffee beans have long been viewed as an undistinguished commodity. Around 70% of coffee is grown in farms under 5 ha (Fitter & Kaplinksy, 2001), so market power is at the other end of the supply chain: 10 global importers control over 60% of global trade. In some countries, buyers collude to drive down prices. Similarly, roasters are highly consolidated, e.g., five European companies controlled over 58% of the market in 1998. This affects governance of the chain and revenues by stage. Producers' prices remained flat or fell slightly over time while consumer prices increased and, in 1995, only 40% of the price stayed in the producing country to be split between producers and traders, implying at best zero rents at the start of the supply chain (Fafchamps & Hill, 2008; Fitter & Kaplinksy, 2001). A survey in Uganda in 2003 showed that the volatility of farm-gate prices did not reflect world prices, consistent with local traders exploiting small farmers' relative lack of information. Recently, though, the industry gives more attention to some of the characteristics of production locations. That can shift some market power to producers changing local communities' incentives to invest in nature and shifting the trade-offs from using it.

Horticulture (fruits and vegetables) Similar results hold in horticulture – boosted by transportation and refrigeration

Box 2 1 2

technologies. Many developing countries with geographical advantages in fruit and vegetables supply, including in Africa, try to reach European markets. Yet, European food retailing is extremely concentrated with the top 5 supermarket chains serving approximately 50% of the market in 1996, with producing countries capturing only 40% of the value. Europeans' demands for higher phytosanitary, social, and environmental standards – plus high predictability – helped out the larger exporters as well. In Kenya and Zimbabwe, for instance, few individuals and companies had capital to export (Dolan & Humphrey, 2000) and such opportunities made them more productive and also more successful within their domestic markets (Pavcnik, 2002). For flowers, recent technological innovations supported expansions by the traditional producers. Ecuador possesses advantages with year-round supply and cheap labor – yet without producer cooperation and differentiated products these advantages do not yield market power. If flower producers are not aware of final market conditions but informed by few importers, they get small profit shares. These dynamics affect the linkages from consumption to degradation and its local net benefits.

Textiles and Apparel In the 1980s, Mexican producers of blue jeans, for instance, moved from serving a small domestic demand to serving the US by partnering with 4 major manufacturers (Bair & Gereffi, 2001). By 2000, several top US retailers joined them, expanding the market. However, the fairly homogeneous nature of their output and a reliance on external inputs was conducive to only small rents, spurred an attempt at upgrading into marketing and design via their own brands. Yet, as in African horticulture, only the few most productive and capitalized firms could manage this. That increased market power and concentrated rents for a domestic elite (Bair & Gereffi, 2001) – while pushing down wages, which exacerbated domestic inequities. The textiles trade used to be driven and governed by cotton producers. However, consolidation of retailers shifted the governance of the supply chain downstream. Thus, cotton producers have shifted to trying cottonseed processing, where market power is not so menaced by international competition and shifting demands (Hutson *et al.*, 2005). Generally, shifts in the power between retail, upstream, and intermediate actors are important for understanding growth implications for the newly industrialized economies (Conway & Shah, 2011). Many developing countries are exporting textiles given foreign requirements that could boost internal productivity. Yet, in terms of surpluses earned, this may raise in-country surplus yet not help cotton per se. All of the dynamics are important determinants of the economic and environmental trade-offs faced, an understanding of which in this case can greatly inform policies focused upon water pollution.

Furniture (forests upstream) This chain has five main stages: forestry; sawmills; manufacturers; buyers and retailers. Demand shifts and retailer innovations raised retail competitive pressures and buyer concentration (Kaplinsky *et al.*, 2003). Traditionally labor intensive, this chain has a trend of falling prices, driven by rising competition and global price convergence with global sourcing (Kaplinsky & Readman, 2005). Buying is now done by a few actors who control higher-value-added activities such as marketing, design and after-sales service. Manufacturing is heterogeneous. South African producers are traditionally large, yet Kaplinsky *et al.* (2003) note declining prices due to the better competitive positions of buyers and suggested shifting into a different value chain (Saligna wood), with varied uses that allow entry with higher unit prices. Ivarsson and Alvstam (2010) examined firms' subcontractors in China and South East Asia. Over half sell over 60% of output to one firm, whose bargaining power implies a larger share of surplus, consistent with Gereffi *et al.* (2005) since the captive supplier is subject to the market power of that 'lead firm' (see also taxonomy in Milberg, 2004). Which chains suppliers sell into greatly changes their incentives for conservation of nature.

Large financial players also have emerged*.* Those include private equity investors, such as infrastructure investment funds, or institutional investors, such as pension and mutual funds (particularly mandatory pension contributions), all attracted by opportunities including the large infrastructure developments (Arezki *et al.*, 2016). To some extent, an increased role for private capital goes along with a reduced or altered role of governments within infrastructure investments. In addition, complex instruments and funding flows can make it hard to trace the lines of ownership, or responsibility, affecting governance.

2.1.6.3 Trade

2.1.6.3.1 Goods & Materials Flows

Flows of goods and inputs rise as smaller shares of resource needs are satisfied domestically and separates consumption from production (Lenzen *et al.*, 2012b). Over three decades, the global exports of food have risen 10-fold (UN COMTRADE, 2013). Trade that crosses national borders affects 41% of materials extracted (Robertson & Swinton, 2005; Wiedmann *et al.*, 2015).

Comparing regions, North-East Asia is by far the biggest net importer of raw materials **(Figure 2.1.7)**, with very high net imports of ferrous metals, petroleum and coal per China's enormous demands for these raw materials within industry and infrastructure. The biggest net exporters are Oceania (mainly Australia), Eastern Europe (mainly Russia), South America (mainly Brazil) and Western Asia (mainly Saudi Arabia) – which export based upon immense natural-resources endowments. Australia has large deposits of metal ores and coal, for instance, while for Russia oil and gas reserves have played important economic roles, yielding considerable export revenues.

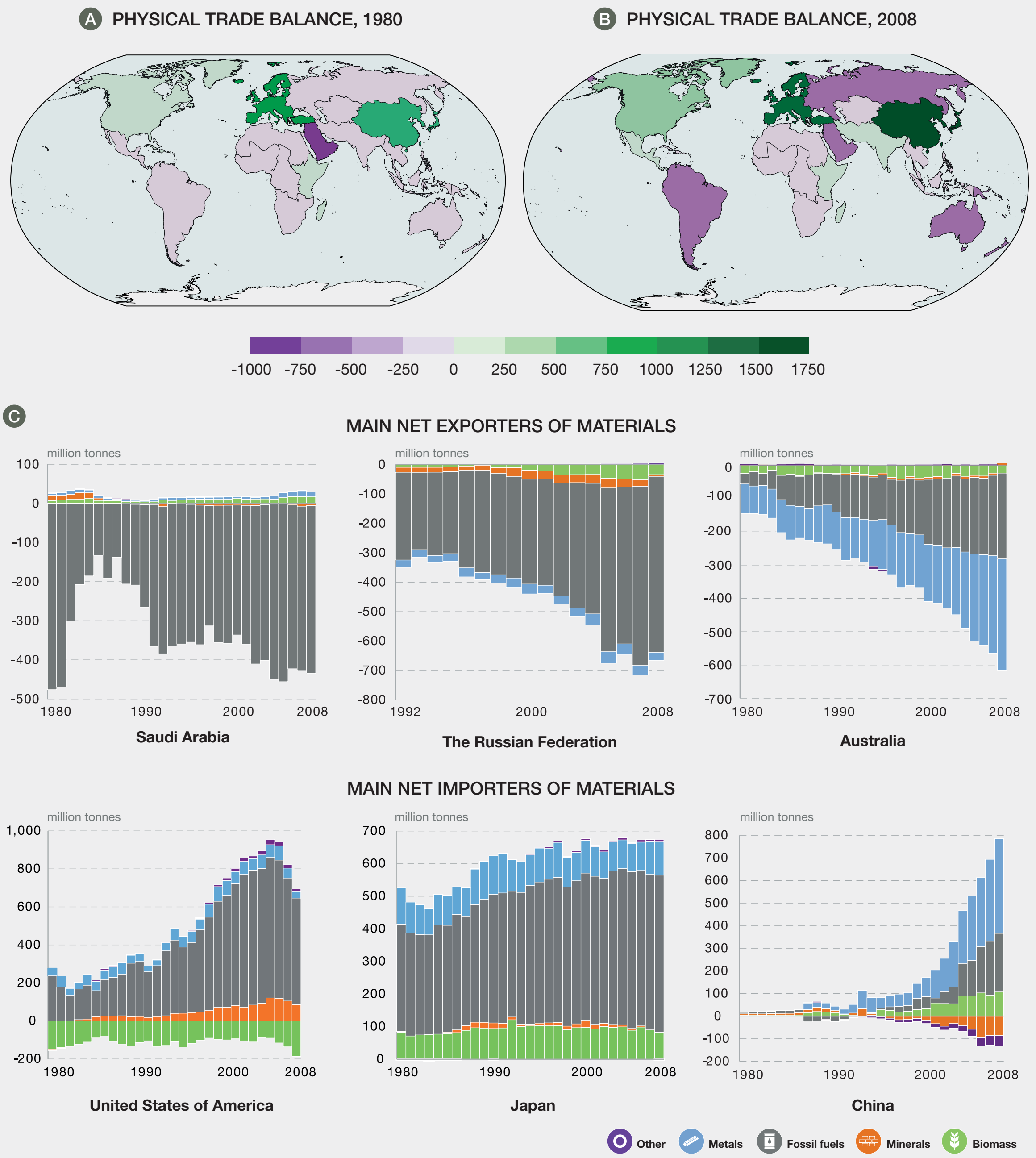


Figure 2 1 7 The physical dimension of global trade. Physical Trade Balances, by IPBES regions, A in 1980, and B in 2008 (millions of tons).

The regions in magenta are net exporters of materials, while regions in green are net importers. Underneath are the top three countries in terms of both net imports and net exports, by material categories and physical trade balances. Source: own elaboration with data from WU (2017) (A, B); Dittrich *et al.* (2012) C.

2.1.6.3.2 Telecoupling and Spillovers: trade-offs embedded within the trading of goods

Ecosystems are ever more shaped by distant interactions among countries or 'telecouplings' as the world is becoming more global. Telecouplings refer to socioeconomic and environmental interactions over distances (Sun *et al.*, 2017).

Spillovers occur as a result of these telecouplings: effects of (seemingly unrelated) events in one region clearly are experienced in other regions.

The growing trade of goods implies many displaced impacts upon nature – between one quarter and one half of the environmental impacts from consumption are felt in regions other than where the consumption occurs: CO_2 emissions, chemical pollutants, biodiversity loss, and depletion of freshwater resources (IPBES, 2018a). For instance, 30% of threatened species (Lenzen *et al.*, 2012b) and 32% of the consumption of scarce water, i.e., water used within regions with water scarcity (Lenzen *et al.*, 2013), have been linked with international trade. This illustrates spillover effects from consumption of traded goods, in which environmental costs from the production of goods to supply international markets are being incurred far from where the consumption occurs.

Displaced deforestation, pollution, water scarcity, soil loss, and erosion all occur at the expense of ecosystems in other countries, in particular developing countries (Lenzen *et al.*, 2012a, 2013; Moran *et al.*, 2013). Studies considering the impacts on biodiversity. Chaudhary and Kastner (2016) found that 83% of total species loss is due to agriculture for domestic consumption while 17% is due to the production for export. Exports from Indonesia to the USA and China generate high impacts (20 species lost regionally for each). An estimated 485 species currently face high risks of extinction in 174 countries, with about one third of those being a result of current land use patterns **(Figure 2.1.8)**. Perhaps 12% of premature deaths in 2007 from air pollution were caused by pollutants generated by other regions, with 22% arising from the exports of goods and services (Zhang *et al.*, 2017). Exporters get economic returns and technological advancements (Daniels, 1999) but also host negative environmental consequences (Schmitz *et al.*, 2012) – including from monocropping plantations, e.g., for soybean in the Amazon and Chaco, avocados in Central Mexico or cotton, sugar, palm oil and biofuels elsewhere, with health impacts (Lin *et al.*, 2014; Zhao *et al.*, 2015).

It is important to recall that sustainability in one country can rely upon unsustainability in others. Meyfroidt and Lambin (2009) find a 'forest transition' in Vietnam involved displacing extraction elsewhere (Dasgupta *et al.*, 2002; Levinson & Taylor, 2008; Stern, 2004; Suri & Chapman, 1998). In the US, the New England region's forests regrew as railroads linked to the Midwest region that grew in exports due to high agricultural productivity (Pfaff & Walker, 2010). Along those lines, Kull *et al.* (2006), Meyfroidt *et al.* (2010), and Meyfroidt and Lambin (2011) tracked trade to link with forest transitions. Leblois *et al.* (2017) find that countries at the beginning of forest transitions deforest thanks to trade, while those at the end reforest from trade.

Trade redistributes emissions of greenhouse gases **(Figure 2.1.8)**. Production for international markets links with 26% (Peters *et al.*, 2011) to 30% (Kanemoto *et al.*, 2014) of global carbon emissions. However, such effects have been neglected in the relevant international treaties, as carbon accounting was considered solely per country – without including the shifting of emissions from importing to exporting nations (Kanemoto *et al.*, 2014; Peters *et al.*, 2011). These spillovers in fact are larger than reductions in emissions. Thus, relocation of production and degradation affects evaluations of net impacts of governance. Regulations on emissions may appear to be 'effective' in regulated locations, even if degradation simply has shifted to other regions. For instance, since 1990 the UK had measured reductions of up to 16% of domestic CO_2 emissions within its energy and water sectors, yet the CO_2 emissions embodied in imports in those sectors, i.e. those emissions associated to the production of products that are imported, rose 208% in the same time period (Kanemoto *et al.*, 2014).

As to the motivations for such enormous increases over time in the global trade interconnections (and maybe for the lack of interest in tracking them for governance), without a question national scarcities of nature's contributions often have been part of the drive underlying country interests in accessing the nature elsewhere, either directly or embedded in outputs (Figure S11) (Galli *et al.*, 2012; Verones *et al.*, 2017). Exports from the global South, for instance, often have been based on natural assets, including oil and gas (Muradian *et al.*, 2012) that were demanded by countries with growing economies but also growing scarcities of energy. Among the importers of nature, Europe had highest trade flows balances which shifted nature's degradation elsewhere (Dittrich & Bringezu, 2010), yet natural flows are a global phenomenon. In short, as illustrated in **Figure 2.1.8**, exports can have significant costs in local nature degradation.

Turning to potential socioeconomic trade-offs involved, which can vary with implementation as trade can occur on positive or negative terms, the large trade flows sometimes have arisen under contracts with unbalanced sharing of gains (Arduino *et al.*, 2012) and such inequities can get institutionalized in intergovernmental agreements. Merme *et al.* (2014) find different distributions of hydropower benefits in the Mekong Basin under actual contracting than would be expected if all exchanges had occurred under transparent contracting in which all parties were fully informed. Arduino *et al.* (2012) consider how many rentals of valuable lands occurred for low fees, evading Tanzanian laws (and resulting in water pollution). Houdret (2012) connect costly uses of water to the mismanagement of public-private partnerships in Morocco. Transboundary rivers feature conflicts (Biswas, 2011), e.g. a lack of trust between India, Nepal, and Bangladesh over the Mahakali River Treaty despite prior political processes (Khalid, 2010).

In such contexts, some refer to resource exchanges not as 'trade' but as 'grabbing' – in order to explicitly question the adequacy of the levels of compensation involved (Dell'Angelo *et al.*, 2018; Franco *et al.*, 2013). The appropriate label is not always clear. Acquisitions without compensation, such as water diversions or cross-border pollution ("e-waste" in Awasthi *et al.*, 2016), may clearly be 'grabbing'. Yet, adequacy of compensation is "in the eyes of the beholder". Trade can allow all countries to gain from others' strengths, but price is critical for equity – including when the global South imports (potentially displacing production). 'Grabbing' parties may justify transactions by arguing that their investments raise the access to or the productivity of underutilized resources. That possible efficiency rationale for the external inputs does not directly address the distributional consequences for vulnerable local populations.

Nature-economy trade-offs also arise in the conservation of nature in lower-income and least developed countries that effectively exports global public goods, such as carbon storage or species habitat, through forest protection. This may earn global funding transfers, also raising issues of adequate compensation. Overall impacts upon local well-being depend on who gets paid, how much, in which conditions.

Concerning lands, over 1000 deals have been recorded, globally, covering ~50 million hectares. Africa hosts over 400 for ~10 million hectares (Anseeuw *et al.*, 2012; Nolte *et al.*,

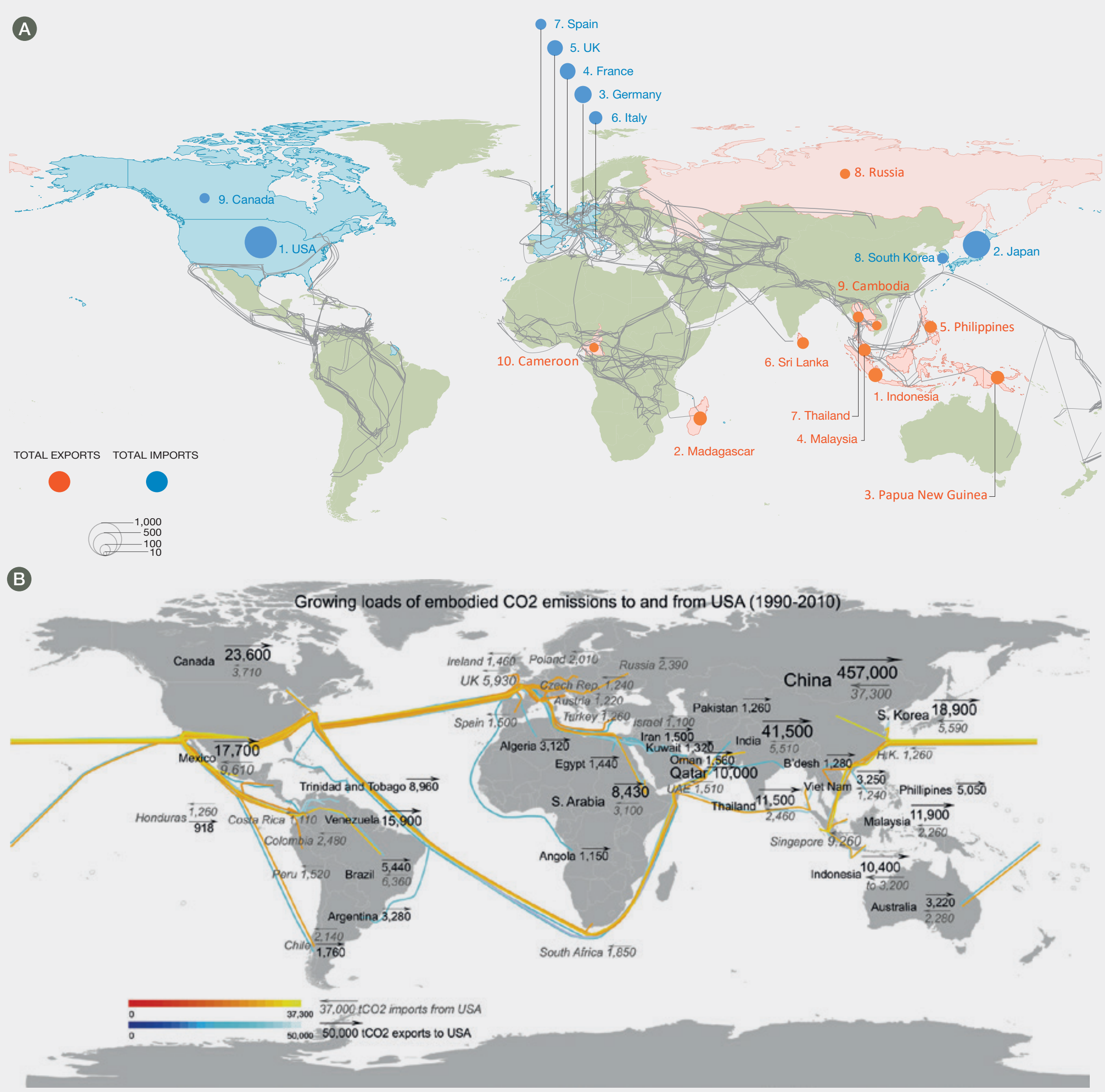


Figure 2 1 8 **Global trade imports and flows measured as biodiversity and CO_2 footprints.**

A Biodiversity footprint showing top ten exporting countries associated with pressures on biodiversity in developing economies and top ten importing countries with respect to pressures on biodiversity (developed and emerging economies); thicker arrows indicate a larger number of threatened species associated with that bilateral trade flow. B Largest growing flows of embodied CO_2 (amount of CO_2 emissions associated to the production of products that are imported to the USA (rightward arrows) and from (leftward arrows), measured as absolute growth 1990-2010 in tons of CO_2). Source: (IPBES, 2018a; Kanemoto *et al.*, 2014; Lenzen *et al.*, 2012a).

2016). Rulli *et al.* (2013) estimate up to 1.75% of cultivable land has been 'grabbed'. Many deals involve conversion of savannah or forest to crops or trees such as oil palm (Borras Jr & Franco, 2012), using water from river basins (Borras Jr *et al.*, 2011). In Africa, investors are largely firms, at times in partnerships with national and local governments. Little evidence exists concerning free, prior, and informed local consent. Instead, weak consultation is reported, yielding protests since customary ownership and custody, with stewardship, coexists with legal state ownership that locally may not be seen as legitimate (Nolte, 2014; Nolte & Väth, 2015). Projected local benefits, e.g., productivity and thus job creation that often is used as justification, have been mixed (Kleemann & Thiele, 2015; Nolte & Väth, 2015). The potential for such conflict must reflect the large shares of global lands held under customary or community-based local regimes (IUCN, 2008), including a significant share held or managed by Indigenous Peoples and Local Communities (see chapter 1) (USAID, 2012).

As to existing plans to address the world's growing agricultural demands, linked also with water, within sub-Saharan Africa, Latin America, Eastern Europe and Central Asia, the lands said to be "available" often also are under formal public ownership and yet used by local groups, including indigenous communities (RRI, 2014). The same issues may arise, then, since regions may suffer implicit "land grabbing" by the consuming countries, via production of agricultural exports which can threaten local food security. The "available" lands also sometimes coincide with areas of high biodiversity. Summing up, if and when lands are converted, justice concerns potentially add to costs in terms of losses of ecosystem services (Sayer *et al.*, 2008).

'Water grabbing' raises all of the same issues as above, again including for agriculture, as noted, and for mining or hydropower generation or often for industry (Merme *et al.*, 2014; Sosa & Zwarteveen, 2012). For the irrigation of cultivable land, demands have been labeled "green" – i.e., extracted by the plants – or "blue" – i.e., pumped (Dell'Angelo *et al.*, 2014; Rulli *et al.*, 2013).

2.1.6.4 Financial Flows

2.1.6.4.1 Remittances

Growing financial remittances after migration, i.e., transfers back to migrants' places of origin, can significantly affect important outcomes for nature within the sending regions. From 1990 to 2015, such remittances rose over 5-fold and were particularly important for poor households in developing countries (e.g., China, India, Philippines, Mexico have the largest absolute inflows of remittances while, as fractions, Tajikistan, Nepal, Moldova and Haiti are high, ranging from one fifth to half of GDP). In 2014, 250 million migrants sent 583 billion US dollars. As the remittances raise disposable income, they can alter consumption patterns in communities. That can, in turn, promote land-cover change due to growth of agricultural activities that need land. In other cases, however, migration yields reductions in subsistence agriculture and, thus, the pressures on lands.

Nine out of the ten most biodiverse countries, globally, are characterized by large- and medium-sized diasporas plus medium to high dependence on remittances. The countries with the largest share of forest lands are not, however, high in migration or dependent upon remittances. Among the top ten countries in the world in terms of highest deforestation rates from 2000 to 2012, only China and the Democratic Republic of Congo have high migration – but even they have low and medium dependence upon remittances. None of those top ten have high remittances per capita.

2.1.6.4.2 Financial Standards

Private investments also are growing and can be very influential. Yet financial returns often do not recognize nature's contributions (World Bank, 2018o). For instance, for sub-Saharan Africa, despite substantial risks of natural depletion, in official assessments total wealth changes are not considered even for large investments. Thus, natural regrowth is not valued, while short-term income from the degradation of nature is counted (World Bank, 2018o).

International institutions can set out environmental and social standards for financial institutions and transactions that borrowers should follow throughout project cycles. Standards can help in doing due diligence to assess risks (EIB, 2014; IFC, 2012; The Equator Principles Association, 2013; World Bank, 2017b). Considering environmental, social and governance (ESG) factors in principles facilitate risk management (Sullivan *et al.*, 2015; van Duuren *et al.*, 2016) that with appropriate counting raises the risk-adjusted, long-term returns from investments (WEF, 2013) and affects assessments of firms' performance (Delmas & Blass, 2010) and financial portfolio (Vörösmarty *et al.*, 2018). By 2016, $23 trillion of assets were managed with 'responsible' strategies that could be of this type – a rise of 25% since 2014 (US SIF Foundation, 2016). Some fund managers aim to track performance with regard to the Sustainable Development Goals, while others track specific social or environmental objectives (Global Impact Investing Network, 2017; GRI *et al.*, 2015; Polasky *et al.*, 2015). Some ideas have been agreed for such guidelines (e.g. The Natural Capital Declaration, GRI Standards for Environmental Reporting; SASB Sustainability Accounting Standards) (GRI *et al.*, 2015; NCFA, 2018; SASB, 2014) but metrics remain a major challenge.

2.1.6.4.3 Tax Havens

The roles of tax havens in the global outcomes for nature are only starting to be documented, given ever larger roles in the global economy. Recent evidence starts to identify possible links between the use of such jurisdictions and the environment (Galaz *et al.*, 2018). Funding via tax havens has been shown to have provided 68% of foreign capital for Amazonian soy and beef production and to have supported 70% of the vessels implicated in illegal, unreported and unregulated fishing.

2.1.7 INDIRECT DRIVERS: GOVERNANCE – MARKET INTERACTIONS

Certification schemes aim to inform supply chain production and consumption. Market-based schemes aim to signal consumers' values to provide incentives for producers to shift processes (Haufler, 2003; Mayer & Gereffi, 2010; Raynolds *et al.*, 2007). Environmental certification exists

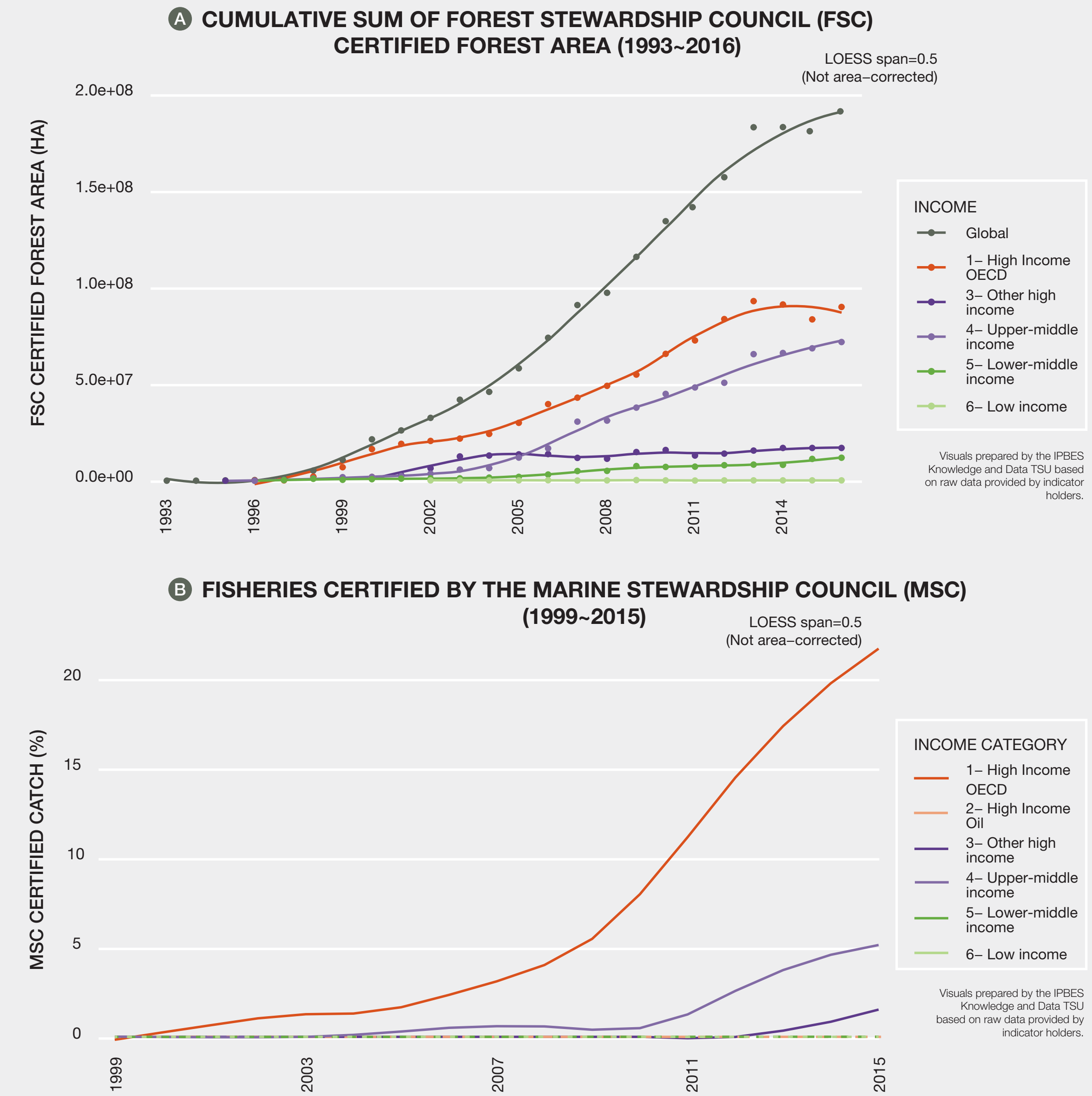


Figure 2 1 9 **Temporal trends in certifications.**

A Cumulative sum of FSC Certified Forest Area (1993~2016); B percentage of fisheries certified by Marine Stewardship Council (1999~2015); this is the sum total of all green weight catch from all certified fisheries, or the weight of landed fish before processing (catch of whales, seals and other aquatic mammals are not included when calculating global catch to compare to MSC fisheries as they are out of scope for MSC certification). Trends show averages from country data, using the World Bank income categories Source: (FSC, 2017).

for a wide range of products – including timber (Klooster, 2005; Molnar *et al.*, 2011) coffee and cocoa (Raynolds *et al.*, 2007; Tscharntke *et al.*, 2015), fish (Constance & Bonanno, 2000), soybean and palm oil (Schouten *et al.*, 2012), nuts and other non-timber forest products (Shanley *et al.*, 2002), horticulture (Hatanaka *et al.*, 2005), floriculture (Hall *et al.*, 2010), biofuels (Selfa *et al.*, 2014) and tourism (Font *et al.*, 2007). Certified area for forests and marine schemes has increased greatly since 2000 **(Figure 2.1.9)**.

Standards dictate the information included within 'labels', which inform actors along the supply chain. They might stimulate a willingness to pay on the part of consumers who value particular practices, as well as firms concerned about their brand reputations as well as political responses (Bartley, 2007; Cashore, 2002; Gereffi *et al.*, 2001; Hatanaka *et al.*, 2005; Potoski & Prakash, 2005). Most of the environmental certifications utilize third-party verification. Thereby, NGOs, scientists and environmentalists design standards and practices alongside industry actors (Cashore *et al.*, 2004; Cheyns, 2011; Gereffi *et al.*, 2001; Hatanaka *et al.*, 2005). Yet, challenges have existed for achieving large impacts, suggesting not only further care in program design and implementation but also a rigorous evaluation of whether impacts arose.

One challenge is that many standards consider production processes, i.e., what the producers did, rather than qualities of outputs that result or specific impacts of the processes such as on nature, creating issues of transparency (Dankers & Liu, 2003). Standards aim to assess things including sustainability, biodiversity, ecosystems, absence of chemical fertilizers and pesticides, quality management, and sociopolitical attributes such as labor and indigenous outcomes (Badgley *et al.*, 2007; Bear & Eden, 2008; Klooster, 2010). Yet, this may present difficulties in measuring the outcomes, or associating them with certification. Many schemes also remain limited in spatial scope. These can make it more difficult to link such schemes with observed differences in, for instance, regional forests and fisheries (Ebeling & Yasué, 2009; Rametsteiner & Simula, 2003).

One additional challenge is to avoid marginalization of smaller producers. Standards developed for large-scale producers or consumer preferences in 'northern' countries may be difficult to apply within small-scale or developing contexts (Foley & McCay, 2014; González & Nigh, 2005). Complex standards may impose requirements that are harder for small-scale producers (Selfa *et al.*, 2014; Tovar *et al.*, 2005), who may not participate in shaping them (Cheyns, 2014; Köhne, 2014; Vandergeest, 2007). There may be costs that smaller-scale and developing country producers with limited capital cannot cover (Clark & Martínez, 2016; Pérez-Ramírez *et al.*, 2012). Their costs may even be higher (Blackman & Rivera, 2011; Lyngbaek *et al.*, 2001; Oosterveer *et al.*, 2014) yet in some cases, they receive political or social support (Quaedvlieg *et al.*, 2014).

Another challenge is to balance rigor and transparency in rule-making process and accessibility (Bush *et al.*, 2013). Legitimacy is often constructed through processes that are open and democratic and incorporate inputs from a variety of actors, including industry stakeholders. That could, however, generate a concern about businesses asserting their interests to the detriment of others (Eden, 2009; Hatanaka *et al.*, 2005; Havice & Iles, 2015; Klooster, 2010). Further, if schemes tend to expand, including in competition among schemes, stringency of such standards could be driven down (McDermott, 2012; Mutersbaugh, 2005; Taylor, 2005). In addition, there may be confusion induced by the presence of multiple such schemes, including industry-led schemes that compete for clients with third-party schemes (Cashore *et al.*, 2007) and can generate situations in which the consumers may not fully understand what each certification label indicates (Bear & Eden, 2008; Yiridoe *et al.*, 2005).

Large-scale public standard setting may then help. For example, the US Lacey Act or the EU's FLEGT (Forest Law Environment, Governance and Trade Mechanism) aim to prevent imports of illegally harvested forest products. FLEGT's Voluntary Partnership Agreements (VPAs) are one effort, that emphasizes independent monitoring, to collaborate with partners in source countries. To improve forest governance, they involve non-state actors such as civil society organizations and the private sector in processes sometimes requiring reconciliation as well as consolidation of conflicting laws (Bollen & Ozinga, 2013). Each VPA includes a system to identify legal products and to license them for import to the EU – with capacity building to help partner countries set up the licensing scheme, enforce, and where necessary reform laws. Legal assurance systems (LAS) are to distinguish illegally produced forest products, with five elements: a definition of legal, in light of producing country laws; a traceability system; a system to verify compliance with the legality definition and traceability system; a licensing scheme; and independent audit capacity.

Guidance for implementation was sought via consultation with major wood-producing countries (Ghana, Cameroon, the Democratic Republic of the Congo, the Central African Forest Commission (COMIFAC), Malaysia, Indonesia and Vietnam) (Hajjar, 2015; Tegegne, 2016) and VPAs have been signed with Ghana, Cameroon, Central African Republic, Republic of Congo, Liberia and Indonesia – while six more countries have been in negotiations (Côte D'Ivoire, the Democratic Republic of the Congo, Gabon, Guyana, Honduras and Laos). Indonesia has done the most such licensing and monitoring, licensing timber and wood-product shipments to the EU and applying standards to shipments to other countries. Some countries that have not yet started such licensing have improved in transparency, while acquiring significant skills, knowledge, and capacities in terms of these FLEGT systems for sharing information, monitoring and traceability of timber.

If rights are not clear, respected, and enforced, certification's outcomes can look very different. Outcomes of the types of certification we considered above appear to depend on effective rights. Forest certification, such as by the Forest Stewardship Council (FSC), considers logging within concessions or communities with effective rights – such as collective *ejido* tenure in Mexico – granted by the state but not always strongly enforced). Studying FSC in Peru, Rico *et al.* (2017) find that where concessions exhibit lower deforestation than surrounding areas, suggesting some effective enforcement, certification had a small positive effect upon forest conditions. However, where concessions had more forest loss than outside, certification has not had significant effect. It also has none within Cameroon (Panlasigui *et al.*, 2018), where PAs do not fare better than outside, suggesting significant limits on forest enforcement. From these examples, it seems that effective rights enforcement complements certifications.

2.1.8 INDIRECT DRIVERS: GOVERNANCE – LOCAL COMMUNITY COORDINATION

Commons or collective property system arrangements are present across the globe in spite of the historical challenges and pressures. Today, they often retain some of their traditional meaning, as part of collective management arrangement of common-pool resources, yet they have responded to various changes. To an extent, awareness of our dependence upon common-pool resources has brought attention to the centrality of property regimes – and their overlaps – for issues including water governance, waste management, congestion, landscape management, and climate change.

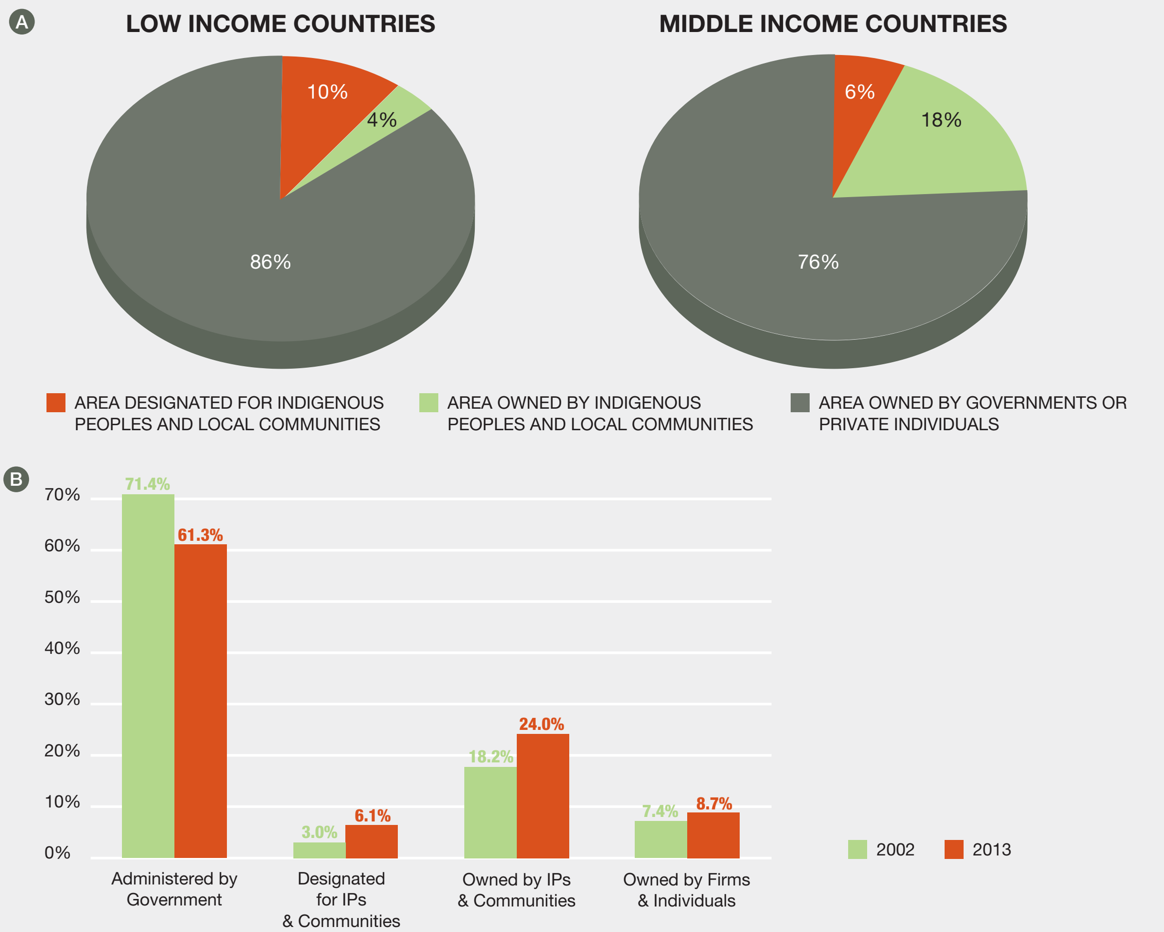


Figure 2 1 10 **"Recent status and temporal change for a number of categories of common land (versus other lands):**

A area under communal tenure regimes for low and middle income countries (including lower-middle and upper-middle income countries), and B % change in statutory forest land tenure in LMICs (low and middle income countries) from 2002 to 2013. Categories shown: area designated for Indigenous Peoples and Local Communities, area owned by Indigenous Peoples and Local Communities and the areas owned by governments or by private firms or individuals. Source: (RRI, 2014).

Historically, and currently in many regions of the world, rural land was owned and governed by local communities – a significant share under varied customary-property-regime arrangements (see chapter 1 for area estimates). State recognition of legal rights applies to only a fraction of the lands (Wall, 2014). Without recognition of legal land rights, many Indigenous Peoples and Local Communities are vulnerable to direct dispossessions and, thus, losses of livelihoods and culture. Customary property systems have often failed to stand up to external pressures related to colonization settlement, expansion of commodity production for agriculture, or forestry, mining, infrastructure extensions, government programs, and conservation programs.

Several international frameworks have tried to address these issues, including the International Labor Organization Convention 169 (ILO, 1989), UN Declaration on the Rights of Indigenous Peoples (UNDRIP), and FAO Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries, and Forests (VGGT) (FAO, 2012b). Also, in many regions communities have gained rights to land resources **(Figure 2.1.10)**, especially within Latin America (Agrawal *et al.*, 2008; Sunderlin *et al.*, 2008; White & Martin, 2002). Across developing countries, it has been estimated that around 27% of the forests are owned or designated for management by local communities, with rights to over 200 million hectares transferred (or just recognized) since 1985. In 2008, globally 24% of forests were owned by communities; 6% owned by governments but used by communities; 9% in private property; and 61% in public hands (Sunderlin *et al.*, 2008).

Securing collective rights and institutions has been considered as a key underlying component in sustained use and management, as communities change with external and internal circumstances (Ostrom, 2000). There are no statistically representative global analyses of effects on nature of community governance, yet there are observations from many case studies: e.g., using data from 80 cases of forest commons across Asia, Africa, and Latin America, Chhatre and Agrawal (2009) associated more local rule-making autonomy with higher carbon storage and livelihood benefits. This can occur because if the sustainability of a locally-relevant common-pool resource system is threatened, local resource users may invest to create new institutions to better local governance.

The recognition that local resource users sometimes craft effective governance has contributed to increased enthusiasm for the devolution of responsibilities to communities for the management of nature (seen within **Figure 2.1.10**). Community-based management after decentralization also can be successful (Amede *et al.*, 2007; Gibson *et al.*, 2005; Kearney *et al.*, 2007; Kellert *et al.*, 2000; Leach *et al.*, 1999; Ribot, 2004; Webb & Shivakoti, 2008) and merits additional understanding too. Further cases of common-pool resources suggest that – without privatization or nationalization – resource users do engage in collective actions to create local institutions to limit inefficient uses of natural resources, including in Indigenous Communities (Acheson, 1988; Baland & Platteau, 1996; Berkes, 1986; McKean, 1986; McKean & Cox, 1982; Ostrom, 1990; Poteete & Ostrom, 2004; Tang, 1992; Undargaa, 2017; Wade, 1988). Motivations for doing so can be clear when locals get direct resource benefits and, thus, are vulnerable to any unsustainable trends (Costanza *et al.*, 1998; Eerkens, 1999; Kelbessa, 2013; Ola-Adams, 1998; Shengji, 1993; Wade, 1988).

Indigenous Peoples and Local Communities have an advantage in designing local institutions, given knowledge of local ecological and social systems (Berkes *et al.*, 1998; Colding & Folke, 2001; Comberti *et al.*, 2015; Gadgil *et al.*, 1993; Nakashima *et al.*, 2012; Ostrom, 1990; Tang, 1994). Furthermore, as locals cross paths more frequently, they can monitor and enforce at lower costs, while also communicating expectations (Berkes, 1986; Ostrom, 1990) and imposing local social costs for violations of agreements. Also, without local participation in the crafting of such rules, constraints may lack legitimacy and credibility and, thereby, be inadequate for conservation (Costanza *et al.*, 1998).

Naturally, past governance institutions have not all been successful, and that reveals the roles of information, values, group size, boundaries, cultural and social homogeneity, and leadership that lowers transaction costs for interactions (Baland & Platteau, 1999; Ostrom, 1990; Wade, 1988). Learning across recent decades highlighted that critical contributions to nature, and livelihoods, have required shared norms, trust, and networks which can be developed through time and effort in reaching agreements (Agrawal, 2001; McKean, 1999; Meinzen-Dick, 2014; Pretty & Smith, 2004; Schlager & Ostrom, 1992). These have been limited by biophysical features, such as size and mobility (Becker & Ostrom, 1995; Schlager *et al.*, 1994), and social features like hierarchical heterogeneity and inequality, unless the well-endowed actors make substantial contributions (Andersson & Agrawal, 2011; Baland & Platteau, 1999; Blomquist, 1988; Dasgupta & Beard, 2007; Olson, 1965). Growing global demands also generate challenges (Agrawal & Yadama, 1997; Chhatre & Agrawal, 2008) with new markets establishing economic relationships lacking prior norms (Berkes *et al.*, 2006; Nietschmann, 1972; Richards, 1997; Smith *et al.*, 2010). For instance, historically, effective local marine regimes were far from market centers (Cinner, 2005; Cinner *et al.*, 2007), yet some institutions have responded to the payoffs from governance to confront even higher external market pressures (Alcorn & Lynch, 1994; Aswani, 1999, 2002; Bauer & Giles, 2002). That included state support of local collective rights which help to hold off commercial interests (Dupar & Badenoch, 2002; Pfaff & Robalino, 2017; Ribot, 2004; Richards, 1997) – while not being a panacea (Hinojosa, 2013).

Contributions to nature and livelihoods depend upon institutional details such as clarity of rights and congruence between such rules and the characteristics of the resource in question. Members of communities have responded better to such voluntary limitations when they have participated in rule design and modification, as well as when monitoring is linked to punishments. Sanctions have been better accepted when matching the seriousness of rule violations, and the context, with mechanisms for resolution of conflicts (Cox *et al.*, 2010). State legitimization of the processes helped (Koppen *et al.*, 2008) – but did not always occur (Bowles & Gintis, 2002; Cudney-Bueno & Basurto, 2009; Sarin, 1993; Utting, 1993; Young, 2001).

Interactions between local and non-local institutions have also mattered, because the ecosystems cross social and ecological scales (Armitage *et al.*, 2007; Berkes, 2008; Brown, 2003; Finkbeiner & Basurto, 2015; Hovik & Reitan, 2004; McKay, 2014). Fisheries provide examples of interactions between states and local institutions, with innovations over time. From the 1960s into the 1980s, small-scale fisheries were seen as failing to realize economic potential and food security (Berkes & Kislalioglu, 1989; Brainerd, 1989; Thompson, 1961), so governance should "rationalize this outdated sector" (Proude, 1973; Rack, 1962) by moving away from the "inefficient traditional practices". That guided aid (Basurto *et al.*, 2017) focused on raising production via improved technologies and infrastructure (World Bank, 2004). By the 1990s, after some notable collapses, over-exploitation became the focus for governance. Lack of rights (Campleman, 1973), mismanagement (Milich, 1999), destructive gear (Christensen, 2018), poverty and overpopulation (Pauly, 1997), urbanization, and globalization all were highlighted, alongside a lack of data. Large-scale offshore industrial catches competed with small fishermen, as well as governance aiming to restrict excess effort plus damaging methods such as trawls that scrape seabeds, longlines that trap seabirds, and non-selective nets that catch fish not consumed and damage protected species (Basurto *et al.*, 2017). This new framing shifted investment towards research on fish stocks (World Bank, 2014) and halted direct lending to fisheries for over a decade, until the World Bank re-entered with lending that was itself focused upon improving organization and governance.

2.1.9 INDIRECT DRIVERS: GOVERNANCE – STATES

2.1.9.1 Adjusting Development Policies

2.1.9.1.1 Property Rights & Resource-Use Rights

Property and resource-use rights, which depend at least in part on the state, affect outcomes for nature in many ways (Fenske, 2011; Platteau, 2000). Such rights arise through both formal and informal institutions, with *de jure* official rights and *de facto* effective rights present in different forms and combinations, and with varied impacts (Arnot *et al.*, 2011; Robinson *et al.*, 2018). Formal titling of land, for instance, is not always sufficient to promote either private investment or conservation (Holland *et al.*, 2017; Sills *et al.*, 2017). Evidence suggests that resource-tenure security is impacted by transport costs, for instance, and thus by distance: remote areas are harder to monitor and, hence, are more open to unsustainable harvesting and illegal invasion and harvesting (Albers & Robinson, 2013; Robinson *et al.*, 2008). Understanding these apparent trends in past impact can guide uses of rights within conservation.

Processes of establishing and defending rights are critical to outcomes for nature and wellbeing. One key process is decentralization, which is ongoing. Decentralization often transfers burdens of enforcing rights to local actors – agencies or users (Larson, 2002; Larson & Soto, 2008) – but sometimes also augments local property and resource-use rights (Coleman & Fleischman, 2012). Like rights in general, decentralization's net impact is specific to (quite variable) contexts, e.g., in Indonesia a recent effort affected forests and livelihoods as a function of many characteristics of communities (Sills *et al.*, 2017). In some settings, collective rights for groups may work better for conservation than do individual rights – although possibly overlapping with them (Baland & Platteau, 1999). Relative impact depends on the fraction of households with use rights, the area and profitability of forest, and species present (Alix-Garcia *et al.*, 2005; Baland & Platteau, 1996; Barsimantov, 2010; Baynes *et al.*, 2015; DiGiano *et al.*, 2013; Griscom *et al.*, 2009). Policy interactions also matter. Other policies such as recent agricultural subsidies and trade policy in Mexico, allowing timber imports from China, undermined domestic forestry profits and responses to collective rights (Ellis, 2014).

2.1.9.1.2 Transportation Investments (by context)

Economic development is influenced by the spatial pattern of roads, which lower transport costs. Globally, transport costs have fallen by ~40% across the last three decades, yielding aggregate economic growth as well as the spatial concentration of economic activity (World Bank, 2009). Highways have raised economic growth (Banerjee *et al.*, 2012; Bird & Straub, 2014; Storeygard, 2016), as well as total employment (Michaels, 2008) and industrial efficiency (Datta, 2012; Ghani *et al.*, 2016) – often, at least in part, through their impacts upon cities.

Some studies have focused upon past rural economic impacts of transport investments. Those are important for trading off with ecological impacts, such as the impacts of roads on forests, which often are higher at forest margins than in highly developed areas (Pfaff *et al.*, 2018). Studies find economic gains in agricultural productivity (Fan & Zhang, 2004; Zhang & Fan, 2004), reduction in poverty, and increased consumption (Asher & Novosad, 2016; Dercon *et al.*, 2009; Gibson & Rozelle, 2003; Khandker *et al.*, 2009) – plus labor shifts from agricultural to non-agricultural sectors (Asher & Novosad, 2016; Gollin & Rogerson, 2010). Another rural impact has been better access to credit and financial services (Binswanger *et al.*, 1993) – though we must allow that road placements often responded to other conditions, so causally identifying impacts can be difficult (Banerjee *et al.*, 2012; van de Walle, 2009). That restricts the quality of impacts evidence (Dulac, 2013; Khandker *et al.*, 2009).

Yet the apparent trends suggest important heterogeneity within economic impacts from transport. Roads have concentrated or dispersed economic activity, depending on the economic conditions. Cities connected to ports, or other cities, often benefitted more from trade and access to markets, as have rural areas along transport corridors, while unconnected rural areas have lost activities (Bird & Straub, 2014; Chandra & Thompson, 2000; Rephann & Isserman, 1994). In addition, labor will concentrate to earn higher wages stemming from economies of scale to human capital (World Bank, 2009). In Brazil, for instance, frontier roads have promoted settlement in many rural areas (Fearnside, 1987) yet, in those regions, urban population growth has been higher than rural rates. In India, given extensively settled rural areas new roads led people into cities (Asher & Novosad, 2016). When considering policy to balance multiple SDGs, the varied trends by context are key.

Transport investments – and in particular roads investments, which differ in impacts from rail – also, have driven large ecosystem losses. Early studies of road impacts mostly considered some economically less developed settings or “frontier” forests (Chomitz & Gray, 1996; Cropper *et al.*, 2001; Nelson & Hellerstein, 1997; Pfaff, 1999). For that broad context, roads expanded the areas where agriculture is profitable, causing further deforestation in the absence of institutional or policy constraints. Such study of deforestation impacts is summarized in reviews (Angelsen & Kaimowitz, 1999; Ferretti-Gallon & Busch, 2014; Geist & Lambin, 2002; Rudel *et al.*, 2009a). Others have summarized trends in how roads affect wildlife and ecosystems (Forman & Alexander, 1998; Laurance *et al.*, 2009). Many authors warn that expected global investments, up to 25 million kilometers by 2050, will surely exacerbate such ecosystem losses (Caro *et al.*, 2014; Laurance *et al.*, 2014, 2015).

Yet the magnitudes and even the signs or directions of transport investments’ impacts varied by: the types of roads; the stage of prior economic development; and economic activities involved (Mertens *et al.*, 2002; Pfaff *et al.*, 2016). While the stories that have dominated the literature and consciousness, including studies of large tracts of undisturbed forest with minimal property rights (Ferretti-Gallon & Busch, 2014; Rudel *et al.*, 2009a), on average suggest potential for high impacts, studies of actual variation in past impacts show that with high prior development, road-induced deforestation is actually lower (Andersen *et al.*, 2002; Pfaff *et al.*, 2007). These trends are suggestive of ways to limit deforestation by confining new transport to existing developed areas (Laurance *et al.*, 2014; Pfaff *et al.*, 2016). In extensively settled, non-frontier areas, for example in India and China, roads investments have even lowered deforestation, if roads encouraged the transition from agricultural to urban sectors (Deng *et al.*, 2011; Kaczan, 2016) and to plantations (Deng *et al.*, 2011; Kaczan, 2016).

2.1.9.1.3 Subsidies to Fuels

Subsidies to fossil fuels have been highly prevalent at least across recent decades, featuring both frequency across space and persistence over time, and all of that in spite of quite enormous costs. The International Monetary Fund states a cost of US$5 trillion – including the externality cost of nature’s degradation – with coal accounting for 52% of post-tax subsidies, petroleum for 33% and natural gas for 10% (Coady *et al.*, 2015). Davis (2016) estimates that there have been US$44 billion just in direct costs from carbon dioxide emissions, alongside traffic congestion, local pollution and also accidents – while noting that the subsidies have greatly reduced relevant actors’ incentives for generating clean innovations. Davis (2014) estimates additional large costs of ‘deadweight loss’ even without any environmental costs.

By all accounts, however, it has been significantly (and persistently) difficult to eliminate these policies that are ‘lose-lose’ in the sense of a worse environment and worse economic efficiency. That seems to be due to enormous public opposition concerning the possibility of their removal, including by affected groups and those advocating on behalf of the poor. However, it was shown that putting into practice a classic adjustment from economics textbooks could actually separate equity concerns from the enormous efficiency losses: cash transfers to the poor can compensate for price rises within any reform to improve key incentives (e.g., Salehi-Isfahani, 2016 on Iran).

2.1.9.2 Increasing Conservation Policies

2.1.9.2.1 Protected Areas and IPLC Lands/Participation

Governments have long created protected areas (PAs) to limit activities imperiling conservation. On the order of 15% of terrestrial and freshwater environments and ~7% of the marine realm are under some form of protection (UNEP-WCMC & IUCN, 2016), making protection the leading strategy to date for conserving biodiversity and ecosystem services. Protected areas were developed to preserve wilderness areas (Ervin *et al.*, 2010; Rodrigues *et al.*, 2004). However, the historically top-down approach to protection has evolved towards more inclusive conservation approaches (Berkes, 2010) – with protection categories ranging from strict (I–IV) to sustainable use (V–VI) (Dudley, 2008). The latter category includes "multiple-use" areas, which sometimes have bottom-up origins (Pfaff & Robalino, 2017). Recent decades saw considerable expansions, globally, in PA numbers and area (UNEP-WCMC & IUCN, 2016). Category VI grew most and it is the largest at ~40% of total PA area, though stricter top-down categories II and IV make up ~27% and ~13% (Juffe-Bignoli *et al.*, 2014), respectively. Also, the distribution of protection is not equal across the regions of the globe. For instance, one quarter of the terrestrial regions and over one half of marine regions are under 5% protected (Butchart *et al.*, 2012; UNEP-WCMC & IUCN, 2016).

Challenges for very significant impacts from PAs, though, arise in both enforcement and siting. Deforestation does occur within PAs, although usually at lower rates relative to the PAs' surroundings, indicating imperfect enforcement (at least for strict PAs), with losses of biodiversity and other services (Coad *et al.*, 2015). Enforcement clearly is critical. Also, it is not always better in strict PAs (Albers, 2010; Ferraro *et al.*, 2013; Fox *et al.*, 2012; Laurance *et al.*, 2012; Nolte *et al.*, 2013). Restrictive marine PAs, which are managed by states, have been effective within countries which have stronger legal frameworks. Bottom-up approaches can require community leadership to succeed, plus support from NGOs and private entities (Jones *et al.*, 2013). They may succeed in part due to lower monitoring costs.

Protected areas have had greater impacts when they effectively limited higher resource pressures. Where pressures are low, PA outcomes may be similar to their surroundings, i.e., impacts can be low and even zero when outcomes are undistinguishable from similar unprotected landscapes (Joppa & Pfaff, 2010; Nelson *et al.*, 2010; Pfaff *et al.*, 2009). One clear reason PAs are in lower-pressure sites is that local actors push back against protection, as they see PAs as a source only of local costs. This is less the case for multiple-use PAs which, depending on locations and enforcement, can have more impact (Nelson & Chomitz, 2011; Pfaff *et al.*, 2014). If PA impacts are higher under pressure, that suggests integration of protection with regional development (Mora & Sale, 2011; Stoll-kleemann *et al.*, 2006), e.g., siting the PAs alongside new roads (Pfaff *et al.*, 2015a, 2015b) and optimizing road siting with impacts on nature and economies in mind (Andam *et al.*, 2010). PAs often imply local cost but also can offer local tourism benefit (Andam *et al.*, 2010; Robalino & Villalobos, 2015).

Indigenous Peoples and Local Communities have long protected, and currently conserve, many ecosystems (see chapter 2.2) and indigenous lands have often had consequential impacts, sometimes more than nearby PAs. Many IPLC approaches to conservation have been scaled up, yet opportunities for participation in global and national policy processes have been limited for IPLCs, although increasing in international organizations such as the CBD. Participation in national biodiversity strategies and action plans (NBSAPs) has been limited to date, with country exceptions. Since 2004, numerous IPLCs have identified concrete actions for adding important principles into national policies and programs for sustainable use of biological diversity (Forest Peoples Programme, 2011), e.g., the Plan of Action on Customary Sustainable Use (adopted in 2014). Many IPLCs are determined to play an active role in implementing this Plan through 2020 and well beyond. For example, a global indigenous coalition from the Amazon, Central America, the Congo Basin and Indonesia pledged to protect 400 million ha of forests (LPAA, 2014) and the Palangka Raya Declaration on Deforestation and Rights of Forest Peoples has concrete policy recommendations to address habitat loss (Forest Peoples Programme, 2014). Amazonian Kayapo people in Brazil are conserving 105,000 km^2 of forests in a frontier characterized by heavy deforestation due to agriculture and pasture expansion, illegal gold miners, logging and infrastructure. They also led (unsuccessful) pressures on the World Bank and other international financing institutions to stop loans for a mega-dam on the Rio Xingu (Zimmerman, 2010). In Kapuas Hulu (West Kalimantan, Indonesia) indigenous Dayak peoples contribute to conserving forest, river and lake habitats that are under threat from oil palm (Colchester *et al.*, 2014; Porter-Bolland *et al.*, 2012).

Given this history, and mixed trends, policymakers and scholars are reconsidering roles of local communities in the context of expansions of both resource use and conservation. Communities' rights have been shown to generate incentives for local protection, monitoring, and enforcement (Berkes *et al.*, 2006). Empowered local fishers have been seen to be more likely to comply with regulations (Bennett & Dearden, 2014). Indigenous and local knowledge, including from women (Agarwal, 2009), has aided conservation success (Brooks *et al.*, 2012; Jones *et al.*, 2013; Stoll-kleemann *et al.*, 2006). Policies that do not undermine local ownership but instead guarantee local involvement in all of design, implementation and benefits (Bennett & Dearden, 2014) have contributed to conservation, as peoples understand their livelihoods depend on maintenance of the environment including via strong organizational and technical capabilities within rural communities (Sim & Hilmi, 1987). Many forests and other biodiverse habitats are within IPLCs' lands and territories (FPP *et al.*, 2016), overlapping areas of high biodiversity and biocultural diversity (Sobrevila, 2008; Toledo, 2013). Yet, there are still limited data about local farmers' and livestock keepers' relations to genetic diversity, in particular for species with cultural or economic values, such as traditional medicines or non-timber forest products (CBD, 2014).

2.1.9.2.2 Payments for Ecosystem Services and Other Incentives

On private lands, payments for ecosystem services (PES) offer compensation for the voluntary acceptance of restrictions to reduce degradation, such as shifts in land uses or polluting practices. PES are conditional on beneficial actions or outcomes. Thus, they generate incentives for voluntary provision of ecosystem services by varied private actors (see also chapters 3 and 6). Payments are made by other private actors (Coase, 1960) or by states, as representatives (Ferraro & Kiss, 2002), based on outcomes like standing forests or related practices (Sattler & Matzdorf, 2013). To date, most PES schemes have used action-based rather than result-based conditionality (Engel *et al.*, 2008; FAO, 2007), if they actually use conditions for payment at all (Ezzine-de-Blas *et al.*, 2016). The payments approach makes sense when the buyers' willingness to pay is above sellers' opportunity costs – else those providers would not supply ES (Nelson *et al.*, 2008; Perrot-Maître, 2006). These payments aim to align private goals with social goals (Dobbs & Pretty, 2008; Muradian *et al.*, 2010). Governments may use them alongside PAs to lower local costs and spillovers, relative to pure mandates alone. For multiple-use PAs, that could even involve providing PES inside PAs – which *de facto* can yield additionality if restrictions alone were being rejected (see Tuanmu *et al.*, 2016 for Wolong in China).

To date, though, PES additional impacts beyond baseline are not so encouraging. PES often have been implemented where opportunity costs are medium to low (Tacconi, 2012), just as for PAs, albeit in this case driven more by private decisions about which lands to volunteer for inclusion. Because information about opportunity costs is private, PES designers face a challenge (Börner *et al.*, 2016; Hejnowicz *et al.*, 2014; Sattler & Matzdorf, 2013), since actors with low profits from clearing forests more frequently volunteer to accept a payment for leaving lands in forest. Thus, payments for standing forest have had limited impacts. Studies suggest low impacts of PES (Robalino & Pfaff, 2013 for Costa Rica). Efficient impact may require targeting.

Yet, if a service is a priority, e.g., if drinking water or the electricity from hydropower are scarce (Brouwer *et al.*, 2010), then actors have targeted influential lands upstream of dams or cities and utilized higher payments to overcome competing pressures. When a service such as clean water is an input to a good with economic importance (e.g., soda or beer), again targeting and payment sometimes are higher. Further, some designs could help states to reveal private opportunity cost (Ajayi *et al.*, 2012; Ferraro, 2008; Polasky *et al.*, 2014 using auctions; Sheriff *et al.*, 2009 using observable data) and how resulting surpluses are shared is important, while some authors have shown that not differentiating payments between regions has efficiency losses (Ezzine-de-Blas & Dutilly, 2017; Lewis & Plantinga, 2007; Lewis *et al.*, 2009, for instance consider fragmentation). In China, while 'PES' were perhaps less voluntary, as the state prioritized large areas per flood risks, the compensation appeared to cover local opportunity costs (Uchida *et al.*, 2007). In some settings in Europe and in the US, large PES seemed to align with private sector goals of transitions in production to ecologically friendly systems, yet market actors may want assurance about permanence. Other challenges include the need to target only some participants, without triggering negative fairness reactions (Alpízar & Cárdenas, 2016; Mercado *et al.*, 2017).

One way to raise the incentives for ecosystem services suppliers is to allow multiple ecosystem services to be sold on the basis of a single shift in land use. In Bolivia, for instance, *Acuerdos Reciprocos por El Agua* yielded both water and biodiversity outcomes (Wunder & Albán, 2008). Payment for one service does not, then, offer the socially efficient 'price' to align the incentives. Private actors should face incentives based on all of the ecosystem-service gains due to their acts. Thus 'stacking', or suppliers receiving a separate payment for each service, can be more socially efficient for PES programs – although not for all regulatory structures (Pfaff & Robalino, 2017).

Another challenge has been uncertainties, given variations in species or other ecosystem-service benefits across locations. Planners may wish to target an ecosystem service, yet monitoring could involve high costs. Hily & Gégout (2016) study PES designs with unobserved costs and benefits which could be considered for biodiversity conservation policy – alongside PAs plus regulations like the Natura 2000 (N2K) policy that covers 18% of the EU's terrestrial surface (or, generally, "command-and-control" like the EU's Habitats Directive and the US Endangered Species Act). Incentives-based contracts for biodiversity conservation in forests have been implemented in EU states including Denmark, Germany and Slovakia (Anthon *et al.*, 2010; Ecochard *et al.*, 2017). Hanley *et al.* (2012) and de Vries and Hanley (2016) review studies of incentives for biodiversity with varied costs and benefits from conservation, hidden information (asymmetric across actors such as their private costs), and stochastic elements as well (Armsworth *et al.*, 2012). Targeting based on costs and benefits has been suggested (Babcock *et al.*, 1997; Duke *et al.*, 2013; Naidoo *et al.*, 2006). Experiences have showed that an understanding that allows planning around such heterogeneity allows gains (Bamière *et al.*, 2013, for example, compare an auction to a uniform subsidy in order to reach a specific configuration of lands). Auctions have been investigated (Fooks *et al.*, 2015; Schilizzi & Latacz-Lohmann, 2007) that consider not only costs but also benefit-cost ratios (Che, 1993; Latacz-Lohmann & der Hamsvoort, 1997). The efficiency from targeted auctions depends on the relative variability of costs and benefits, as well as their correlation (Ferraro, 2003), however, and any implementation assumes states have accurate knowledge, which may not hold for biodiversity.

For this domain, once again policies have considered collectives, or groups, attempting to apply lessons from common property settings, as 27% of forests in developing countries are under collective title and this percentage may increase with devolution (Agrawal *et al.*, 2008; Molnar *et al.*, 2011). Private rights and state enforcement have not always succeeded (Dietz *et al.*, 2003). Positive group examples exist for: forests (Pagdee *et al.*, 2006); irrigation infrastructure (Wade, 1985); fisheries (Acheson, 1988; Feeney *et al.*, 1990); and pasture (Moritz *et al.*, 2013). Communication and trust are key elements (Hackett *et al.*, 1994; Ostrom, 2000; Pretty, 2003). Inequality hinders collaboration and participation, yet gains are lower for the socioeconomically disadvantaged (Agrawal & Gupta, 2005; Kumar, 2002). In PES for collective titles and decision making (Hayes *et al.*, 2017; Kerr *et al.*, 2014), i.e., when contracting with groups of relevant landholders, responsibilities and rewards are collective and communities motivate members using internal governance to address challenges such as free-riding. A limited literature suggests collective PES could help in rule setting (Hayes *et al.*, 2015, 2017), attitudes towards rules (Sommerville *et al.*, 2010), and, ultimately, sustainable resource use (Clements *et al.*, 2010) – especially when local actors are involved in the designs of programs (Cavalcanti *et al.*, 2010; Kaczan *et al.*, 2017; Walker *et al.*, 2000).

Pre-existing collective arrangements have been important in PES, leveraging members' existing collective motivations (Muradian, 2013; Muradian *et al.*, 2010; Porras *et al.*, 2008), and facilitating the coordination with intermediaries (Jack *et al.*, 2008). Collective contracts can help due to lower per-participant costs, given economies of scale in monitoring (Kaczan *et al.*, 2017) and lower transactions costs with fewer large contracts (Kerr *et al.*, 2014). Also, in terms of ecosystem-service benefits, contracts which cover larger areas can of habitat can match needs of species (Swallow & Meinzen-Dick, 2009).

Collective contracting could face a challenge when sanctions are required to enforce compliance, as has become apparent for "non-point" emissions, where emissions cannot be linked to people due to monitoring costs. While schemes exist if only aggregate pollution is measured (Alpízar *et al.*, 2004; Cason & Gangadharan, 2013; Cochard *et al.*, 2005; Poe *et al.*, 2004; Segerson, 1988; Spraggon, 2002, 2004; Vossler *et al.*, 2007; Xepapadeas, 1991) in practice they are not adopted – partially due to a lack of fairness, as people are punished for others' acts. Yet such an approach can work with strong collective function (Kaczan *et al.*, 2017).

2.1.9.2.3 Choosing Policy Instruments

Many instruments have been used to either support or regulate activities that affect nature, both incentives and restrictions. For instance, current policy debates consider a carbon tax (a "price") which does not dictate a specific process or technology, as well as restrictions on level of output. When quantities have been restricted, sometimes "cap-and-trade" regulations have started with a limit – e.g., on total fish extracted or total emissions – that is broken up into individual limits, which individual actors are allowed to trade flexibly among each other. Firms that innovate need fewer emissions permits and, thus, could sell permits to other firms – creating an incentive to innovate.

While the implementation of these kinds of policies has often assumed 'perfect information', a fundamental challenge arises with various types of uncertainty and other deficient information. Weitzman (1974) considered uncertainty in regulations' costs and benefits, finding that the best policies considered relative sensitivity of the costs and the benefits. A cap policy allowed costs to vary, while a price policy (via a tax) allows amounts, e.g., emissions to vary. Thus, when the benefits of regulations are very sensitive at a threshold, it has been deemed better to be sure of quantities through caps (using trading for cost flexibility). However, if regulations' costs were sensitive, as is the economy, it has been deemed better to keep a handle on the costs, by using taxes. This has all been applied for different uncertainties (Fishelson, 1976; Stranlund & Ben-Haim, 2008; Yohe, 1978) and non-linearities in costs and benefits (Kelly, 2005; Yohe, 1978).

2.1.9.3 Equity Considerations

2.1.9.3.1 Wealth-based and Race-based Differences

Equity is an important, yet complex aspect of policy related to economic development and nature. For regulations like emissions limits, with permits trading for efficiency, distributional outcomes have varied greatly (Bento, 2013; OECD, 2006). For instance, regulations may unequally burden low income laborers – who face additional effects if firms shift into capital (Fullerton & Heutel, 2007; Fullerton & Monti, 2013), or employment shifts sectors (Bento, 2013), such as in the US post-1970s due to the Clean Air Act (Greenstone, 2002; Walker, 2013). Political implications of policy costs draw increasing attention (Bento, 2013; Bento *et al.*, 2005; Fullerton, 2011; Kolstad, 2014; Parry *et al.*, 2006; Pizer & Sexton, 2017). Looking ahead, based upon past efforts, policy revenues from pollution taxes or auctions of permits may invested in reducing other taxes (Bento & Jacobsen, 2007; Dinan, 2012; Metcalf, 1999, 2008; Parry, 1995; "revenue recycling" in Poterba, 1991b) or in tax credits or specific programs for lower-income households.

In evaluating equity implications of the environment policies put into place during past decades, challenges remain for calculating benefits and costs. First, willingness to pay by citizens is hard to know, although the lower-income households seem less willing to pay due to limited income. Second, heterogeneous behavioural responses generated heterogeneous impact from policies, e.g., changes in exposure risks, even if policy was "provided equally" (Bento, 2013; OECD, 2006).

Trade-offs based on heterogeneities across actors also arise when a few small producers are more efficient, putting efficiency and equity in tension (Birkenbach *et al.*, 2017; Brandt, 2005; Brinson & Thunberg, 2016; Da-Rocha & Sempere, 2017; Grafton *et al.*, 2000; Homans & Wilen, 2005; Olson, 2011). Transferable fishing quotas (ITQ) have offered examples, as efficiency may be high if a fleet has fewer vessels – avoiding 'overcapitalization' – yet that favours large industrial producers over artisans. Small-scale

Box 2 1 3 United States, examples of inequalities in exposures to environmental quality.

Scholars have illustrated equity issues concerning, for example, chemical facilities' toxic emissions (Ash & Fetter, 2004; Mohai *et al.*, 2009) and cumulative health risks from multiple pollutants (Morello-Frosch & Shenassa, 2006; Morello-Frosch *et al.*, 2011; Sadd *et al.*, 2011; Su *et al.*, 2009), as well as for environmental amenities, such as grocery stores and more healthful foods (Hilmers *et al.*, 2012; Morland *et al.*, 2002), parks (Boone *et al.*, 2009; Sister *et al.*, 2010), and overall tree cover (Heynen *et al.*, 2006; Landry & Chakraborty, 2009; Schwarz *et al.*, 2015).

There are debates over how best to document disparities, for risks and amenities (Chakraborty *et al.*, 2011; Mohai *et al.*, 2009; Mohai & Saha, 2006), yet race- and income- and wealth-based disparities appear to have persisted in varied forms. Crowder & Downey (2010) found that, at neighborhood level, black and Latino households were more likely to experience high levels of proximate industrial pollution – and across levels of income. Varied case studies document communities' struggles against lead smelters (Bullard, 2000), toxic chemical facilities (Purifoy, 2013), concentrated animal feed operations (Wing *et al.*, 2000), oil refineries (Lerner & Bullard, 2006) and cumulative impacts from multiple polluters (Sze, 2007).

As exposures are based on location, this raises locational segregations by race as well as wealth and, thereby, the legacy of racially-based housing (Katznelson, 2005; Lipsitz, 2006; Satter, 2009) and residential policies based on house type and lot size (Meyers, 2003; Nelson, 1996). As race corresponds with wealth, segregation is apparent, including as per discriminatory residential steering practices within real-estate (Bullard *et al.*, 2007; Ford, 1994). Some degree of immobility is central within exposure inequity, with race and wealth limiting options (Aiken, 1985; Jepson, 2012; Mills, 1997), since wealth disparities are a self-reinforcing feature that limits the mobility of minorities (Bullard, 2007; Darity *et al.*, 2006; Oliver & Shapiro, 2006). Poorer families might well, then, make rational choices to face higher pollution, so as to lower their costs, given lower incomes. Further, adding resource amenities or reducing environmental dis-amenities, which yields higher rents, could help local owners but hurt renters.

Unequal exposures over space and groups can be due to public choices, for instance in the US for communities struggling against hazardous waste incinerators and dumpsites (Bullard, 2000; Cole & Foster, 2001) and solid waste facilities (Pellow, 2004). Public zoning choices interact with immobility if the dis-amenities drive out those who can afford to move (Silver, 2007; Taylor, 2014), although political inclusion in environmental decisions is a core plank of environmental justice – indeed the definition of environmental justice for the USA Environmental Protection Agency (EPA) is: "fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (US Environmental Protection Agency, 2016, 2018). However, in considering the past trends in placements of dis-amenities, the EPA failed to issue a single finding of racial discrimination in the permitting of hazardous facilities under the Civil Rights Act (US Environmental Protection Agency, 2016). Thus, even explicit statements do not guarantee political inclusion.

Post the Civil-Rights-era, policies also advance "color-blind racism" (Bonilla-Silva, 2010) using seemingly race-neutral terms such as 'multifamily' or 'subsidized' (Morris, 1997). A California report suggests those least likely to resist waste-to-energy facilities: low income; high school or less education; and open to promises of economic benefits (Cerrell Associates & Powell, 1984). This maintains disparities (Bonilla-Silva, 2010). It seems such inequities may be shaped by broader mechanisms, e.g., those underlying mass incarcerations (Agnew, 2016; Brown *et al.*, 2016; Gilmore, 2007; McKittrick & Woods, 2007; Pellow, 2016; Woods, 1998).

fishers or vessel owners may simply sell and exit, lowering welfare in lower-income communities (Carothers *et al.*, 2010; Olson, 2011; Stewart & Walshe, 2008). Fewer vessels could also lower employment, although extended fishing seasons could increase the total hours worked, increasing the overall wage bill. Consolidation of production within a few larger firms also impacts many shore-side firms as well as employment within the processing sector (Abbott *et al.*, 2010; Anderson *et al.*, 2011; Birkenbach *et al.*, 2017; Brandt, 2005; Copes & Charles, 2004; Olson, 2011). To address this, states have in some cases restricted the transfers of fish permits, reducing efficiency gain (Da-Rocha & Sempere, 2017; Grafton *et al.*, 2000; Kroetz *et al.*, 2015).

Moving to environmental quality and exposures, some example of outcomes have illustrated the issue of unequal distributions of environmental burden, one present in many parts of the world.

2.1.9.3.2 Policy Responses (rights, subsidies)

In fisheries and forests, public restrictions on extraction have been shown to have the capacity to help efficiently trade-off nature and individuals' basic needs. Extending to individual actors can further increase efficiency and address equity too. A lack of agreed rights and restrictions in, e.g., open-access fisheries, have been showed to be responsible for dissipation of economic rents and degradation of stocks (Caddy & Cochrane, 2001; Charles, 1988; Gordon, 1954; Kronbak, 2014). On a global scale, those fisheries harvested by multiple countries are more likely to be degraded (McWhinnie, 2009), while exclusive economic zones to exclude foreign fishers are a response. Economic costs of misaligned incentives are over $80 billion annually (Kelleher *et al.*, 2009), including from misallocations of labor and capital (Homans & Wilen, 2005; Kelleher *et al.*, 2009; Manning *et al.*, 2018; McElroy, 1991; Pauly *et al.*, 2002). Restricting effort or gear lowers inefficiencies – but all individuals must be limited or rents get dissipated and inequity arises (Homans & Wilen, 1997; Wilen, 2006). If regulators close access after a fixed total harvest, instead of fixing individual rights, then fishers will race (Birkenbach *et al.*, 2017) with costs (Grafton, 1996; Huang & Smith, 2014) and risks (Pfeiffer & Gratz, 2016).

Individual fishing quotas (IFQs) or catch shares reduced costs of racing by offering more secure shares of total allowable catch (TAC). Catch-share systems have grown since the 1970s (Christy, 1973) in part because exclusive economic zones made it possible for regulators to restrict access (Costello *et al.*, 2010; Tveteras *et al.*, 2011). Shares give fishers a stake in the health of a fishery and may lower collapse (Costello *et al.*, 2008; Essington *et al.*, 2012; Melnychuk *et al.*, 2012). For a non-mobile fish species, one variant is "Territorial Use Rights for Fisheries" (TURFs), which give a specific harvester exclusive access to an area (Wilen *et al.*, 2012). Incentives issues and fairness issues still arise (Abbott *et al.*, 2010; Bromley, 2009; Grimm *et al.*, 2012; Kristofersson & Rickertsen, 2009). Some may be addressed by property rights for collectives, as found in small-scale fisheries (Acheson, 1988; Basurto *et al.*, 2012; Feeney *et al.*, 1990; Leal, 1998), which produce half of the total global fish harvest (Jacquet & Pauly, 2008). One way or another, though, all such decisions about rights allocations have equity implications.

Another response to marine equity issues is subsidies, raising equity and efficiency issues just as for fossil fuels (CWN'18/10). *The Sunken Billions* (FAO, 2009c) has estimated total global rents from marine fisheries and found that overfishing lost US$51 billion in rents in 2004 (supported by Sumaila *et al.*, 2012). An update found losses of US$83 billion in 2012 (World Bank, 2017a) These figures suggest that in some areas rents were negative, i.e., revenues did not cover costs, necessitating subsidies for firms to continue (World Bank, 2018o). Despite data limitations, such results clearly suggest widespread overfishing and declining fish stocks, i.e., huge inefficiencies likely to involve and lead to inequities if limitations are then extended.

Any limitation on communities' extraction rights is a significant equity concern for the IPLCs, including in the context of trade that responds to national differences in the rights for resources (Chichilnisky, 1994; Krausmann *et al.*, 2009). Affluent 'Global North' industrialized countries import from resource-rich countries in the 'Global South', where stocks have fallen (Garmendia *et al.*, 2016)but states often capture little surplus. Martínez-Alier (2002) notes 'ecological debt' to the South, referencing varied inequalities over time within such exchanges relevant for nature (while here we focus upon the rights issues underlying inequities, this links to 'grabbing' above).

Indigenous Peoples, in particular, have highlighted threats from petroleum and mining activities, which were authorized and incentivized by national governments, as in Ecuador (Forest Peoples Programme, 2007). Mining's threats to the food security of Indigenous Peoples were seen in the Philippines (Working Group on Mining in the Philippines, 2009). Violent confrontations have occurred, e.g., an incident occurred in 2009 in Peru after a lack of consent by Indigenous Peoples for petroleum firms to enter indigenous territories. Indigenous Peoples in Latin America, Asia, and Africa are not categorically opposed to mining – although they struggle to hold companies and governments accountable for the negative local impacts (Herbertson *et al.*, 2009; Richardson, 2007). Water contamination from mining, for instance, continues to stir up such heated conflicts (Anaya, 2011; Van de Wauw *et al.*, 2010; van der Sandt, 2009). In the Philippines alone, by one account, there were 800 extrajudicial killings. in the period 2001–

2006, associated with protests against mining (Doyle *et al.*, 2007).

2.1.9.3.3 Equity & Environmental/Energy Taxes (context dependence)

Equity impacts of taxes have varied across contexts, including by the type of commodity plus the physical, social and climatic characteristics. Relevant characteristics have included the transport infrastructure, housing stock, diffusion of technology, incomes, and patterns of work (Cronin *et al.*, 2017; Pizer & Sexton, 2017). In the UK, the share of households' budgets spent on natural gas falls with household total expenditure, since gas is used for heating. In this case, natural gas taxes are regressive, i.e., their burden falls more heavily on the poor. Yet, the budget shares for natural gas rise with household expenditure in Mexico – where there is less need for heating overall and less adoption of home-heating capital at lower incomes. Comparing the UK to the US, which has more similar incomes, due to climate the UK does less cooling – whereas air conditioning uses significant electricity in the US (less in coastal areas which also exhibit higher incomes). Mexico is warmer but its electricity budget shares are lower, with low air conditioning (Davis, 2014). In general, equity impacts depend upon use. Another example is the gasoline tax – which is progressive or neutral in the UK, yet regressive in the US because of more use by the poor with less use of public transit plus longer commutes.

Electricity taxes' direct effects have been regressive, for most settings, reflecting the importance of electricity. Much as for food and water, the expenditure shares decline with the income level. US households with lowest expenditures devote nearly 7% of their total spending to electricity, over three times the budget share for the wealthiest decile (Pizer & Sexton, 2017). In the UK, electricity budget shares decline from over 8% among the poorest households to barely 1% for the wealthiest. Likewise in Mexico, to a lesser degree (Pizer & Sexton, 2017). Flues & Thomas (2015) find electricity taxes to be regressive in 21 OECD countries based on expenditure shares.

Yet, energy and gasoline taxes tend not to be regressive in poorer countries, as vehicle ownership rates as well as commuting patterns matter greatly. Transportation-fuels taxes are thought to be progressive in Brazil, China, Costa Rica, Mexico, and Turkey, as well as in Chile and Hungary, where vehicle ownership differs across incomes by an order of magnitude (Flues & Thomas, 2015; Pizer & Sexton, 2017). In Ethiopia, modern transportation in any form is beyond the reach of the poorest households and, thus, a transportation-fuels tax is strongly progressive (Flues & Thomas, 2015; Sterner, 2012). Indirect effects of taxes, however, still sometimes have been regressive. For instance, diesel taxes raise the cost of public transport, which impacts the expenditures of low income people (Flues & Thomas, 2015; Pizer & Sexton, 2017). Yet overall, low income households have been less affected by the indirect impacts of energy taxes because they consume less (Hannon *et al.*, 1978; Herendeen *et al.*, 1981). Mass transit systems lower private vehicle use in Europe, where longer commutes in one's own vehicle are rare (Haghshenas & Vaziri, 2012; Stutzer & Frey, 2008). In contrast, in the US, lower-income people are likely to own automobiles and drive relatively long distances (Pizer & Sexton, 2017). Gasoline taxes even have had significant effects on economic growth (Hamilton, 2009; Kilian, 2008a, 2008b) – plus upon housing markets (Sexton *et al.*, 2012), in terms of both home construction (Molloy & Shan, 2013) and home price (Morris & Neill, 2014).

Finally, in terms of how such issues arise in official measurements, perceived regressivity falls if considering groups in terms of their consumption instead of expenditures, which fluctuate less – most likely as they track expected lifetime income (Poterba, 1991a). How one ranks households matters so much that: if calculating using income, fuel taxes in Germany and Sweden have been regressive; while using expenditures, it is the opposite. A challenge for addressing equity issues, then, is that expenditures can vary considerably across households which have the same income.

2.1.10 INDIRECT DRIVERS: GOVERNANCE – GLOBAL COORDINATION

"Global commons" often refers, loosely, to resources domains in which many countries interact, indicating shared natural resources such as the oceans, the atmosphere, outer space and the polar regions. According to the World Conservation Strategy (IUCN, 1980), in this common form of usage: "global commons includes those parts of the Earth's beyond national jurisdictions … the open ocean and the biodiversity it contains … or [parts] held in common, as the atmosphere and the Antarctica".

Global commons clearly merit attention, including specifically those domains with common-pool resources, which are rivalrous – i.e., one consumes at the expense of others – and for which it is costly to exclude potential users, e.g., when a resource is large and abundant, plus resource users are disconnected from each other. A leading challenge is the design of governance structures and management systems capable of addressing multiple public and private interests given resources with those characteristics. Mutually agreed mutual coercion is called for to avoid 'tragedy of the commons' at any level (Hardin, 1968; Ostrom, 1990).

Conditions can make global collective management easier or harder. For instance, resource scale, number of users, absence of a shared culture for resource users, and more heterogeneity globally than for local management of common-pool resources (Dietz *et al.*, 2003) all matter. Social learning about the resource dynamics and the implications of diverse uses is critical too.

Various global environmental protocols were deployed in the last 50 years, especially after the 1972 Stockholm Intergovernmental Conference. The Montreal Protocol to address the 'ozone hole', for instance, has become a reference for linking governments and the private sector and contributing to promote economic, technological, and behavioural changes. On the other hand, many legally binding protocols do not provide a full solution for global commons governance, since they are slow to be implemented, or lack either monitoring or enforcement capacity and activities. Patterns of adoption over time can be seen within **Figure 2.1.11**, by country income levels (also see Figure S16).

Some cooperation has involved aquatic ecosystems, including wetlands that reduce impacts of floods, coastal storms and high temperatures as an alternative to 'grey' or engineered solutions. Loss of wetlands to food production reduces flood protection and storm-water management, a tradeoff. Yet, nonetheless, one third of global mangrove ecosystems are depleted or severely degraded. In India, Philippines, Vietnam and the Americas they have been extensively cleared and overall the world has lost 50% of wetlands since 1900. Davidson (2014) review 189 reports of changes in wetlands, reporting average long-term losses of natural wetlands near 50%, since 1700, and as high as 87% – with rates of loss more than three times faster for inland wetlands. Facing such pressures, the Ramsar Convention on Wetlands of International Importance is one intergovernmental mechanism concerning wetlands protection globally. To date 169 countries participate, having designated over 2,200 wetlands of international importance (Ramsar Sites) which together cover an area of 215 million hectares, an area that is equivalent to the size of Mexico. Yet it remains uncertain whether these commitments by national governments to the Ramsar Convention have actually had impacts in significantly reducing rates of wetlands loss.

Other global agreements also concern water management, e.g., the Boundary Waters Treaty of 1909 set up mechanisms to resolve disputes over waters between the US and Canada, while the Helsinki Rules on Uses of the Waters of International Rivers of 1966 include recommendations for regulations when rivers and connected groundwater systems flow across national boundaries. Approved and adopted by International Law Association (ILA), this still lacks any enforcement.

Among 'global' coordination actions, we consider regional social systems and ecosystems, especially if they cross international boundaries. One example is the Johnston Agreement of 1955 concerning Israel, the West Bank, the Gaza Strip and Jordan, with conflict-resolution mechanisms regarding water scarcity. The Indus Waters Treaty of 1960 addresses water distribution between Pakistan and India. Regulatory authority for three "eastern" rivers (Beas, Ravi, Sutlej) was given to India, with the authority for three "western" rivers (Indus, Chenab and Jhelum) given to Pakistan and mechanisms for water sharing sketched out for sectors such as irrigation, transport and power generation. One global effort has been the Convention on the Protection and Use of Transboundary Watercourses and International Lakes – Water Convention – due to the United Nations Economic Commission for Europe. This entered into force in 1996, with 40 states and the European Union as parties and mandates to: improve states' efforts to shield and organize shared water systems and groundwater; and promote cooperation with joint decisions including governance with monitoring, research, consultations, warning systems and knowledge exchange.

Moving to the oceans, recognition of the International Council for the Exploration of the Sea as an expert body for the governance of marine resources occurred in 1928, while in 1945 the FAO was founded to identify and address key challenges to revitalizing the fisheries sector in Europe. Challenges were over-fishing and over-capacity. Regional

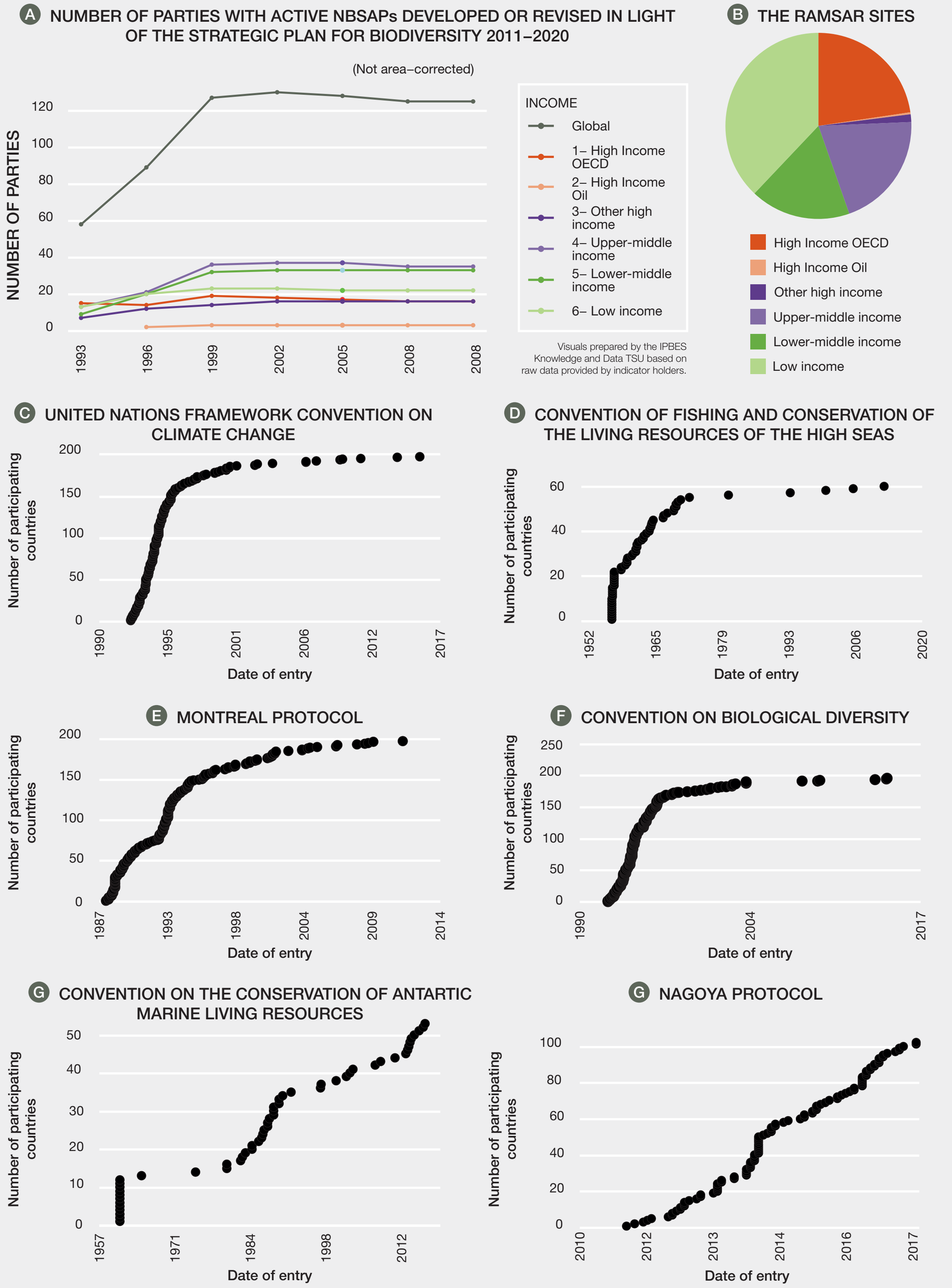


Figure 2 1 11 **Temporal trends in number of parties joining global agreements:**

A Parties with active National Biodiversity Strategies and Action Plans (NBSAPs) as per the Strategic Plan for Biodiversity 2011-2020; B Ramsar sites area per category of countries; and the number of countries in C the United Nations Framework Convention on Climate Change (1990~2017), D the Convention of Fishing and Conservation of the Living Resources of the High Seas (1952~2034), E the Montreal Protocol (1987~2014), F the Convention on Biological Diversity (1990~2017), G the Conservation of Antarctic Marine Living Resources (1957~2012), and H the Nagoya Protocol (2009~2017).

Average values per country using World Bank income categories for Figures A and B: High Income OECD (a:21, b:) High Income Oil (a:3, b:), Other high income (a:16, b:), Upper-middle income (a:40, b:), Lower-middle income (a:34, b:), Low income (a:27, b:) and Total (a:141, b:). Source: (Australian Government - Department of the Environment and Energy, 2017; CBD, 2018a, 2018b; UN, 1966; UN Secretariat to the Antarctic Treaty, 2018).

Fisheries Management Organizations (RFMOs) were established to manage highly migratory stocks, such as different tuna species. Around this time, global fishing effort shifted to the Southern Hemisphere, as key fish stocks in the Northern Hemisphere stocks were depleted. Latin American countries then began to claim jurisdiction over the 200 miles extending from their coastlines. Expansion of global fishing fleets prompted the establishment of national sovereignty over coastal waters via the United Nations Conference on the Law of the Sea convention (meetings 1958 to 1982). Exclusive economic zones (EEZs) were established, giving jurisdiction over 200 nautical miles from national coasts. This allowed countries to manage fish stocks in their national waters using licensing systems to restrict or more generally manage both national and foreign fishing vessels in those waters.

Other key international agreements within this sector include the UN Convention on Fishing and Conservation of Living Resources of the High Seas, as well as the FAO Code of Conduct for Responsible Fisheries that promotes a 'precautionary approach'. In addition, the Convention on the Conservation of Antarctic Marine Living Resources established an MPA and the closures of bottom-trawling fisheries to protect resources located outside of national jurisdictions (Caddy & Cochrane, 2001; Wilen *et al.*, 2012; Wright *et al.*, 2015).

International cooperation on transboundary environmental degradation (water, air, CO_2) also has been studied (Barrett, 1999, 2001, 2013; Barrett & Stavins, 2003; Wood, 2011). Cooperation can be 'strategic', depending on beliefs about the decisions of others, creating an obvious setting for spillovers from one country's decisions. While getting cooperation can be daunting if goals are insufficient or too ambitious (Barrett *et al.*, 2006; Vale, 2016), participation tipping points can be reached if enough countries join then (Barrett & Dannenberg, 2015; Green, 2015).

Alternatively, agreements among smaller sets of countries with common interest are highlighted. Though not global solutions, they are superior to countries acting alone (Finus *et al.*, 2009; Tavoni, 2013). Multiple such small agreements, each acceptable within like groups, could constitute complementary elements in global political frameworks for environmental governance (Falkner *et al.*, 2010; Hale & Roger, 2014). Technical innovations matter greatly. Barrett *et al.* (2006) shows that technologies with increasing returns can succeed where coordination by countries is possible: if the treaty enters into force only after a specific number of countries has signed on, then no country loses and each country could gain from signing on after that number.

Focusing on biodiversity in particular, CITES is an example of a form of global governance that is evolving in implementation via interaction with its member states, in light of species scarcity. CITES is an agreement between governments to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Its implementation responds to changes in nature to ensure that biodiversity is not compromised. UN member states signed CITES, then established a mechanism to implement the agenda. For example, the government of India signed and ratified in 1976, then established a CITES Management Authority, coordinated by a Director in Wildlife Preservation, alongside authorities including the Wildlife Crime Control Bureau.

Efforts to enforce CITES' provisions have affected how species-based trade and illegal activities are regulated, with provisions to reform national-level environmental legislation in conjunction with the CITES Secretariat (administered by UNEP in Geneva). For instance, India amended its Wild Life (Protection) Act of 1972 to integrate CITES provisions, then took several initiatives to build capacity for implementation, such as establishing a self-sustaining multilateral mechanism (including China, Germany, India, Kenya, South Africa, Thailand, Uganda and United States) for funding a program to Monitor the Illegal Killing of Elephants (MIKE) in Asia. Along these lines, Nigeria put in place guidelines for wood-product vendors to require letters of support and CITES permits. That may indicate a shift to sustainable harvesting, updated per species' threats. Yet impacts remain unclear for these iterations between countries and international instruments.

2.1.11 INDIRECT-TO-DIRECT DRIVERS: ACTIONS THAT DIRECTLY AFFECT NATURE

Given the demands for a good quality of life, and characteristics of society including governance, individuals and societies undertake actions with intentional and unintentional impacts on nature. Each action can be carried out in different ways, with different impacts on nature and on actors. Major trends for actions and impacts are shown in **Figure 2.1.12** for groups of countries with different development levels (https://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf), revealing the global trends (see Figure S17). Actions (economic sectors) and their direct consequences on ecosystems are discussed below.

2.1.11.1 Fisheries, Aquaculture and Mariculture

Fisheries, aquaculture and mariculture play an increasing role in food security, livelihoods, and the global economy, yet fish stocks are being depleted. Fish provide ~20% of all animal protein globally (FAO, 2009b), and almost 60 million people were engaged in fisheries and aquaculture in 2012, most in Asia (84%) and Africa (>10%) (FAO, 2014). Value added in fisheries in 2011 was estimated to be over US$24 billion, i.e., 1.26% of the GDP of all the African countries.

Industrial fishing's footprint is 4 times that of agriculture, covering at least 55% of oceans' areas. Data from a new digital platform (Global Fishing Watch, 2018; Kroodsma *et al.*, 2018; McCauley *et al.*, 2016) allows for remote monitoring of vessels in the sea, providing new insights **(Figure 2.1.13)**. They permit monitoring of the 2012–16 activities of more than 70,000 industrial fishing vessels. As much as 85% of the fishing in remote parts of the oceans was by only five countries (China, Spain, Taiwan, Japan and South Korea). Global fishing hot spots include the northeast Atlantic (Europe) and northwest Pacific (China, Japan, and Russia), plus upwellings off South America and West Africa **(Figure 2.1.13)**. Lowest efforts were in the Southern Ocean, the northeast Pacific and the central Atlantic, and in the exclusive economic zones (EEZs) of many island states **(Figure 2.1.13)**.

Smal-scale or non-industrial fisheries (SSF) comprise a large share of global fisheries. SSFs account for over 90% of commercial fishers (over 100 million people), and nearly half (46%) of the global fish catch (Basurto *et al.*, 2017; Béné, 2008; World Bank, 2012). SSF practices entail less bycatch, less destructive gear, and less fuel consumption (Pauly, 2008), more sustainable than industrial fisheries, though with considerable ecological impacts (Alfaro-Shigueto *et al.*, 2010; McClanahan *et al.*, 2009). Yet, SSF statistics are often unreported (FAO, 2016b; Salas *et al.*, 2007). FAO efforts to elevate the profile of SSFs (FAO, 2014) have been improving the reliability and the quality of SSF data (FAO, 2016b).

While three-quarters of major marine fish stocks are fully or over-exploited or depleted —3% underexploited, 20% moderately, 52% fully, 17% overexploited, 7% depleted, 1% recovering from depletion (FAO, 2005, 2016b), efforts are being undertaken to shift trends and increase sustainability. The global fishery community is incrementally adopting sustainable development principles since 1992, including under the umbrella of mainstreaming biodiversity (Friedman *et al.*, 2018). Cross-sectoral cooperation has also been particularly critical to address disagreements, with approaches increasingly including biodiversity considerations. Conservation increasingly adopts more socially inclusive approaches. Efforts on sustainability relate to the Maximum Sustainable Yield (MSY; UN, 2017), which sets harvesting standards. Also, ecologically sound farming systems include aquaculture and integrated farming systems. For instance, in December 2016, 296 fisheries in 35 countries were certified as sustainable by the Marine Stewardship Council Fisheries Standards aiming for healthy ecosystems and long-term sustainability of stocks. Marine spatial planning to reduce conflicts between large- and small-scale fisheries as well as other sectors is increasing in many parts of the world (Douvere & Ehler, 2006). Such planning encompasses ecosystem-based management (FAO, 2003; see McLeod & Leslie, 2009), marine protected areas (FAO, 2011a), and an adaptative management perspective based on participation of the diverse stakeholders (Ehler & Douvere, 2009; Levin *et al.*, 2018).

In contrast, knowledge of inland fisheries is limited, despite societal and ecological significance. Inland fisheries are in lakes, reservoirs, rivers, floodplains, wetlands, lagoons and estuaries. Their economic and food security contributions can be invisible (Lynch *et al.*, 2016, 2017; Youn *et al.*, 2014), with inaccurate or unavailable data (Bartley *et al.*, 2015). Currently, global estimates (FAO, 2016b) suggest a production of about 11.9 million metric tons, over 12% of fisheries production. Over the past decade, the outputs from inland fisheries rose by over 30% despite threats from dam construction, water withdrawals, and pollution. For instance, migratory Caspian sturgeons lost 90% of their habitats (Barannik *et al.*, 2004).

Global fish production is concentrated in a few countries and firms. Overall, Asia accounted for 89% by volume and 79% by economic value in aquaculture (Bostock *et al.*, 2010). Thirteen large corporations from seven countries control a significant fraction (11–16%) of global marine catch (9–13 million tons) and control the largest stocks, with the highest economic values (19–40%), while operating through an extensive global network of subsidiaries (Österblom *et al.*, 2015).

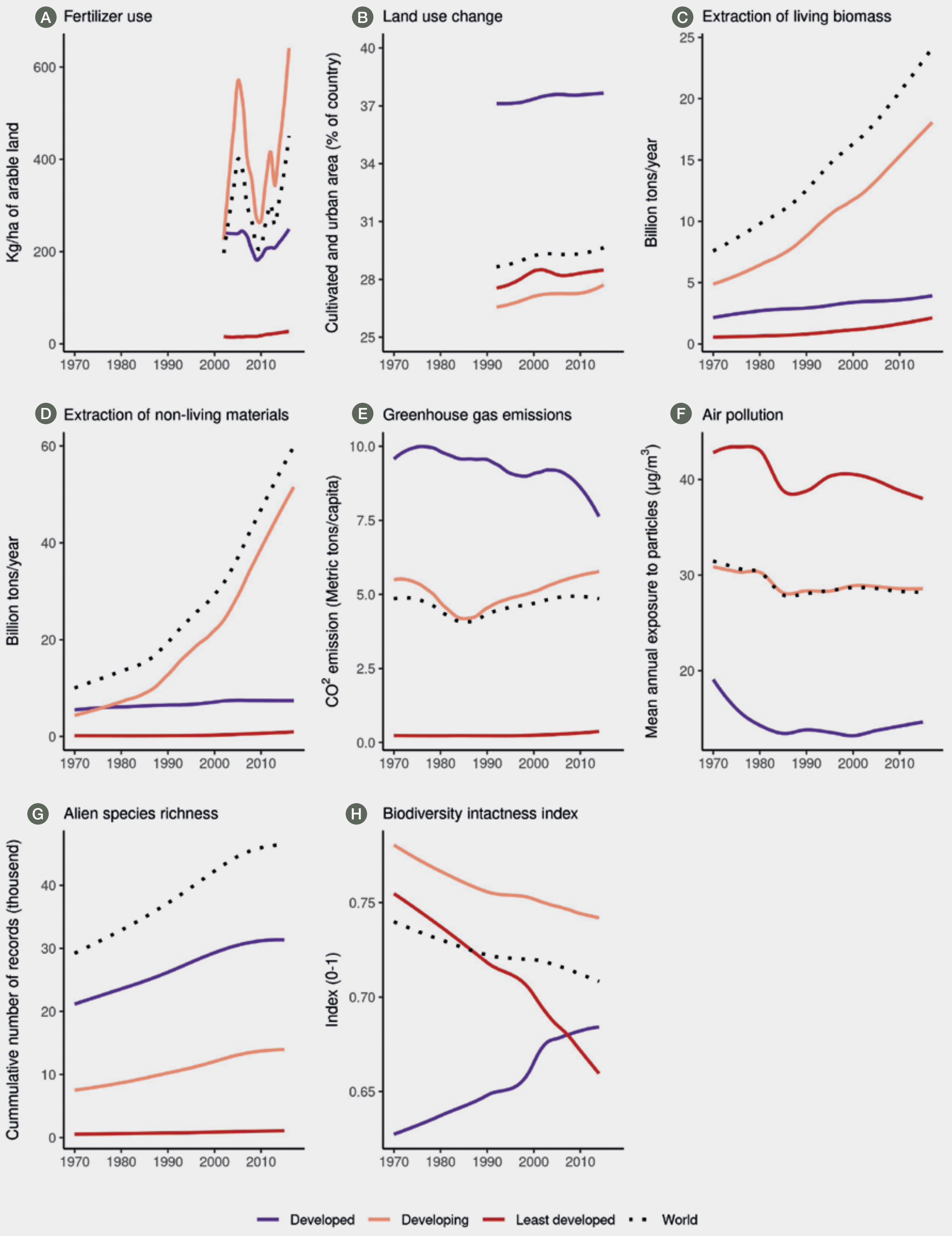


Figure 2 1 12 **Temporal trends for selected indicators of actions and direct drivers.**

Data shown are trends, per country, averaged (A, B, E, F, H) or totaled (C, D, G) by development categories: A **Fertilizer use:** Fertilizer consumption measures the quantity of plant nutrients (kg) used per unit of arable land per year; B **Fraction of cultivated and urban area:** Proportion of total area of country with cultivated and urban land cover, based on ESA CCI Global Land Cover v2.0.7; C **Extraction of living biomass:** Millions of tons per year extracted from agriculture, forestry, fishing, hunting and other types of living biomass; D **Extraction of nonliving materials:** Millions of tons per year extracted of fossil fuels, metal ores, and minerals for construction and industry; E **Per capita greenhouse gases emissions:**

metric tons of CO_2 emitted per year; E **Air Pollution:** mean annual exposure to particles larger than 2.5 micrometer of diameter in micrograms per cubic meter; G **Alien species:** Cumulative number of first records of alien species; H **Biodiversity intactness index:** relative change in abundance of native species as compared to a pristine system. Source: ESA (2017); FAO (2018b); Newbold *et al.* (2016); Ritchie & Roser (2018); Seebens *et al.* (2017); World Bank (2018c); WU (2017).

A

B

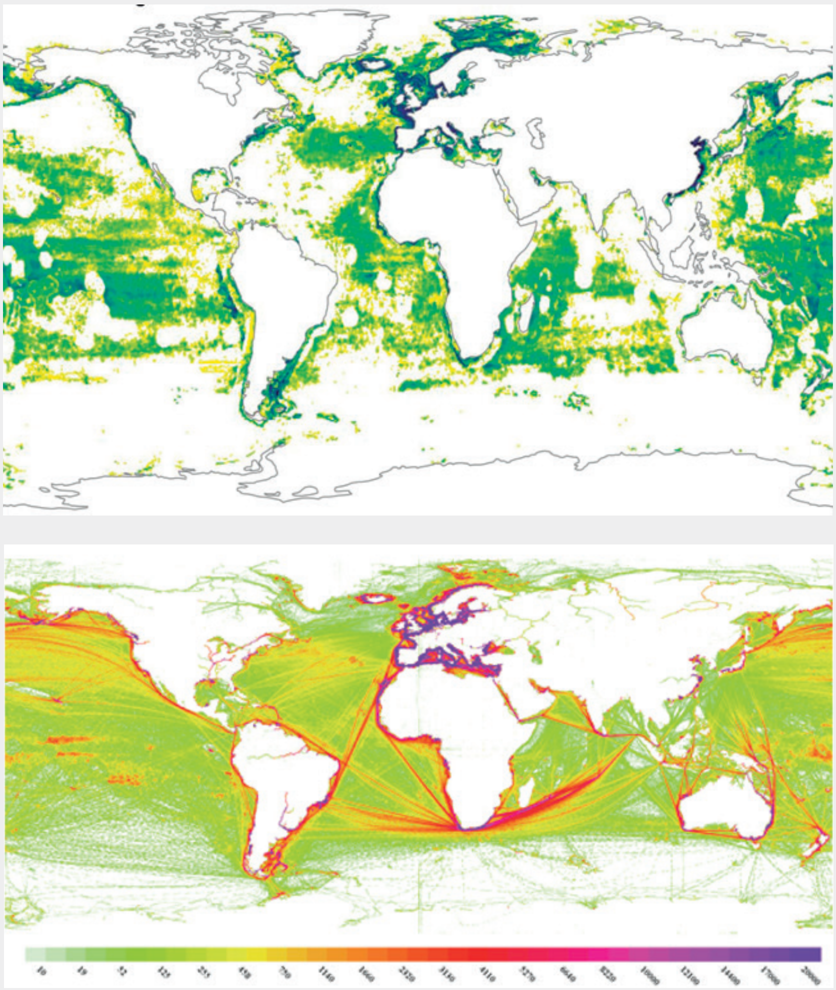


Figure 2 1 13 **Fishing and transportation impacts on the global oceans of all vessels detected with Automatic Identification Systems (AIS).**

A The spatial footprint of fishing. Effort (hours fished per square km (h km-2)) in 2016. B Global Network of Ship Movements (data 2012). Daily records for each 0.2° x 0.2° grid cell. Colored scale shows the number of messages recorded over the year in a cell. The boundaries, names and designations used do not imply any form of official endorsement or acceptance by the United Nations. Source: (Kroodsma *et al.*, 2018; UN, 2016d).

The contribution of aquaculture to global fish production is increasing, with an average annual expansion rate of 9.5% and 6.2% in 1990–2000 and 2000–2012, respectively (FAO, 2014). Yet its contribution to the total fish production has widely fluctuated, especially after 2000 (OECD, 2016). This expansion has incorporated an increasing list of species with different regional and economic importance values (FAO, 2014). The production of aquafeed has increased four times to 29.2 million tons by 2008 (UN, 2017) and it is contributing to national economies (US$6.4 billion in 2014), particularly within developing countries. Fishmeal and fish oil are produced mainly from harvesting stocks of small, fast reproducing fish (e.g., anchovies, small sardines and menhaden). Aquaculture is also emerging as an ecologically friendly alternative (Cottier-Cook *et al.*, 2016), although its growth is having mixed effects upon coastal and marine ecosystems (Figure S19). For instance, selective fish farming for high-performance breeds affects species diversity (Zhou *et al.*, 2010). Aquaculture also contributes to coastal habitat destruction via both wastes (nutrients, feces, antibiotics) disposal and introduction of invasive alien species and pathogens. Aquaculture also contributes to further depleting fish stocks, due to the large fish meal and fish oil requirements (Naylor *et al.*, 1998, 2000). These effects are species dependent. For instance, shrimp and salmon farming have net negative effects, while carp and mollusk farming have net positive effects on global fish supply and food security (Naylor *et al.*, 2000)**.**

2.1.11.2 Agriculture and grazing (crops, livestock, agroforestry)

The wide range of agricultural systems includes plant and animal-based systems, mixed farming, and newly emerging organic, precision, and peri-urban agricultural systems. Agroecosystems cover close to 40% of lands and continue to expand as there is a need to provide food, fuel and fiber for the 9–12 billion people expected by 2050 (Nyaga *et al.*, 2015). More than 175 species constitute the most frequently and extensively cultivated species, globally, with large variations in agricultural yield (Monfreda *et al.*, 2008). While agriculture's inputs and its outputs constitute the bulk of world trade, most food produced today is consumed domestically.

In 2000 there were 15.0 million km^2 of cropland (12% of the Earth's ice-free land surface) and 28.0 million km^2 of pasture (22%) (Ramankutty *et al.*, 2008). Impacts from agriculture are huge (HLPE, 2013; Pretty *et al.*, 2006; SDSN, 2013), e.g., 70–90% of withdrawals from rivers, lakes, and aquifers (Foley *et al.*, 2005) and 25% of global greenhouse gas (GHG) emissions from land clearing, crop production, and fertilization (Burney *et al.*, 2010). During 1980–2000, most new agricultural lands in the tropics came at the expense of intact or disturbed forests (Gibbs *et al.*, 2010). In Africa, agricultural expansion is farming for subsistence (small plots for sorghum, maize, millet) but sugarcane and soybeans are responsible for most agricultural expansion in South America. Rice, wheat, millet, and sorghum dominate South Asia, consistently over time, though tree plantations increased from ~11 to ~17 million hectares between 1980 and 2000, with oil palm plantations responsible for over 80% of this expansion, particularly since the 1990s (Gibbs *et al.*, 2010; Ramankutty *et al.*, 2008).

Agricultural intensification has also increased, with mixed social and ecological outcomes. For instance, water withdrawals and pesticide use have doubled, fertilizer use has tripled, chicken density has increased 10-fold, and cattle density has risen by 20% (Figure S20). Between 1985 and 2005 crop production rose 47% as yields rose 28%, while global crop and pasture lands rose 3%, largely in the tropics (Foley *et al.*, 2011; Poore & Nemecek, 2018). Extensive grazing occurs in 91% of lands, with intensive rising to 9%, largely for livestock production (IPBES, 2018a). An analysis of 60 cases found that agricultural intensification rarely leads to win–win social-ecological outcomes, often increasing food or provisioning services with mixed outcomes for regulating services, that support long-term productivity, and overall well-being (Rasmussen *et al.*, 2018).

Livestock production uses a third of crop production for feed and three quarters of land in total, with consequences for nature as animal-based foods, and especially beef, require more water and energy than plant-based foods (Ranganathan *et al.*, 2016). This all translates into greenhouse gas emissions as well (FAO, 2008). Substantial variation exists in conversion efficiency (i.e., animal products divided by feed to produce them), from 8–10% in Europe to only 1–2% in sub-Saharan Africa, Latin America and South Asia (Krausmann *et al.*, 2008).

Diverse agricultural systems exist, though, with combinations of short-lived and perennial crops together with timber and non-timber products developed over centuries in rural areas, including by IPLCs. Varied agro-silvo-pastoral systems allow maintenance of biodiversity, lower nature's degradation and provide a wide range of material, regulating and non-material contributions (Altieri *et al.*, 2012; Balvanera *et al.*, 2014; González-Esquivel *et al.*, 2015; Kanter *et al.*, 2018; Moreno-Calles *et al.*, 2015). Yet, the associated local and indigenous ethnoecological knowledge is being eroded by migration, urbanization, affected by extension programs, and by agricultural policies oriented to expand the areas under intensive pesticide-based monocultures in support of the international trade of agricultural commodities. For instance, a 70% decline in the cultivation of native plant varieties was observed in the Asia and the Pacific region, with reductions in genetic resources (IPBES, 2018b).

Still, small landholders play crucial roles. It is estimated that small-scale (< 2ha) farms generate ~30% of crops and food supply, using 24% of land, and with high agrobiodiversity (Ricciardi *et al.*, 2018). They also play a key role in maintaining the genetic diversity of managed species (IPBES, 2018b). In Mexico, for example, small-holders cultivating rainfed maize reach yields equal to 3 t/ha, and can feed more than half of the country's population while having a large genetic diversity (Bellon *et al.*, 2018).

As pristine areas fall, the design and management of sustainable agroecosystems (Altieri, 1995) has been applied in agroforestry, sustainable intense agriculture, and integrated pest management (Barrios *et al.*, 2018) with gains for biodiversity and ecosystem services (Bawa, 2004; Du Toit *et al.*, 2004; IAASTD, 2009; Nyaga *et al.*, 2015; Pimentel *et al.*, 1992; Schroth *et al.*, 2004; Tscharntke *et al.*, 2005; Vandermeer & Perfecto, 1995). Zomer *et al.* (2016) find for 2010 that over 43% of agricultural lands had at least 10% tree cover (FAO forest definition). This can connect forests, as is the case within the Mesoamerican Biological Corridor (MBC) launched in 1990 to link forests in northern Colombia with those of southern Mexico.

Organic agriculture has also developed rapidly in more recent decades, including in larger-scale systems, with a focus on utilizing lower off-farm inputs and, where possible, cultural, biological and mechanical pest management. By 2006, such practices covered over 31 million ha in 120 countries (Alexandros *et al.*, 2012). With variable outcomes, they may improve biodiversity, soil and water quality and nutritional value, although not always providing higher yields and lower consumer prices when compared to large-scale monocropping (Seufert & Ramankutty, 2017).

2.1.11.3 Forestry (logging for wood & biofuels)

Between 1990 and 2015, global forest area fell from 4.28 billion to 3.99 billion ha, while the area of planted forests rose from 167.5 to 277.9 million ha (Payn *et al.*, 2015). Forests currently cover one-third of terrestrial area (FAO, 2012a), and a large fraction of people depend at least in part on forests (FAO, 2012a). A challenge has been to manage forests to sustain livelihoods and yet maintain regenerative capacity to ensure long-run survival of forests (MacDicken *et al.*, 2015).

Global harvests of roundwood in 2017 were estimated to be 3.9 billion m^3 of which 1.9 billion were industrial and 1.9 billion were fuelwood (~50% respectively) (FAO, 2018c). Harvests of industrial roundwood are falling in high income OECD countries but increasing in lower-middle and upper-middle income countries (Figure S22). Asia has the highest proportion of agricultural land (52%) and the lowest of forest (19%). Temperate areas within East Asia, Europe, North America, and Southern and Southeast Asia show the largest increases in planted forests. Native species are found within 80% of the planted forests, while introduced species dominate in South America, Oceania and Eastern and Southern Africa as a result of industrial forestry there.

Much forest biomass generates energy, as solid, liquid and gaseous fuels, accounting for 14% of the global energy mix in 2014 (IEA, 2017), while generating greenhouse gas emissions. Between 1960 and 2014, bioenergy use rose 2.7-fold, most in Africa (4.1-fold), yet the share of bioenergy in energy supply declined (15% to 10%) over the same period (De Stercke, 2014). Global use of fuelwood peaked in the mid-1970s and has been falling since the 1980s. Over a quarter of global fuelwood harvested in 2009 was deemed unsustainable, with geographical variations. Over 250 million rural people live in fuelwood-scarcity "hotspots", mostly in South Asia and East Africa (Masera *et al.*, 2015). Of all wood in fuel, about 17% is converted to charcoal, of which production rose over 3-fold during 1961–2015 (FAO, 2016a) given the population growth, poverty, urbanization and prices of alternatives (FAO, 2017a).

Over decades, and centuries, the maintenance of forest cover and biodiversity has been possible, in cases at least, alongside the harvesting of timber and non-timber forest products. Experiences from implementing sustainable forestry in past decades shows that it can achieve higher levels of success where attention is given to planning, establishing permits, and legal rights (MacDicken *et al.*, 2015). As discussed above, forest certification standards for sustainable harvest have been developed by several organizations, including the Forest Stewardship Council (FSC, 2018) and the Programme for the Endorsement of Forest Certification (PEFC, 2018). For tropical forests, such certifications have, in cases, provided varied environmental and social benefits for local communities, with lower short-term profits (Burivalova *et al.*, 2017).

Sustainable community forestry is found in Latin America (Mexico, Central America, Colombia and Peru), Canada and the US (Gilmour, 2016; Merino & Cendejas, 2017; Nagendra, 2007), while sustainable family forestry occurs in Northern and Central Europe (Finland and Austria). Often, community forest is managed within agroforestry systems such as for shade coffee and cacao. For instance, within the lands of IPLCs in Mexico and Central America, there is evidence that community forestry is as efficient as protected areas in preserving forests and conserving biodiversity (including both bird and mammal species) and reducing rates of greenhouse gas emissions (Bray & Merino-Pérez, 2004; Duran-Medina *et al.*, 2005; Merino & Cendejas, 2017; Merino-Pérez, 2004). However, economic and environmental benefits of community management are still understudied and, in the case of tropical forests, its social impacts could be either positive or negative (Burivalova *et al.*, 2017).

2.1.11.4 Harvesting (wild plants and animals from seascapes and landscapes)

Harvesting and use of non-timber forest products (NTFPs) is a core component of livelihoods for forest-dependent communities around the world. About 350 million people in or adjacent to forests depend on NTFPs for subsistence and income (World Bank, 2004). NTFPs include any biological resources found in forests other than timber (e.g., seeds, oils, foliage, game animals, medicinal plants, spices, bark, mushrooms, fuelwood). Poor rural populations heavily depend on medicinal plants when healthcare is limited, with Africa being most dependent (IPBES, 2018b).

Data are patchy, as consumption is often local, outside markets, and not within national statistics. A meta-analysis of 51 studies in 17 countries found that NTFPs represented, on average, 22% of total income for sampled populations. They also play key roles as equalizers of local income distributions (Vedeld *et al.*, 2007) because the poor rely more on them. A study (Belcher *et al.*, 2005), of close to 100 cases across Africa, Asia and Latin America supports that the households with lower incomes relied more on NTFPs for their livelihoods – such that degradation and overexploitation impact the rural poor more (Belcher *et al.*, 2007; Shackleton & Shackleton, 2004), especially the old and the young.

Some NTFPs have large markets. For instance, maple syrup earned ~US$350 million in 2015, up 18% from 2011. Canada produced 82% of it, followed by the US (7.6%) and Germany (2.3%) (Barlow *et al.*, 2015). Rattan from humid and sub-humid forests in Indonesia (80%) earned over US$70m (62,000 tons) in 2008, down 70% from 2000 (Hirschberger, 2011). Empirical evidence is biased towards such traded NTFPs, which are a small fraction (Belcher *et al.*, 2005). While commercialization may maintain and even improve livelihoods, market chains with many intermediaries can lower local economic returns and increase overexploitation of the products (Buda Arango *et al.*, 2014; Marshall *et al.*, 2006).

Bushmeat is an important source of protein and provides food security and livelihoods for many forest-dependent rural and urban populations in low- and lower-middle income countries. In the tropics, at least 6 million tons of large to medium size mammals, birds and reptiles are harvested every year (Nasi *et al.*, 2011), with 1 to 5 million tons within the Congo Basin alone (Fa *et al.*, 2003; Wilkie & Carpenter, 1999). About a third is commercialized and reported in national statistics (Karp *et al.*, 2015; Nasi *et al.*, 2011). Many species can survive high offtake but for slow-breeding species even low offtake can be devastating (Van Vliet *et al.*, 2010, 2007). Some literature suggests that the rare species are seldom targeted and are a small share of offtake (Abernethy & Ndong Obiang, 2010; Nasi *et al.*, 2011; Van Vliet *et al.*, 2010), yet a large number of primate species are threatened.

In high and middle income countries, hunting, and trophy hunting in particular, now are mostly recreational, aimed at large game species (bears, wolves, lynx, red deer, wild boar) and at birds (ducks, geese, waders, doves, passerines). Around 6 million wild ungulates are harvested every year, with a mixed set of motivations (Bauer & Giles, 2002). Yet hunters have declined in many parts of Europe and the US. Game fishing targets larger members of many species, which tend to be the most fecund, yielding disproportionate impacts on biodiversity. A large number of species (85) targeted by the International Game Fish association are considered 'threatened' by IUCN. In contrast, most Arctic hunting and fishing is for local consumption – often regulated separately (CAFF, 2013) – with nutritional and cultural significance, especially for Indigenous Peoples.

2.1.11.5 Mining (minerals, metals, oils, fossil fuels)

Mining activities directly and indirectly affect the livelihoods of most people around the world, via contributions to the production and use of minerals, metals, oils and fossil fuels. Hundreds of mineral commodities have uses in energy, construction, manufacture, and industrial processes. Mining contributes a large fraction of the world's GDP, particularly among emerging economies, with over 60% of GDP for 81 countries in 2014, and more than 17,000 large-scale sites in 171 countries (Matos *et al.*, 2015). Oil, gas, coal and minerals (e.g., bauxite, copper, gold, iron ore, lead, nickel, phosphate rock, silver, tin and zinc) are close to a quarter of natural capital globally, and close to 7% of total wealth (World Bank, 2006). Thus, this is an extremely important economic sector.

Yet, it features imperfections in rights, markets and legal structures. Valuable resources have had destructive consequences as well, such as in Africa's 'diamond wars' (Gylfason, 2009), although systematic quantitative global data on these issues largely are missing. As global gold demand increased after the international financial crisis, within the South American moist forest ecoregions more than 90% of the deforestation linked with gold mining occurred within four major hotspots: Guianan (41%), Southwest Amazon (28%); Tapajós–Xingú watersheds (11%); and Magdalena–Urabá along with Magdalena valley montane forest (9%) (Alvarez-Berríos & Aide, 2015). Some of the more active zones for all this deforestation associated with gold mining deforestation occurred in or within 10 kilometers of protected areas (Alvarez-Berríos & Aide, 2015).

Mineral deposits of *Al, Fe, Cu, Au*, and *Ag* are concentrated in the Andes, Rocky Mountains, North-East America, Australia, South-eastern and Western Africa, Northern and Eastern Europe, and in Eastern and South-Pacific Asia. Globally, bauxite and silver mines are within zones with intermediate to high biodiversity (Murguía *et al.*, 2016). Further, as the ice melts with climate change, new areas are opening up to mining within the Arctic and the Antarctic regions, including with important petroleum reserves in the Arctic (AMAP, 2018).

Surface mining is a driver of land-cover change, pollution of surface and ground water, and air quality degradation, constituting a health hazard in many regions. Although it occupies under 1% of land area, it has negative effects upon vast areas (Schueler *et al.*, 2011; Sonter *et al.*, 2014), locally for biodiversity perhaps more than agricultural expansion (Deikumah *et al.*, 2014). Severe landscape transformations include not only deforestation but also the opening of pits, vast amounts of waste, large quantities used of freshwater, and chemical and physical pollutants released into air, land and water (Palmer *et al.*, 2010). Coal and gold mining (Epstein *et al.*, 2011; Palmer *et al.*, 2010) can severely modify a landscape, including via extensive destruction of forest and the corresponding loss of habitats (Asner *et al.*, 2013; Swenson *et al.*, 2011; Wickham *et al.*, 2007).

Subsequent processing also released carbon dioxide, sulfur dioxide, methane, particulate matter, mercury and other heavy metals, generating acid rain and raising the bioavailability of mercury and other heavy metals (Epstein *et al.*, 2011; Palmer *et al.*, 2010). In the main gold production region of Colombia, gold mining is responsible for the highest reported concentration of mercury in the air (a thousand times above the WHO's allowable level) (Cordy *et al.*, 2011), putting ~150,000 people at high risk of mercury poisoning (Spiegel, 2012). Artisanal and small-scale gold mining is the leading source of anthropogenic mercury emissions globally (UNEP, 2013). Mining also occurs in oceans, in over 50 countries. While seabed mining is a currently relatively small, the growing demand for minerals has led to 18 contracts granted in the last 4 years by the International Seabed Authority (ISA), for ~1 million km^2 in the Pacific, Atlantic, and Indian Oceans beyond any national jurisdiction (Wedding *et al.*, 2015).

While large companies produce most of the minerals traded internationally, small-scale mining is an important economic activity, particularly in the developing world. Many poor rural people see it as a best livelihood option (Spiegel, 2012), yet they may not capture much economic surplus in the value chain (Hilson, 2003; Hinton, 2005). Whole countries rich in minerals have had limited long-term impacts on their economies from mining. Latin America has large deposits of copper, iron, gold and silver. Chile, Bolivia and Peru are the major mining countries of South America. Africa is estimated to have 40% of the world's gold, 60% of cobalt, and 90% of platinum. Yet, booming mining sectors in mineral-rich countries may not have large gains in local communities, especially when also taking into account environment and health impacts (Gordon & Webber, 2008). Many countries have been unable to use mining wealth to greatly boost their economies (Auty, 2006; Sachs & Warner, 1995). Furthering the potential for local net costs, the sector also has been linked to social and environmental conflicts, and illegal activities, with a few large multinational companies controlling large networks of exploration sites with the largest human rights violations (Inter-American Court of Human Rights and Bebbington & Bury, 2013; see sections 2.1.6.3.2 and 2.1.9.1).

2.1.11.6 Infrastructure (dams, cities, roads)

While the development of infrastructure has negative direct consequences on the environment, it has both negative and positive indirect effects (see also sections 2.1.5.3, 2.1.6.2, 2.1.9.1.2, 2.1.11.1). Rivers have been modified for thousands of years to regulate floods and to ensure water supply for irrigation, industries and settlements, recreation, navigation and hydropower generation. Over past decades, the numbers of dams and reservoirs, and their overall storing capacities, have greatly increased. Currently, about 50,000 large dams (higher than 15 m), and an estimated 16.7 million reservoirs (larger than 0.01 ha) hold approximately 8,070 km^3 of water (Lehner *et al.*, 2011). Close to 8% of the world's rivers are affected by cumulative upstream reservoir capacities exceeding 2% of the annual flow. Smaller reservoirs (> 0.5 km^3) account for a small fraction of the water stored, yet substantially affect rivers, increasing their spatial extent (Lehner *et al.*, 2011). These changes have decreased the global annual sediment flux to the coastal zones by 3.7 billion tons, leading to river sediment starvation and thus coastal erosion in delta regions and estuaries with negative consequences upon habitats, while increasing coastal and estuarine turbidity, negatively affecting biological systems. These estuaries and deltas are estimated to concentrate some of the largest population density in the world, including a large share of coastal mega-cities (UN, 2017).

Urbanization has multiple and complex linkages to the environment (Bai *et al.*, 2017; Grimm *et al.*, 2008). Currently, urban areas account less than 3% of the total land area (Grimm *et al.*, 2008; McGranahan *et al.*, 2005), although urban expansion is faster than urban population growth (UN, 2014), often driven by positive feedbacks between urbanization and economic growth (Bai *et al.*, 2012). From 1970 to 2000, urban land use expanded by 58,000 km^2 (Bai *et al.*, 2012; Seto *et al.*, 2011). The expansion of cities is linked to infrastructure to supply demands of urban living (e.g., transportation of people, goods, energy, water), with effects in and beyond the boundaries of urban areas. Growing urban populations create more impervious surfaces, which reduce water infiltration, affecting regional climates and hydrology (Chen *et al.*, 2010a; Tayanc & Toros, 1997; Žganec, 2012). Infrastructure development projects designed to address the supply of natural resources may also displace people, take agricultural land out of production, and alter ecosystems (Liu *et al.*, 2016c; Vitousek *et al.*, 1997b; Zhang, 2009). Yet, urban infrastructure attracts people from rural areas, potentially lessening the land uses in fragile and/or low productivity ecosystems, stimulating ecosystem recovery and improving biodiversity conservation (Aide & Grau, 2004; Grau & Aide, 2007; Grau *et al.*, 2003).

Urbanization is also a major cause of losses of lakes and wetlands in multiple countries (Davis & Froend, 1999; Prasad *et al.*, 2002; Wang *et al.*, 2008). Production and consumption in cities can exacerbate air and water pollution – with negative health consequences (Guo *et al.*, 2013; Liu *et al.*, 2016b; McMichael, 2000; Zhu *et al.*, 2012). Urban land expansion also reduces habitats, particularly in biodiversity hotspots (Elmqvist *et al.*, 2013; Seto *et al.*, 2012). Urbanization and urban activities shift spatial and temporal patterns of rainfall (Shi *et al.*, 2017), while physical structures influence regional temperatures through heat islands (Giridharan *et al.*, 2004; Sobstyl *et al.*, 2018). On the other hand, cities can also be champions of environmental stewardship, for instance by building flood-resilient cities and reducing varied emissions of greenhouse gases (Bai *et al.*, 2018; Solecki *et al.*, 2018). Biodiversity friendly cities are also now found (Botzat *et al.*, 2016).

Roads and transportation infrastructure have been associated with both increased pressures upon forests and habitats or, in contexts, relocation of pressures away from nature (Benítez-López *et al.*, 2010). New roads certainly have led to losses of forest (Boakes *et al.*, 2010; Laurance *et al.*, 2015) but with highly varied impacts depending on their contexts – from large losses to no net effects, across tropical forests in Latin America, to even some positive effects in more highly populated and developed areas, such as within India. The indirect effects of transportation investments through transport costs, and related responses, can be much bigger than the direct effects of projects (Edwards *et al.*, 2014; Weng *et al.*, 2013).

Increasing human encroachment, land reclamation, and coastal development have big impacts on coastal environments (UN, 2017) including on nature, e.g., mangroves that help with resilience. To meet growing land demand for housing and recreation, industry, commerce, and agriculture, large-scale land reclamation projects are increasing along coasts, although coastal protection is also increasing. Large-scale dredging has occurred in several countries in Asia and the Middle East, beyond the near-shore environments, for creation of airports, tourism facilities and islands. Land reclamation is linked to the degradation of wetlands, seagrass beds and decreased coastal water quality, with negative impacts on regional groundwater regimes discharges to the coasts.

Challenges posed by the growth of infrastructure vary by country (Bai *et al.*, 2017; McGranahan *et al.*, 2005), typically with more and better infrastructure as income rises (World Bank, 1994). High income countries have built more energy and telecommunications connections, as well as more extensive transport networks in locations with a higher density of population and industry. In contrast, while infrastructure has expanded tremendously in many rapidly growing cities and peri-urban settlement in Africa and South and East Asia, it still lags the growth of population and service demands – leading to local environmental degradation – while the inadequate design and maintenance of that new infrastructure lead to its severe deterioration and significantly reduced lifespans. Urban growth within the less-developed countries also brings complex challenges, as for increasing the provision of basic services, such as clean water and sanitation (Cohen, 2004, 2006; Elmqvist *et al.*, 2004; Hardoy *et al.*, 2013; Seto *et al.*, 2013; UN, 2014; World Bank, 2015b; Young *et al.*, 2009), although such challenges have also offered opportunities for locally developed solutions (Nagendra *et al.*, 2018).

2.1.11.7 Tourism (intensive and nature-based)

Tourism has dramatically grown in the last 20 years. Total international departures and arrivals tripled globally, with greater increases from high income and upper-middle income countries (Figure S23). Much is domestic, e.g.: 3,260 million versus 29 million international for China; and 1,600 million domestic tourism trips versus 70 million international for the US (UN, 2017).

Between 2009 and 2013, tourism's global carbon footprint rose from by 40%, from 3.9 to 4.5 $GtCO_2$-eq, accounting for ~8% of global greenhouse gas emissions (Lenzen *et al.*, 2018), with transport a big contributor. In 2010, tourism required 16,700 PJ of energy, 138 km^3 of fresh water, 62,000 km^2 of land, and 39.4 Mt of food (Gössling & Peeters, 2015). Yet impacts vary considerably: one-night accommodations require 3.7 - 3,700 MJ of energy depending on the luxury conditions of accommodations and transport. Largest increases have been observed for the most resource-demanding options for the growing global class of wealthy travelers (UN, 2017). Most of the footprint of tourism is exerted by high income countries. These rapid increases in demand are effectively outstripping decarbonizations of tourism-related technology (Lenzen *et al.*, 2018).

Demands for nature-based and eco-tourism also have risen. While the latter aims for consistency with conservation by operating at small spatial scales to minimize ecological and social impacts, the former often operates at larger spatial scales and promotes national development objectives (Brandon, 1996). Their effects are, thus, quite different. The number of visitors to 280 protected areas within 20 countries has been increasing over time in all countries, particularly in those with lower income levels – with the exception of the United States and Japan (Balmford *et al.*, 2009).

2.1.11.8 Relocations (of goods and people)

Transportation of goods and people has risen drastically in recent decades (see also 2.1.11.6). The number of air flights has doubled, globally, and tripled for high income OECD countries (Figure S23), while seaborne carriage of oil has doubled, general cargo has quadrupled, and the carriage of grain and minerals has nearly quintupled. Voyage lengths also have increased (UN, 2017).

Relocation of goods and people has direct, indirect and cumulative impacts on nature (Rodrigue *et al.*, 2016). Noise and toxic emissions – e.g., carbon monoxide – directly cause harm. Catastrophic events involving ships (such as collisions, fires, foundering, wrecks) produce serious direct impact on marine ecosystems (UN, 2017). Indirect effects include chronic impact along frequent trade routes **(Figure 2.1.13)**. Cumulative impacts include those upon the global climate, with 15% of the global CO_2 emissions associated with the transportation sector (Rodrigue *et al.*, 2016), and more than 3.5% of climate forcing attributed to air transportation (Lee *et al.*, 2010).

Introduction of invasive alien species is linked to transportation of goods and people. In both the 20th and 21st centuries, trade was one of the most important factors in the widespread distribution of invasive alien species in both aquatic and terrestrial ecosystems (Hulme, 2009; Seebens *et al.*, 2016) (Early 2006). Accidental introductions of invertebrates and algae had steep increases recently, as those species are difficult to regulate and are closely associated with increasing human activity such as trade, migration, and tourism (Hulme, 2009; Kowarik, 2011).

2.1.11.9 Restoration

With degradation currently impacting the well-being of at least 3.2 billion people, with losses of more than 10% of the annual global gross product (IPBES, 2018a), there is an urgent need for restoration to avoid biodiversity loss, mitigate climate change, and ensure continued global ‘life support’ (Aronson & Alexander, 2013; Navarro *et al.*, 2017). Sustainable land management practices, with restoration actions to avoid, reduce and reverse land degradation, have been shown to provide benefits that exceed their costs in many places, though their overall effectiveness is context-dependent (IPBES, 2018a). While financial costs are easy to quantify and can seem high, assessing restoration’s short-, medium-, and long-term effects on nature’s contributions is challenging. They are not all perceived and valued (IPBES, 2018a).

While recoveries due to restoration of ecosystems and landscape may not be complete (Benayas & Bullock, 2012; Jones *et al.*, 2018), they yield multiple direct and indirect benefits for nature and people: increased material benefits from nature; climate regulation; and also spiritual gains (Benayas & Bullock, 2012; Brancalion *et al.*, 2014; IPBES, 2018a). Restoring the structure and function of degraded ecosystems contributes to longer-term ecosystem resilience (Kaiser-Bunbury *et al.*, 2017; Suding, 2011) as well as to short-term mitigation and adaptations to climate change (Locatelli *et al.*, 2015). Restoration is an obvious complement to conservation for biodiversity (Possingham *et al.*, 2015) and ecosystem services. Ultimately, its goals depend on the extent and nature of degradation and local needs and decision processes. Recovery of the prior “intact” ecosystem may not be possible, or desirable, in some contexts (Hobbs *et al.*, 2014).

International conventions recognize the importance of restoration at national and global scales. Restoration is a key piece of Aichi Biodiversity Targets 14 and 15 established by the Convention on Biological Diversity (CBD). Ecosystem- and landscape-scale restorations are also approaches of the UN Convention to Combat Desertification, UN Convention on Climate Change, Ramsar Convention on wetlands, Convention on Migratory Species, and Sustainable Development Goals. The Bonn Challenge to restore 150 million hectares of forest 2020 was expanded by a United Nations’ New York Declaration on Forests to restore 350 million ha by 2030 (IUCN, 2015). This is not just to plant trees but also to use regenerated forest sustainably, manage tree plantations, agroforestry and agricultural systems, and protect wildlife reserves with ecological corridors or river or lakeside planting to protect water (IPBES, 2018a). No similar global-scale challenge has yet been proposed for restoration of non-forest ecosystems.

Restoration is implemented by state agencies, local communities, non-government organizations, and the private sector. Approaches range from passive to active interventions, with distinct costs, limitations, and outcomes. Passive approaches that rely on natural recovery mechanisms have the highest rates and extent of recovery overall (Jones *et al.*, 2018), particularly for tropical forests (Crouzeilles *et al.*, 2017). Interventions can focus on specific habitats and ecosystems or at the scale of landscapes, encompassing mosaics of different land uses, ecosystems and land covers.

Yet large gaps remain between restoration targets and achievements, reflecting gaps in capacity, finance, policy, and enforcement (Stevens & Dixon, 2017). Restoration is legally mandated in some countries (e.g., Brazil, China), particularly after certain activities (e.g., mining or wetland drainage or as related to required protections for rivers and streams). Compensatory restoration, required in some countries, requires the party responsible for ecological damage to compensate the public for ecosystem services loss (Rohr *et al.*, 2018). In other cases, biodiversity offsets create a mechanism for off-site restoration to compensate for the biodiversity losses caused by development projects. For example, to offset vegetation losses due to industrial development of oil palm during 1973–2013, the industry would need to restore natural vegetation across 8.7% of Kalimantan (Budiharta *et al.*, 2018) in order to get to no net loss (rather than, e.g., any net gain).

Achieving restoration targets in international treaties and conventions will require avoiding more degradation and conversion of ecosystems, plus effective and long-lasting restoration practices at national scales (Chazdon *et al.*, 2017). With climate and biodiversity policies, this is a basis for progress on sustainable futures (Aronson & Alexander, 2013; Benayas & Bullock, 2012; Brancalion *et al.*, 2014; Budiharta *et al.*, 2018; Chazdon *et al.*, 2017; Crouzeilles *et al.*, 2017; De Groot *et al.*, 2013; Egoh *et al.*, 2014; Hobbs *et al.*, 2014; IUCN, 2015; Jones *et al.*, 2018; Kaiser-Bunbury *et al.*, 2017; Locatelli *et al.*, 2015; Navarro *et al.*, 2017; Possingham *et al.*, 2015; Rohr *et al.*, 2018; Stevens & Dixon, 2017; Suding, 2011; Suding *et al.*, 2015; Verdone & Seidl, 2017).

2.1.11.10 Illegal activities with direct impacts on nature

Illegal activities constitute major threats to nature and livelihoods. In maritime regions, they add to depletion of fish stocks. Coastal zones of developing countries are particularly susceptible to illegal, unreported or unregulated (IUU) fishing that peaked during the mid-1990s. In 2011, IUU fishing was estimated at 26m or 33% of global catch including fish and other marine fauna (UN, 2017) and 20–32% by weight of wild-caught seafood imported to the US (Pramod *et al.*, 2014). Locally, IUU fishing is highest off West Africa, estimated at ~40% of total catch, with 32% in the Southwest Atlantic and as much as 1.5 million tons/year in Indonesia (**Figure 2.1.14**; Agnew *et al.*, 2009). Note that 70% of vessels known to be linked to IUU fishing are flagged under tax-haven jurisdictions (Galaz *et al.*, 2018).

IUU fishing is lucrative, due to high-value species plus no taxes – as is permitted by weak governance (Fisheries and Oceans Canada, 2009). While efforts have improved oceans governance over the last decade, not all regions are overseen by regional fishery management organizations (RFMO) while not all RFMOs are effective in monitoring and controlling IUU fishing. The Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (PSMA), which came into force in June 2016, has grown to 54 parties (with all 28 EU members counting as just one). Endorsement by 170 states of the FAO Code of Conduct for Responsible Fisheries (CCRF) in 1995 has contributed to lowering IUU fishing. While this is voluntary, Australia, Malaysia, Namibia, Norway and South Africa, have incorporated provisions into national law. Recent improvements in vessel monitoring systems are available, for both larger- and small-scale fishing vessels, providing geo-referenced descriptions of fishing areas and at scales useful for policy (Global Fishing Watch, 2018; Kroodsma *et al.*, 2018; McCauley *et al.*, 2016).

Illegal forestry has important negative consequences on forests, aggregate economic wellbeing, and livelihoods of forest communities (Smith, 2004). Hoare (2015) has estimated that 80 million m^3 of timber was illegally produced in 2013 by the nine main producers in tropical countries. Overall illegal logging is estimated to be 10–15% of global timber production (Brack & Hayman, 2001; RIIA, 2017; SCA & WRI, 2004) though rates of up to 50% are reported for several countries (Guertin, 2003; Tacconi *et al.*, 2003). In 2013, Indonesia (50%), Brazil (25%) and Malaysia (10%) accounted for most of the illegal timber harvests worldwide, with large timber sectors (Hoare, 2015), while Ghana, Cameroon, DRC, Laos, Papua New Guinea and Republic of Congo are also large contributors, with much higher proportions of production being illegal (e.g., almost all DRC production) (Hoare, 2015). In 2013, illegal logging emitted over 190 million tons of CO_2, more than total emissions from Denmark, Norway and Sweden (Hoare, 2015). Economic impacts are largely revenue losses for states and, in some cases, private forest owners. These hurt livelihoods for forest-dependent people and displacements of people through corrupt land and forest acquisition practices (Pokorny *et al.*, 2016; Tacconi, 2007b). Illegal production of biofuel is large especially in Africa. Most wood pellets and fuelwood in Asia and the Pacific and Latin America are produced legally at medium to large scale, yet in Africa a significant share is associated with small-scale, poor, informal actors (Mohammed *et al.*, 2015). Fuelwood harvesting has the most effects on dry forest, grassland and savannas.

A number of factors have contributed to drive illegal logging, beyond the costs and the returns from sustainable forest management (Pokorny & Pacheco, 2014), including quite poor investment incentives for companies (Contreras-Hermosilla, 2001), poor governance ranging from weak enforcement capacity (Ehara *et al.*, 2018) and over-regulation to corruption including infringements of weak property rights (Alemagi & Kozak, 2010; Cerutti *et al.*, 2013; Contreras-Hermosilla, 2001; Pokorny, 2013; Pokorny *et al.*, 2016; Smith *et al.*, 2003; Tacconi, 2007a). Most of the reported illegal logging is industrial logging in developing countries, yet small scale (artisanal or chainsaw) and on-farm illegal logging has been reported as quite significant in some cases (Cerutti *et al.*, 2013; Hoare, 2015). Its growth is explained by two factors. First, it is the increased timber sourcing from secondary forests, fallows and farms as natural forest concessions move further away with corresponding increases in transport costs. Second, it is the reduction in illegal industrial logging due to improvements in transparency.

Poaching also greatly threatens biodiversity (Clarke & Rolf, 2013) and is rising **(Figure 2.1.14c)** given increasing demands for bushmeat, traditional medicine, souvenirs, pets and luxury goods (Hofer *et al.*, 1996). Poaching has pushed many species to the brink of extinction, even those in the IUCN's list of threatened species, e.g., rhinos and tigers.

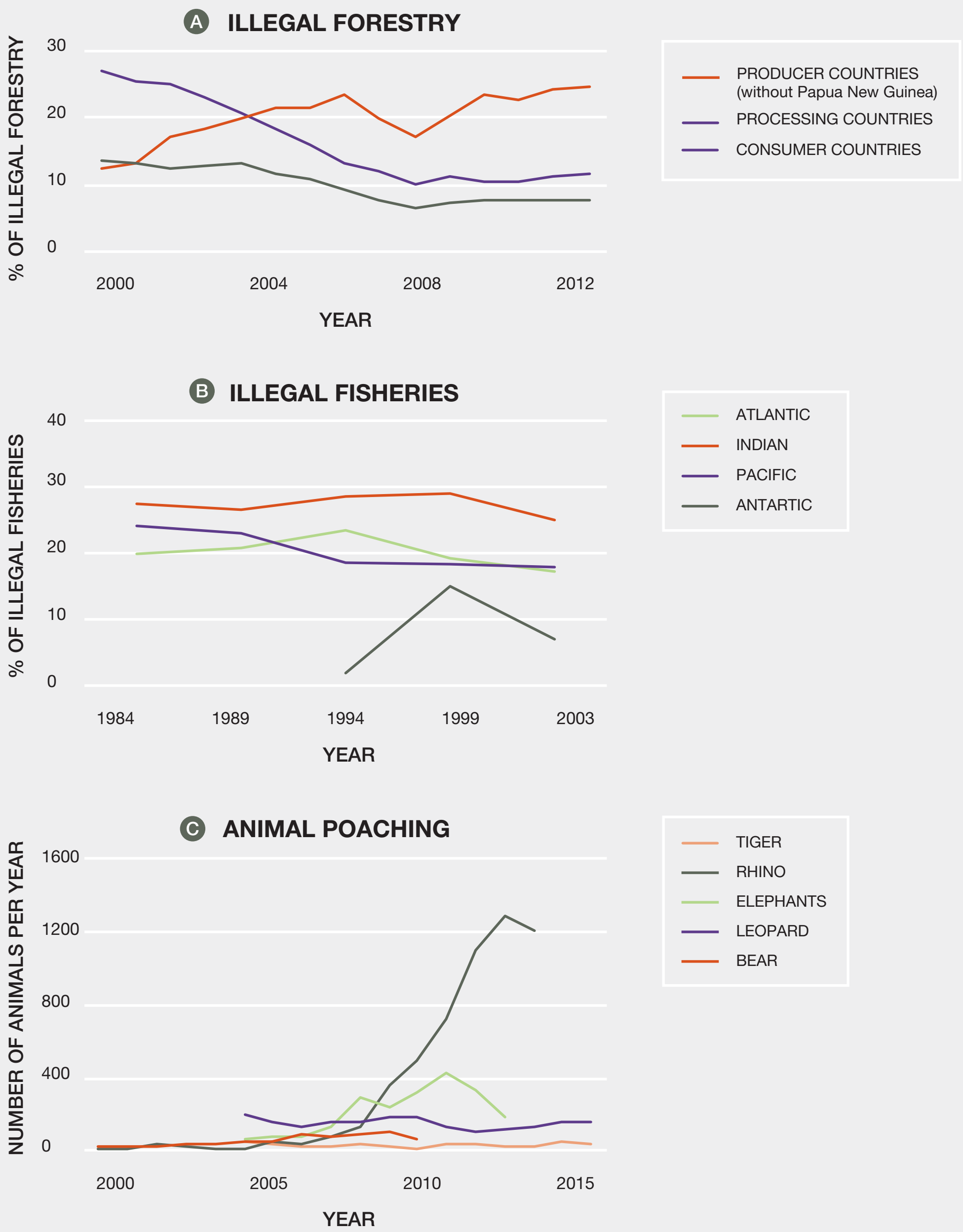


Figure 2 1 14 **Trends in illegal extractions from nature.**

A Producers, processers, and buyers of illegal wood: Percentage of total from 2000 to 2014, B Illegal fisheries: percentage of total fisheries that is illegal by region from 1984 to 2003, C Animal poaching: total number of animals per year from 2000 to 2017. Sources: Illegal forestry: Hoare (2015); Illegal fisheries: Agnew *et al.* (2009); Illegal poaching: data from the Wildlife Protection Society of India (http://www.wpsi-india.org/) for India only (Leopard/Tiger) and from http://www.poachingfacts.com/, reporting for some countries only and considering only years with consistent presence of data (Rhino/Elephant/Bear).

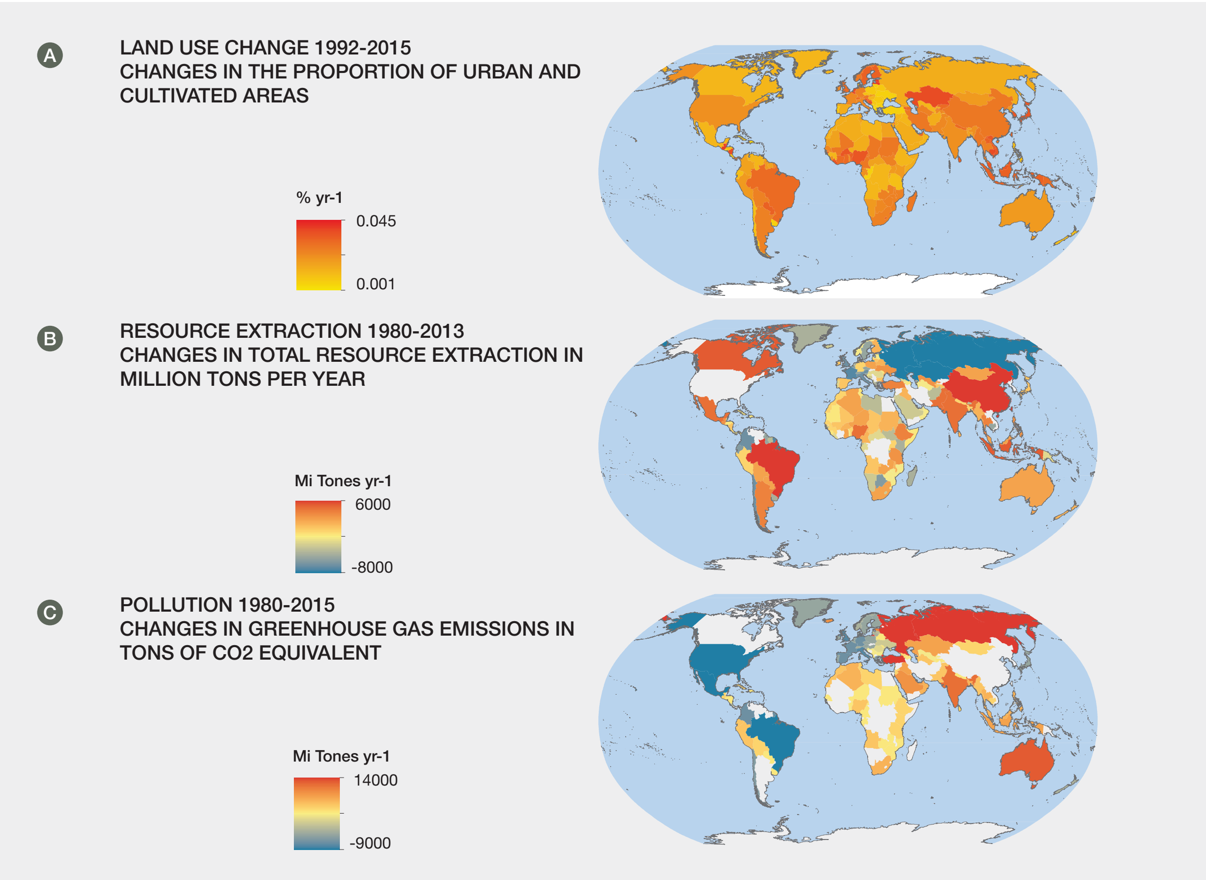
Various international organizations (e.g., WWF, IUCN) and agreements (e.g., CITES) include considerable efforts to eliminate poaching and countries (Kenya, Tanzania, South Africa) have taken drastic measures to control it and punish poachers, e.g., applying 'shoot-on-site' (Messer, 2010). While some of these mechanisms have slightly decreased poaching in many countries, it is still difficult to bust the invisible connections between the poachers and the recipients or users of animal parts.

Poaching has been promoted, to date, by several factors. Corruption, combined with different standards with respect to poaching bans, has greatly weakened law enforcement (Smith *et al.*, 2003). There is a lack of detection of tons of animal parts, or live animals, crossing political boundaries including international borders. Further, poor infrastructure, together with poorly equipped personnel engaged in trying to control poaching in many of the countries where it primarily takes place, reduces timely responses when a poaching incident is reported. But even when policy instruments officially are in place and their implementation is in fact being actively attempted, the lucrative financial gains for poaching driven by the high demand for animal parts and live animals have pushed poachers to discover innovative means of evasion (Knapp, 2012; Lindsey *et al.*, 2013; Milner-Gulland & Leader-Williams, 1992; Warchol & Kapla, 2012).

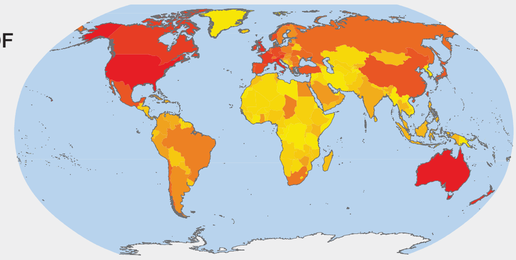
2.1.12 DIRECT DRIVERS OVERVIEW: AGGREGATING IMPACTS ACROSS SECTORS

Human actions to satisfy needs and goals – as above fisheries, agriculture, logging, harvesting, mining, infrastructure, tourism, transport, restoration – clearly affect nature quite considerably. Their aggregated impacts are classified in IPBES into five categories of direct drivers: land-use / sea-use change; resource extraction; pollution; invasive and alien species; and climate change. Each of these are addressed in independent sections below, with an introductory overview.

Overall temporal trends (**Figure 2.1.12**, maps in **Figure 2.1.15**, Figure S18 for IPBES regions) for the 5 categories of direct drivers show steady increases over the past five decades, across the planet, with differences across trends. Rates of land-use change are lower relative to several decades ago although still accelerating in selected countries, given urbanization, agriculture and grazing. Extraction of living biomass has increased overall, yet while some countries dramatically raised output, others did the opposite as they outsourced their demands. Pollution has diverse patterns. Total greenhouse gas



D ALIEN SPECIES 1950-2000
RELATIVE CHANGES IN CUMULATIVE NUMBER OF RECORDS OF ALIEN SPECIES



E CLIMATE CHANGE 1950-2015
CHANGES IN MEAN ANNUAL TEMPERATURE IN DEGREE CELSIUM

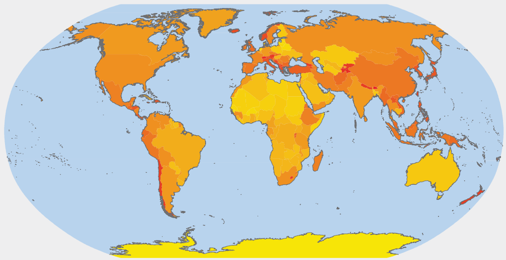


Figure 2 1 15 **Temporal trends per country for direct drivers**

A Land use change: changes in the proportion of urban and cultivated areas within each country calculated using country area data and Global Cover data 1992-2015 (see Chapter 2.2 for further details); B Resource extraction: changes in total resource extraction per year in million tons for 1980-2000, C Pollution: changes in greenhouse gases (CO2, CH4, N2O, CFCs, HFCs, PFCs, SF6, NF3) emissions in tons of CO_2 equivalent for 1980-2015. D Invasive alien species: changes in cumulative number of records of alien species for 1950-2005; E Climate change: changes in mean annual temperature in degree Celsius for 1950-2000 using Chelsa Climate Data. Sources: Hijmans et al. (2005), OECD (2018a), Ritchie & Roser (2018), Seebens *et al.* (2018), World Bank (2018p), WU (2015).

emission has doubled since 1980 (Figure S17, S27) while human-induced warming reached ~1°C (±0.2°C) above pre-industrial levels in 2017 (see section 2.1.17). While air pollution is highest for least developed and lower income countries, important decreases in the rates of emission of greenhouse gas emissions are observed in some of the developed and higher-income countries, due to increased awareness, as well as changes in policies linked to energy sources. Also, the increase is greatest for intermediate – but fastest growing – income levels, developing countries **(Figure 2.1.12)**, where population and income are increasing sharply. Alien species are escalating, especially for developed countries where the arrivals started earliest, and populations are both dense and dynamic. Current cumulative records of alien species are ~40 times larger in developed than in least developed countries. Though comparable across Europe and Central Asia, the Americas and Asia and the Pacific, they are ~4 times lower in Africa (Figure S29). Finally, while climate change is of course a global phenomenon, with global mixing of emissions, some countries are particularly challenged by the fastest rates of changes (see below – and also trends by units of analysis in chapter 2.2 complement this section).

Humanity's footprint has touched 75% of the terrestrial world and much of the oceans (Venter *et al.*, 2016). 25% of the world's terrestrial potential primary productivity has been appropriated largely through cropping and grazing (78% of the appropriation), followed by forestry, the construction of infrastructure, and human-induced fires (22%) (Krausmann *et al.*, 2013). Several biodiversity hotspots have been shown to present very small areas of no or low human footprint, as is the case of Western Australia, Tropical Andes, Northern Cerrado and Central Asian Mountains (Venter *et al.*, 2016). Lowest appropriation values (11–12%) are found in Central Asia, the Russian Federation, and Oceania (including Australia), while the highest ones are found in Southern Asia (63%), as well as Eastern and Southeastern Europe (52%).

A global map of anthropogenic impact on marine ecosystems (Halpern *et al.*, 2008) revealed that by 2007, around 40% of the world's ocean surface was affected by multiple drivers, such as changes in sea temperature, by-catch, habitat transformation, ocean acidification, and ocean pollution. An evaluation of the changes between 2008 and 2013 (Halpern *et al.*, 2015) revealed that more than 65% of the ocean experienced increases in cumulative impact during that period. Globally, increases in climate change related stressors, including sea surface temperature anomalies, ocean acidification and ultraviolet radiation, drove most of the increase in cumulative impact. Yet, impacts from most commercial fishing operations decreased in 70–80% of the ocean (Halpern *et al.*, 2015), confirming previous suggestions (Pauly *et al.*, 2002; Worm *et al.*, 2009) that global catch has stabilized or is declining in most parts of the ocean, and that well-managed fisheries are achieving sustainable yields.

2.1.13 DIRECT DRIVERS: LAND/SEA-USE CHANGES

2.1.13.1 Expansion of agriculture and cities

Over half the Earth's land surface is under cover types of anthropic origin, including agricultural lands, pasture and range lands, and cities (Foley *et al.*, 2005; Hooke *et al.*, 2012). Agricultural expansion is by far the most widespread form of land cover change, with over one third of the terrestrial land surface currently being used for cropping or animal husbandry at the expense of forests, wetlands, prairies and many other natural land cover types (FAO, 2016a; Foley *et al.*, 2005). Population growth (Nelson *et al.*, 2010), followed by urbanization and raising incomes, which are then linked to increasing per capita resource consumption (Liu *et al.*, 2003), clearly are major drivers of deforestation (Lambin & Meyfroidt, 2011).

Over five decades, the largest per cent changes in land use are associated with urban areas (**Figure 2.1.12**, **Figure 2.1.15**, Figure S24). City areas doubled in 1992–2015. The most severe increases were for tropical and subtropical savannas and grasslands, deserts and xeric shrublands, where the urban areas tripled.

Agricultural area increased by over 100 million hectares between 1980 and 2000 across the tropics, half at the expense of intact tropical forests (Gibbs *et al.*, 2010). Pasture for cattle contributed to the largest agricultural land expansion in Latin America, with an increase of ~35 million ha in South America and ~7 million ha in Central America (Gibbs *et al.*, 2010). In 1980–2000, cropland area increased by half in East Africa and a quarter in West Africa, while falling in Central Africa (Gibbs *et al.*, 2010). Africa lost the highest share of tropical forests in the 1980s, 1990s, and early 2000s (IPBES, 2018b). In Southeast Asia tree plantations occupy the largest share of agricultural land, which rose by 7 million ha in 1980–2000, while by the 1990s oil palm was responsible for over 80% of the expansion in tree plantations (Gibbs *et al.*, 2010). Timber extraction and fuelwood collection have also led to forest loss, while opening land for agriculture (Haines-Young, 2009; Hooke *et al.*, 2012). Yet, fuelwood collection is not a main driver, as it is based on collection of dry wood.

Deforestation rates are generally falling, with varying patterns across countries. China has seen high afforestation (FAO, 2015b), due to conservation and restoration over 30 years, in particular since 2000 (Viña *et al.*, 2016). In contrast, despite conservation policies in the 2000s (Macedo *et al.*, 2012; Nepstad *et al.*, 2014), Brazil continues to have significant deforestation (FAO, 2015b).

Other important drivers of the consequential expansion of agriculture – and shift in landscapes – include ongoing shifts toward animal-based diets (Alexander *et al.*, 2015; Rask & Rask, 2011) as well as the collapse of the Soviet Union, which triggered the abandonment of farms and, thereby, recoveries of prairies, woodlands and forests (Alcantara *et al.*, 2012; Bauman *et al.*, 2011; Hostert *et al.*, 2011; Ioffe *et al.*, 2012; Kuemmerle *et al.*, 2008), although some of the latter shifts were followed by a more recent re-cultivation in Southern Russia, Ukraine and Northern Kazakhstan (Meyfroidt *et al.*, 2013).

Following all of this, the global extent of wetlands has declined by 30% between 1970 and 2008 (Dixon *et al.*, 2016), and total loss has been estimated to be as much as 87% (IPBES, 2018a). Losses were greatest in the tropics and sub-tropics, where population growth and agricultural expansion were also highest (UNEP, 2016c). In the last two decades, peatland cover has reduced from 77% to 36% (Miettinen *et al.*, 2012). Peatlands are largely found in South-East Asia, which contains an estimated 56% of all of the tropical peatlands by area (Page *et al.*, 2011).

2.1.13.2 Fragmentation

Land-cover change has increasingly fragmented remaining land cover (see chapter 2.2). Currently, about 20% of the forest areas around the world are close (<100 m) to a forest edge, while 70% are within 1 km (Haddad *et al.*, 2015). Only 20% of tropical areas hold forest areas larger than 500 km^2 (Potapov *et al.*, 2017). The global extent of such areas decreased by 7.2% in the last decade (Potapov *et al.*, 2017), as a result of industrial logging, agricultural expansion, fire, and mining/resource extraction. The certification of logging concessions under responsible management had negligible impact in terms of slowing this fragmentation (Potapov *et al.*, 2017).

2.1.13.3 Landscape/seascape management intensification

Technological advances in agriculture, fisheries, aquaculture, and forestry over the last 50 years (see 2.1.5) led to increases in extraction, yields, and investments (in machinery and inputs), while often increasing the area of influence of these activities (farms or fishing grounds). The IPBES Land Degradation Assessment showed that intensive land use can lead to progressive changes in ecosystem functions and, in cases, irreversible changes then land abandonment (IPBES, 2018a).

Livestock density and herd management are the main causes of rangeland degradation, which can be exacerbated by changes in fire regimes and harvesting

(IPBES, 2018a). Asia has the most rapid grassland change (Akiyama & Kawamura, 2007). Agricultural intensification in regions has been linked to the stabilization or even reductions in agricultural land area, particularly for the sub-Saharan African region (Ausubel *et al.*, 2013; Brink & Eva, 2009; Lambin & Meyfroidt, 2011; Ramankutty *et al.*, 2006; van der Sluis *et al.*, 2016; van Vliet *et al.*, 2015; Wood *et al.*, 2004). When linked to subsistence agricultural production with low soil fertilities, low usage of agrochemicals, and low yields, this has led to reductions for natural land cover types (Brink & Eva, 2009; Wood *et al.*, 2004). Yet, agricultural intensifications have led to increases in yields that have come at the cost of an accelerated pollution of both soils and water (IPBES, 2018a)

2.1.13.4 Land degradation

Land degradation is the reduction or loss of biological or economic productivity and complexity (including soil erosion, deterioration in physical, chemical, biological or economic properties of soils and long-term loss of vegetation) of cropland, rangeland, pastureland forest and woodlands in arid, semi-arid and dry sub-humid areas, that results from land uses or form a combination of processes, including those arising from human activities and habitation patterns (IPBES, 2018a). Degradation is occurring in all land cover, land use and landscape types, in all countries (IPBES, 2018a). Degradation is hard to measure (Herold *et al.*, 2011; Houghton, 2012; IPBES, 2018a; Lambin, 1999), given a paucity of data and the absence of estimates, especially in the tropics (Houghton, 2012). Degradation is driven by multiple drivers including land use change, intensification, pollution, and invasive alien species, many distant from where impacts are felt (IPBES, 2018a). Loss in forests, for example, are linked to uncontrolled logging (Tacconi, 2007b), fires, agricultural expansion (Lawrence, 2005; Van Vliet *et al.*, 2012) and also charcoal (Ahrends *et al.*, 2010; Chidumayo & Gumbo, 2013). Most prominent in Latin America and Asia is timber extraction while, in Africa, it is fuelwood and charcoal (48%) (Hosonuma *et al.*, 2012; Kissinger *et al.*, 2012). Desertification, i.e. land degradation in arid, semi-arid and dry sub-humid areas, is particularly severe for 38% of the world's population, including pastoralists and smallholder farmers tending lands disproportionately vulnerable to degradation (IPBES, 2018a).

Soil degradation includes loss of soil as well as changes in its physical, chemical and biological properties (IPBES, 2018a). Erosion causes nutrient loss (Lal, 2014) and reduction of agricultural productivity, plus flooding, water pollution and sedimentation of reservoirs (Munodawafa, 2007; Rickson, 2014). Erosion may also negatively affect the global carbon, nitrogen and phosphorus cycles (Chen *et al.*, 2010b; Quinton & Catt, 2007). Indeed, soil organic carbon, has fallen globally from land conversion and unsustainable land management practices (IPBES, 2018a). Reliable global estimates of the magnitude and extent of soil erosion are unavailable but its occurrence in all countries can be confirmed (IPBES, 2018a).

Soil acidification is associated with atmospheric deposition of strong acids (acid rain), as a result of emissions of sulfur dioxide and nitrogen oxides exacerbated by anthropogenic activities. Acid deposition on poor soils covered by temperate forests (Driscoll *et al.*, 2001; Greaver *et al.*, 2012), forest and crop harvesting (especially if frequent) (Likens *et al.*, 1998) and loss of nutrients due to rain and irrigation (leaching) (Lawrence *et al.*, 1987) can all exacerbate its effects.

Global soils in over 100 countries are affected by salinity, linked to climate change and increased use of irrigation for production of crops (Squires & Glenn, 2009). Salinity occurs naturally, yet it is often exacerbated by irrigation at rates not adequate to exceed evapotranspiration rates (FAO & ITPS, 2015), by poor drainage or groundwater levels near the soil surface (< 2m), by the use of brackish water to irrigate, by intrusion of seawater near coastal areas, and by shifts from deep rooted perennial vegetation to shallow rooted annual crops and pastures (FAO & ITPS, 2015).

2.1.14 DIRECT DRIVERS: RESOURCE EXTRACTION

2.1.14.1 Rates of extraction of living and nonliving materials from nature

Extraction of living biomass and nonliving materials is increasing as both populations and per capita consumption **(Figure 2.1.4, Figure 2.1.12, Figure 2.1.15)** increased sixfold from 1970 to 2010, while the demand for materials used in construction and industry quadrupled during that time.Materials for construction and industry increased 4-fold, with the most dramatic increases for lower-middle (7-fold) and upper-middle income countries (11-fold) and the Asia and the Pacific region (10-fold for whole region) (Robinson & Bennett, 2004; Schandl & Eisenmenger, 2006; Schandl *et al.*, 2016) and, generally, the growing economies (Figure S18, Figure S25, Figure S26). The use of biomass, fossil fuels, metal ores and non-metallic minerals doubled from 2005 (26.3 billion tons) to 2015 (46.4 billion tons), growing an annual rate of 6.1%.

Yet extraction rates varied widely by country, barely increasing in Africa since 1970 (Schandl *et al.*, 2016). The global shares for Africa, Latin America and the Caribbean, and West Asia were relatively constant over four decades, with all growing in total volume, while Europe and North America fell sharply in terms of their global shares of direct extraction (Schandl *et al.*, 2016). These differences may reflect sectoral shares (see above), as extraction for agriculture, forestry, fishing, hunting only doubled in 50 years but construction and industry rose more (WU, 2015).

Cascading effects of extraction can be manifested as biodiversity losses and accelerated changes in climate (Butchart *et al.*, 2010), most prominently in tropical forests, marine, coastal and polar ecosystems (Bradshaw *et al.*, 2009; Geist & Lambin, 2002). Some types of extraction also result in land-use change, with consequences for biodiversity, soil erosion and degradation, GHG emissions, and potential loss of an array ecosystem services (Geist & Lambin, 2002).

Extraction beyond sustainable levels has consequences for biological dynamics and ecosystem function. Yet assessing what levels of extraction of resources are sustainable is very complex, as species- and context-specific efforts are needed. Impacts of overexploitation can be observed in life histories, genetic patterns of populations, and community and ecosystem functions (Ticktin, 2004). Wildlife extraction through hunting from tropical forests, for instance, is estimated to be well above the sustainable rate (Bradshaw *et al.*, 2009) and for terrestrial species, exploitation (26%) is the second most common threat preceded only by habitat loss (50%) (WWF, 2016).

2.1.14.2 Freshwater withdrawals

Freshwater resources are unevenly distributed. About one third of the Earth's land subsurface is underlain by relatively homogenous aquifers (exclude the Antarctic), often in large sedimentary basins with suitable conditions for groundwater exploitation (WHYMAP & Margat, 2008). Asia (30.72%) harbors most of these aquifers, followed by Africa (28.48%), Central/South America (17.64%), Europe (10.88%), North America (6.78%) and Oceania (5.49%). Most of the largest global aquifer systems are found within Africa (35%), followed by Asia (27%), the Americas (22%), Europe (11%) and Oceania (5%) (Richey *et al.*, 2015; WHYMAP & Margat, 2008).

Global water withdrawals are hard to calculate, as their estimation depends upon reliable data at the local and country level, yet reliable data are limited to a few countries. Estimations by FAO suggest that water withdrawals have risen from less than 600 km^3/year in 1900 to nearly 4,000 km^3/year in 2010, faster than population growth (FAO, 2011c). The surface waters of key river basins such as the Colorado, the Huang-He (Yellow River), the Indus, the Nile, the Syr Darya, and the Amu Darya are heavily used (WRI, 2000) and 21 of 37 aquifers have exceeded their 'sustainability tipping points' during 2003–2013 (Richey *et al.*, 2015). Increased groundwater extraction has been attributed to agricultural use (69%), industrial use (19%) and direct human consumption (12%) (FAO, 2011c; Wada *et al.*, 2014) with growing populations, industries and, more generally, economies (Alcamo *et al.*, 2003; FAO, 2011c; Mekonnen & Hoekstra, 2011).

Depletion of water resources interacts with many biophysical and societal drivers to contribute to negative impacts on nature and societies. Withdrawals, with climate change, lower mean annual run-off across river basins in Asia and America (Haddeland *et al.*, 2014), as well as water quality (Navarro-Ortega *et al.*, 2015). Depletion threatens water and food security, alters hydrological regimes (Arroita *et al.*, 2017), induces land degradation (Dalin *et al.*, 2015), and conflicts (Richey *et al.*, 2015). Threats from excessive extraction are pronounced in arid and semi-arid regions (Haddeland *et al.*, 2014). Irrigated agriculture leads to drastic effects on wetlands and wildlife conservation (Lemly *et al.*, 2000).

Facing scarcities, improved agricultural and water management practices have been developed to reduce water stress. Successful cases involving smallholder farmers have received considerable attention in recent years. In those involving Indigenous Peoples, land and water management have been integrated (Critchley *et al.*, 2008) – suggesting that improvements are possible despite decreasing aggregate resource availability at global scales (Pretty *et al.*, 2000).

2.1.15 DIRECT DRIVERS: POLLUTION

Quantitative assessments of pollution are limited to a few systematically monitored variables – with inconsistent data quantity and quality across countries. The most robust available data are from remote monitoring, including greenhouse gas emissions and the presence of aerosols (i.e., particulate matter). Country data on access to improved sanitation (e.g., municipal waste or use of pesticides or fertilizers) is available (FAO, 2018a, 2018d; OECD, 2018b; Ritchie & Roser, 2018; World Bank, 2018h), although again with varied data quantity and quality. Significant emissions into the atmosphere, water bodies, and terrestrial systems from industrial activities and households remain unquantified. Yet, currently available data on related metrics suggest that the global pollution levels have increased at rates at least comparable to the total population growth.

2.1.15.1 Emissions into the atmosphere

Population growth, economic activity, energy consumption and technology drive anthropogenic greenhouse gas (GHG) emissions – such as carbon dioxide (CO_2), nitrogen oxide (NO_x), and sulphur dioxide (SO_2) – that trap heat in the atmosphere and contribute to global climate change. Emissions from transportation contribute GHGs and conventional air pollutants and particulates (UNEP, 2016e). Smaller particles (PM 2.5) are important threats to human health (WHO, 2016). GHG emissions have risen consistently, combining them with small particles, all countries show increases in air pollution (**Figure 2.1.12**, Figure S27, Figure S28). Largest increases are found in Northern Africa, Central Asia, and East Asia – due to a lack of regulations as well as to geological and climatic factors.

Some countries have sharply increased CO_2 emissions since 1980, while others reduced them (Figure S28). Europe and the Central Asian region reached peak CO_2 emissions in 1990, steadily decreasing since then. The Asia and the Pacific region has surpassed Europe and America to become the largest emitter of CO_2 since 2004. Major CO_2 producing regions are the United States (15%), the European Union (10%) and India (6.5%), which with China account for 61% of the total global emissions (Olivier *et al.*, 2015). CO_2 emissions increased on average (14%) in Latin America and the Caribbean, from 2006 to 2011 (UNEP, 2016d; World Bank, 2017c). During 2000–2010, Africa, Asia and the Pacific, Latin America and North America increased 15% in methane emissions (UNEP, 2016d). Thus, while GHG emissions are driven by economic development, displacement of production and extraction by trade allows for emissions, in some cases, to have fallen for higher incomes while increasing for lower incomes.

The reduction in GHG emissions in developed countries is actually a transference of GHG to developing countries, referred to as "GHG leakage", through international trade, which accounts for ~30% of CO_2 emissions (see also 2.1.6.3.2) (Aichele & Felbermayr, 2015; Kanemoto *et al.*, 2014). In fact, higher-income countries did not actually reduce emissions, but just shifted them. For instance, during the 1990–2011 period, developed countries reduced emissions by 1.59 Gt while developing countries increased emissions by 13.7 Gt. However, after assessing the CO_2 leakage by assigning responsibility to consumers, in 2011 developed countries transferred 2.95 Gt of CO_2 to developing countries through trade (Kanemoto *et al.*, 2014). Developed countries shifted their non-CO_2 GHGs emissions to developing countries even more strongly than they did for CO_2.

Emissions of nitrogen oxides (NO_x) are associated with roads transport, energy production, and many commercial, institutional and household activities. NO_x emissions contribute to acid deposition and eutrophication and have drastically increased. Asia, including the Middle East, accounts for ~30% of the global emissions. NO_x emission levels have decreased in the US and in Western Europe, while increasing in Africa over the last decade (Figure S28; EEA, 2014; UNEP, 2016b).

Emissions of SO_2 from the combustion and oxidation of fuels and other materials have risen due to industry and shipping. Asia showed an increasing trend since 2000, contributing 41–52% of global emissions, while emissions from North America and Europe declined from 38% to 25%. SO_2 emission from industry increased from 32% to 38%, while those from international shipping increased from 9% to 25% over the last decade (Klimont *et al.*, 2013) as trade rose.

Emissions of particles into the atmosphere ($PM_{2.5}$ -particles smaller than 2.5 micrometers) are highest in least developed countries **(Figure 2.1.12)** and in high income oil producing countries (Figure S28). Northern Africa has highest $PM_{2.5}$ emissions (De Longueville *et al.*, 2014; Van Donkelaar *et al.*, 2010). Emissions due to residential energy use, such as heating and cooking, are prevalent in India and China. Those from traffic and power are high in the US (Lelieveld *et al.*, 2015).

Higher levels of exposure of human population to air pollution within lower-income countries, especially in Northern Africa and Central Asia, can be attributed to climatic / geological factors (arising from, e.g., dust and storms), predominant energy sources, and agricultural emissions (Lelieveld *et al.*, 2015). Additionally, another important factor is the fact that dirtier phases of industrial processes are exported to lower income countries with reduced regulations and enforcement (see also 2.1.6.3.2).

Other airborne contaminants also have had major impacts on nature and people. Mercury enters the atmosphere from volcanoes, and coal burning, then is transported to areas such as the Artic, with a 10-fold increase in upper-trophic-level mammals such as beluga whales, over the past 150 years (AMAP, 2018). Global emissions of nitrogen from synthetic fertilizers and the expansion of nitrogen-fixing crops are several orders of magnitude larger than pre-industrial levels (Vitousek *et al.*, 1997a).

Noise's effects on nature are increasingly observed. Expansions of human populations, transport networks and extraction have a range of impacts upon species, depending on auditory capacities (Shannon *et al.*, 2016) and noise wavelengths (Todd *et al.*, 2015). Underwater noises that are due to shipping are significant marine pollutants (Williams *et al.*, 2015). Behavioural changes for both individuals and entire ecological communities have been observed in response to a wide range of noise sources and exposure levels (Shannon *et al.*, 2016; Todd *et al.*, 2015; Williams *et al.*, 2015).

2.1.15.2 Contaminants dissolved in/carried by water

Water quality has fallen over the last five decades, with key environmental and societal impacts. Major sources include untreated urban sewage and industrial and agricultural run-off, erosion, airborne pollution, and salinization, as well as oil spills and dumping of substances into the oceans. It is estimated that over 80% of urban and industrial wastewater is released to freshwater systems without adequate treatment, a volume six times as large as that in all of the world's rivers, i.e., 300–400 million tons of contaminants (UN, 2003; UN-Water, 2015; WRI, 2017; WWAP, 2012).

One available indicator on water quality is that of access to improved sanitation facilities which shows very contrasting patterns among countries with different income levels, as 60% of the population in low income countries do not have access to such facilities (World Bank, 2018m). Over 600 million people lack access to safe drinking water, nearly half in Africa, followed by Asia, then Latin America and the Caribbean (WHO-WEDC, 2013). Large regional variance in wastewater treatment includes 70% in Europe but as low as 20% in Latin America (Sato *et al.*, 2013). Untreated urban wastewaters dumped into the environment (Beketov *et al.*, 2013; Malaj *et al.*, 2014; Moschet *et al.*, 2014; Stehle & Schulz, 2015; Van Dijk *et al.*, 2013) contain fecal coliforms, organic pollutants (UNEP, 2016b, 2016c, 2016d, 2016e, 2016f), heavy metals, and pharmaceutical residues (Cleuvers, 2004; Santos *et al.*, 2010; Wilkinson *et al.*, 2016). About a quarter of the rivers in Latin America, 10–25% in Africa and up to 50% in Asia have severe pathogen pollution, largely caused by untreated wastewater (UNEP, 2016a). More than 200 types of molecules derived from pharmaceutical processes have been measured in natural waters (Pal *et al.*, 2010; Petrie *et al.*, 2015), frequently anti-inflammatory drugs, antiepileptic, contraceptives or antibiotics. These impair organisms in rivers (Brodin *et al.*, 2014) and in estuarine and marine waters (Guler & Ford, 2010; Kidd *et al.*, 2007; UNESCO & HELCOM, 2017). Human health and nature concerns also include chemicals like dissolved metals (zinc, copper, aluminum) or surfactants, whose risks to aquatic ecosystems remain high even within higher-income countries (Johnson *et al.*, 2017).

Agriculture causes most soil erosion and nutrient run-off to freshwaters (Quinton *et al.*, 2010). Fertilizers used in crop production are also drained into continental, coastal and marine water bodies at accelerating rates (Figure S21), with nitrogen fluxes (mainly as nitrate) rising 4- to 20-fold in the last decade (Camargo & Alonso, 2006; Mekonnen *et al.*, 2015). Nutrients from fertilizers in continental water bodies flow into coastal waters, stimulating excessive plant growth and, in extreme conditions, hypoxia or oxygen-depleted "dead zones" plus harmful algal blooms that affect primary and secondary productivity (Altieri *et al.*, 2017). By 2008, 494 coastal dead zones were listed. Pesticides, agricultural insecticides, and newer generation molecules (like pyrethroids and neonicotinoids) (Stehle & Schulz, 2015) reduce macroinvertebrate richness in rivers by up to 40% (Beketov *et al.*, 2013; Van Dijk *et al.*, 2013), while urban and agricultural herbicides exert effects on non-target species like algae (Malaj *et al.*, 2014; Moschet *et al.*, 2014). Ecotoxic chemical micropollutants, including pesticides, pharmaceutical residues, plastics, and dissolved metals all exert chronic effects and have endocrine disruptive properties that affect freshwater biodiversity and jeopardize the health of water ecosystems (Beketov *et al.*, 2013; Malaj *et al.*, 2014; Moschet *et al.*, 2014; Stehle & Schulz, 2015; Van Dijk *et al.*, 2013).

Lower water quality has led to severe changes in the ecohydrology of water systems (Carpenter *et al.*, 2011). In the past decade, the trend of deterioration has shifted from developed to developing countries, with increasing population and economic activity (UNEP, 2016a). The Water Quality Index (WATQI), an index ranging from 0 (worst) to 100 (best) that combines five parameters (pH, dissolved oxygen, total phosphorus, nitrogen concentrations, electrical conductivity) was 69.21 in 2012, globally, with the highest values in Europe (80.38), then Oceania (79.19), the Americas (76.59), Asia (76.59) and Africa (57.74) (Srebotnjak *et al.*, 2012). Climate change, hydrologic flow modification, land-use change, and aquatic invasive species interact with other drivers of water pollution (Carpenter *et al.*, 2011; UNEP, 2016a) to help explain this significant spatial variation.

Marine water quality is strongly affected by oil spills and the dumping of toxic compounds. Oil spills, toxic for marine life and difficult to clean up, are a major contamination source. In 1990, 1.1 million tons of oil was lost via spills. As technologies and policies have improved, by 2015 the magnitude was ~25,000 tons. Yet spills still contribute over 10% of oils entering the oceans (Anderson, 2013). Marine pollution is also affected by dumping and dumping bans (UN, 2017). Authorities are paying more attention to "black" lists of substances that should not be dumped (toxic organohalogen compounds, carcinogenic substances, mercury and cadmium), as well as "grey" lists (e.g. arsenic, lead, copper and zinc and their compounds, organosilicon compounds, cyanides, fluorides and pesticides) (IMO, 1972). In 2003–2012, the total chemicals entering seas rose by 12%, down 60% in North America and Europe but up 50% in the Pacific (UN, 2017).

Emissions of NO_x have acidified freshwater ecosystems (Skjelkvåle *et al.*, 2001; Stoddard *et al.*, 1999). Lakes and streams of eastern North America and Northern and Central Europe are highly acidified, with pH values ranging from 4.5 to

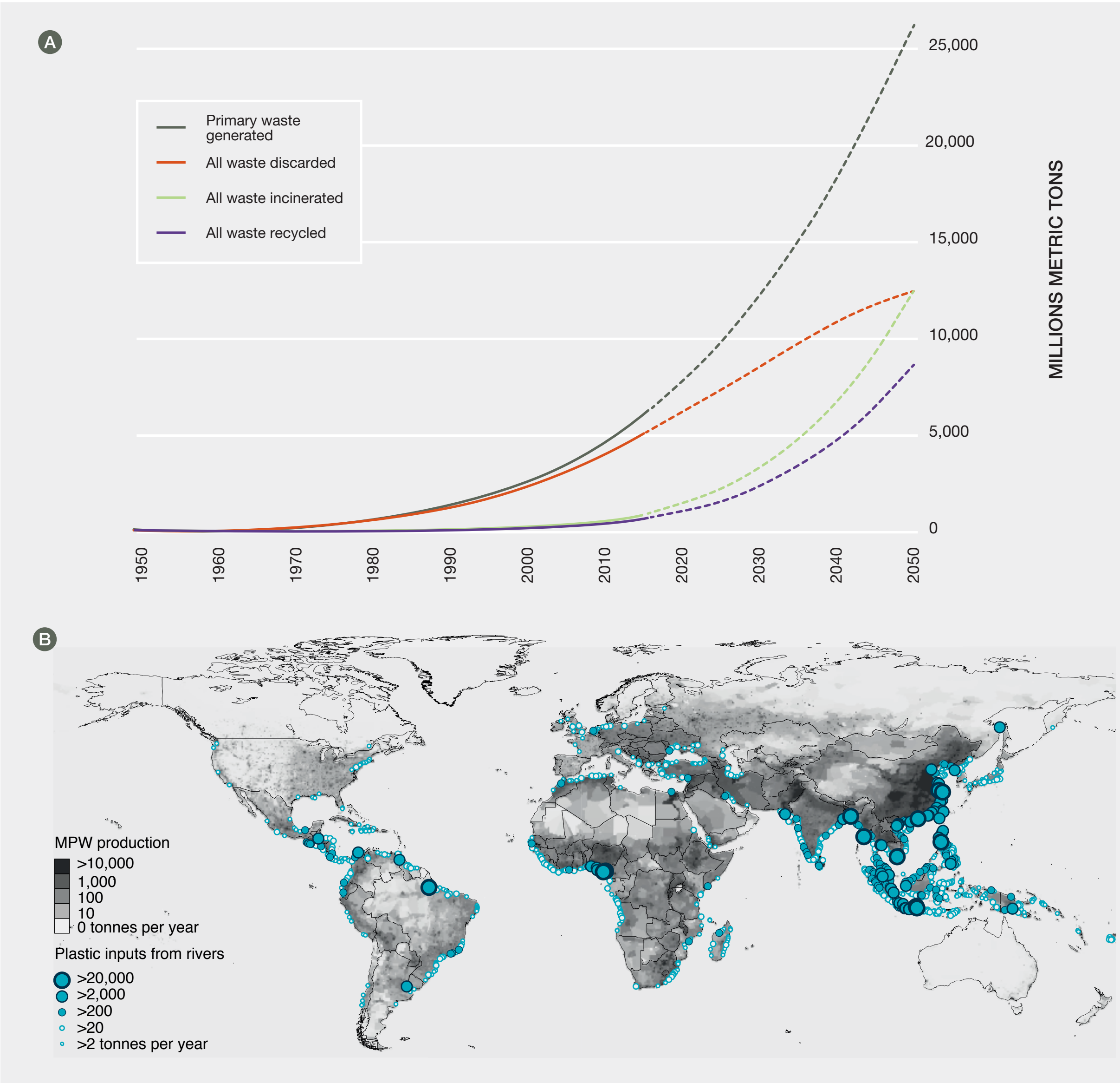


Figure 2 1 16 **Plastic waste production and flow into global oceans.**

A Trend of cumulative plastic waste generation and disposal (1950~2050); B Mass of river plastic flowing into oceans in tonnes per year; river contributions are derived from individual watershed characteristics such as population density, mismanaged plastic waste (MPW) production per country and monthly averaged run-off; the mode is calibrated against river plastic concentration measurements from Europe, Asia, North, and South America. Source: Geyer *et al.* (2017), Lebreton *et al.* (2017).

5.8 (Doka *et al.*, 2003; Skjelkvåle *et al.*, 2001). Further, salinity levels rose nearly one third in Asia, Africa and Latin America between 1990 to 2010. Severe and moderate salinity levels affect one in 10 rivers in these three continents, making it harder for poor farmers to irrigate their crops (UNEP, 2016a).

2.1.15.3 Disposal or deposition of solids

Solid wastes are increasing, globally, although it is uncertain by how much as systematic solid-waste accounting often remains a challenge. Solid waste is mostly generated in and disposed of in cities. Waste is larger in urban areas, correlated with purchasing power (Hoornweg *et al.*, 2013). Cities produce 1.3 billion tons of solid wastes, per year, for instance. Municipal waste per capita has doubled over the last decade (Hoornweg & Bhada-Tata, 2012).

Solid wastes have impacts at different scales. For neighborhoods, ill-managed waste contributes to respiratory ailments, diarrhea and dengue fever, sewage blockages and therefore local floods (Hoornweg & Bhada-Tata, 2012). At the regional and global scales, solid waste emits methane, contributing to climate change, and produces leachates which contaminate the soils and aquifers. Every type of disposal (incinerating, recycling, downcycling) produces adverse environmental impacts, e.g., all of them contribute to GHG emissions in different ways. Solid waste disposal accounts for almost 5% of the total global GHG emissions (Hoornweg & Bhada-Tata, 2012).

Globally, the composition of waste is changing. Waste that is environmentally and economically costly to dispose has been increasing, while organic waste is decreasing. Yet, regional variation is significant. For example, electronic waste composed of both hazardous wastes and strategic metals (rare earth materials), which have to be separated to be properly disposed of or recycled, is the fastest growing type (UNEP, 2012). Electronic waste management is poorly regulated too, accumulating in landfills and often exported to lower-income countries. Recycling by informal sectors has had negative health effects (Ongondo *et al.*, 2011; UNEP, 2012).

Plastic pollution is escalating, and it is accumulating in the oceans at alarming rates **(Figure 2.1.16)**. Global production of plastic resins and fibers rose at an annual rate of 8.4% from 1950 to 2015, over twice as faster as GDP (Geyer *et al.*, 2017). Perhaps 5% ends up in oceans due to inadequate waste management (Jambeck *et al.*, 2015). Globally, 1.15–2.41 million tons of plastic currently flow from riverine systems into oceans every year (Jambeck *et al.*, 2015; Lebreton *et al.*, 2017; UNEP, 2016a). The top 20 polluting rivers were mostly in Asia and accounted for two thirds of global annual input (Lebreton *et al.*, 2017), while the top 122 polluting rivers contributed over 90% of inputs – and are still largely in Asia, with a few in Africa, plus South and Central America, and one in Europe (Lebreton *et al.*, 2017). Besides rivers, plastic wastes enter via mismanagement in coastal regions (Hoornweg & Bhada-Tata, 2012; Jambeck *et al.*, 2015).

On average, every square kilometer of ocean has 63,000 microplastic particles on its surface (Eriksen *et al.*, 2014; Isobe *et al.*, 2015). Much of it is within the five sub-tropical ocean gyres, where ocean currents cycle and gather marine debris. East Asian seas show concentrations 27 times the average, followed by the Caribbean and the Mediterranean (Law *et al.*, 2010). Plastic is also accumulating along the shorelines (UNEP, 2016a). The ratio of plastic to fish by weight in the oceans was 1:5 in 2014 (Ellen MacArthur Foundation, 2013).

Plastic fragments are a particular concern, as they are difficult to remove from the environment and can be ingested (Barnes *et al.*, 2009), affecting at least 267 species including 86% of all marine turtles, 44% of all seabird species, and 43% of all marine mammals (Derraik, 2002; Laist, 1997). This can affect humans through food chains. For instance, 25% of fish sold for human consumption in a Californian market were found to have microplastics debris (Rochman *et al.*, 2015). Beyond macro- and micro-plastics, plus persistent organic pollutants (POPs; Mato *et al.*, 2001), non-indigenous species (Barnes, 2002) and algae linked with red tides (Masó *et al.*, 2003) are transported with plastics (Barnes *et al.*, 2009), while concerns exist about discarded fishing gear (Gilman *et al.*, 2016).

2.1.16 DIRECT DRIVERS: INVASIVE ALIEN SPECIES (IAS)

Nearly one fifth of the Earth's surface is at risk of plant and animal invasions – including many biodiversity hotspots (IPBES, 2018a). Alien species doubled in the last 50 years (**Figure 2.1.12**, **Figure 2.1.15**, Figure S29; chapter 2.2; chapter 3) and threaten native species and ecosystem services (Capinha *et al.*, 2015; Simberloff *et al.*, 2013; Vilà *et al.*, 2010) as well as economies and human health (Kettunen *et al.*, 2009; Pyšek & Richardson, 2010; Vilà *et al.*, 2010).

The cumulative number of alien species that have been recorded is ~40 times greater within the developed than within least developed countries, due in part to trade and population but also to detection capacities (**Figure 2.1.4**, **Figure 2.1.6**, **Figure 2.1.9**, Figure S29) (Seebens *et al.*, 2017, 2018). While the current recorded levels of alien species in Europe and Central Asia, the Americas, and Asia and the Pacific are all similar, levels are lower in Africa. (Figure S29) (Seebens *et al.*, 2017, 2018). The number of alien species recorded is not equivalent to the number of IAS, as no estimates of invasibility are available and that can vary dramatically across alien species.

IAS hotspots are often in developed countries within North America, Europe and Australasia (Dawson *et al.*, 2017). The number of established alien species, and also their rates of invasion, have risen during the last century (Aukema *et al.*, 2010; Blackburn *et al.*, 2015; Lambdon *et al.*, 2008). In addition, the rate of emerging alien species – never encountered before as aliens – is high, with one quarter of first records in 2000–2005. The rate of introduction of new IAS seems higher than ever before and with no signs of slowing (Seebens *et al.*, 2017, 2018).

Major drivers of invasions are expansions of trade networks, higher human mobility, continuous habitat degradation and climate change. The latter exacerbates nitrogen deposition and increases fire frequency (Aukema *et al.*, 2010; Early *et al.*, 2016; IPBES, 2018a; Seebens *et al.*, 2018). The eradication of established IAS is very expensive (IPBES, 2018a; see more in chapter 2.2).

2.1.17 DIRECT DRIVERS: CLIMATE CHANGE

Climate change is currently a major driver of change in nature, with strong direct global impacts, that also affect impacts of other drivers. Unprecedented rises in atmospheric concentrations of GHGs (namely carbon dioxide, methane and nitrous oxide) across at least the last 800,000 years (IPCC, 2014), are extremely likely to have been the dominant cause of observed warming trends worldwide (IPCC, 2014). Natural variations in global temperatures are considered to be low, as compared to such human-induced warming. The latter is growing beyond a threshold that could not have been otherwise exceeded through natural variation (Herring *et al.*, 2016; IPCC, 2014).

Human-induced warming reached ~1°C (±0.2°C) above pre-industrial levels in 2017, with rises of 0.2°C (±0.1°C) per decade (IPCC, 2018)**.** Impacts include thermal stress, coral bleaching, and melting of sea and land ice (IPCC, 2013). The highest velocities in temperature change are found in flat landscapes and at higher latitudes (Loarie *et al.*, 2009). Most land regions are warming faster than the average, most ocean regions slower (UNFCCC, 2015). Evidence of long-term geophysical and biological changes due to warming is now more clear in many parts of the world – such as in the retreat of mountain glaciers, the earlier arrival of spring (Smit *et al.*, 2001), and changes in the phenological responses of vegetation (Root *et al.*, 2003)and in primary productivity (Lucht *et al.*, 2002). Changes in precipitation have also occurred. Areas in tropical regions have exhibited increased precipitation while areas in subtropical regions have exhibited decreased precipitation (Rummukainen, 2012). Precipitation has decreased more drastically in Northern and Central African Countries and Western Asia (Hijmans *et al.*, 2005).

Climate models have assessed impacts of anthropogenic forcing described above on increases in the frequencies and intensities of extreme events (King *et al.*, 2015) – e.g., heat waves, droughts, heavy rainfall, storms and coastal flooding (IPCC, 2018; McBean, 2004; Mitchell *et al.*, 2006) (see chapter 4 for further details). These events result from sporadic weather patterns (Luber & McGeehin, 2008) and they can be intensified by climate variability (e.g., due to El Niño/Southern oscillation) (Cai *et al.*, 2015; L'Heureux *et al.*, 2016; Newman *et al.*, 2018; Weller *et al.*, 2016). The increase in the frequency and intensity of such extreme events has been linked to considerable effects on well-being, with losses of life, injuries, and also other negative health effects, together with damages to property, infrastructure, livelihoods, service provision and environmental resources (UN, 2016c). In particular, important increases in the frequency and intensity of devastating hurricanes have been projected (Bender *et al.*, 2010; Emanuel, 2017; Knutson *et al.*, 2010; Ornes, 2018; Risser & Wehner, 2017).

The effects of all of these changes – temperature, precipitation, and frequency and intensity of extreme weather events – can accumulate and interact for further unexpected nonlinear change, with perhaps irreversible impacts on nature and nature's contributions to people and to society – including economic growth and food and water security (Burke *et al.*, 2015; Franzke, 2014; Friedrich *et al.*, 2016; Hegerl *et al.*, 2011; Schneider, 2004). Climate-driven changes can interact with other direct drivers, at times exacerbating impacts on nature and society (IPBES, 2018b, 2018a). Interactions of climate with other factors could also initiate nonlinear climate responses, yielding more extreme and/or rapid effects of climate change (Mitchell *et al.*, 2006).

2.1.17.1 Sea-Level Rise

From 1901 to 2010, the global sea level rose by 0.19m (0.17 to 0.21m), with an ongoing rate of rise of over 3 mm yr^{-1} across recent decades. This rate of sea-level rise (SLR) is faster than that experienced across the previous two millennia, and is likely to continue or accelerate (Alverson, 2012; IPCC, 2014). The increase in global temperature has a direct linkage with SLR (Church *et al.*, 2006), as SLR results from ocean thermal expansion, with reductions in the glaciers and the Greenland and Antarctic ice sheets (Cazenave & Cozannet, 2014; IPCC, 2014).

SLR is not homogeneous. In 1993–2012, the western Pacific Ocean exhibited a rate of SLR three times higher than the global mean, while much of the west coast of the Americas had a sea level reduction (Cazenave & Llovel, 2010; Stammer *et al.*, 2013). SLR is, in turn, a contributor to climate change acceleration (Galbraith *et al.*, 2002; Goodwin, 2008), and the increased severity of storm-surge events (Church *et al.*, 2008; Nicholls & Cazenave, 2010). Low-lying coastal areas, including many cities, beaches and wetlands are the most vulnerable to flooding and land loss from SLR (Nicholls & Cazenave, 2010; Sallenger *et al.*, 2012), with the total threats being the highest in densely populated areas (Stammer *et al.*, 2013). For instance, most countries in South, Southeast, and East Asia are highly vulnerable to SLR because of the widespread occurrence within those regions of very densely populated deltas, while a number of countries in Africa are highly threatened due to low levels of development combined with rapid population growth rates in coastal areas (Nicholls & Cazenave, 2010).

2.1.17.2 Ocean Acidification

Ocean acidification also drives loss in coastal and marine ecosystem services. In most cases, it is generated by anthropogenic CO_2 emissions (Doney *et al.*, 2009). Acidification results in biochemical alteration of salt water ocean ecosystems (Doney *et al.*, 2009). Current acidity is estimated to be the highest since the extinction of dinosaurs 65 million years ago, above levels experienced at least over 800,000 years (Lüthi *et al.*, 2008). Acidification is most critical for the shallow-water areas over-saturated with calcium carbonate. The highest concentrations of anthropogenic CO_2 are in near-surface waters, as mixing of these waters into the deeper oceans can take centuries. About 30% of the anthropogenic CO_2 is at depths shallower than 200 m, while nearly 50% is at depths shallower than 400 m (Feely *et al.*, 2004). The pH has fallen more than 30% since the industrial revolution, with a massive threat to marine biodiversity (Hoegh-Guldberg & Bruno, 2010). Highest concentrations of anthropogenic carbon in the oceans are in the North Pacific (3.2 Pg C) and the Indian Ocean (3 Pg C). If current rates of GHG emissions are not mitigated, oceans will be vastly different places by the mid-to-late 21st century (Gattuso *et al.*, 2015).

Ocean acidification negatively affects marine organisms and function, which in turn feedback to climate change. Acidification hinders the ability of calcifying organisms to build and maintain their calcium carbonate skeletons and shells, along with creating changes in other fundamental metabolic processes. Acidification also leads to increased phytoplankton production of dimethyl sulfide (DMS) (Gypens & Borges, 2014; Six *et al.*, 2013), which contributes to warming of the Earth's temperature due to a reduction in the reflection of solar radiation. Coral bleaching may also result from ocean acidification, although complex impacts upon the multiple trophic layers are hard to evaluate and predict (Hattich *et al.*, 2017; Kroeker *et al.*, 2010).

Impacts of increasing CO_2 upon the total Net Primary Production of marine systems and, thus, decreasing carbonate concentrations in the oceans and the atmosphere remain largely unknown. A global analysis reports that ~97% of reef areas exhibited warming trends, from 1985 to 2012. Coral bleaching incidents over the last two decades have been more frequent and more severe (Heron *et al.*, 2016). Summarizing, ocean acidification has been affecting fundamental physiological and ecological processes of organisms (Hoegh-Guldberg & Bruno, 2010; Pörtner *et al.*, 2014), leading to changes in the structure of marine ecosystems that underpin risks and vulnerabilities to food and income security (Hoegh-Guldberg *et al.*, 2017). Thus, the impacts of ocean acidification have a direct consequence for societies, including changes in national economies (Busch *et al.*, 2015; Robinson *et al.*, 2010).

2.1.18 PAST PATHWAYS: INCREASING CONNECTIVITY AND FEEDBACKS

Over 50 years, societies and nature have dramatically changed due to many complex interactions among the indirect drivers, among the direct drivers, and between the indirect and direct drivers. With a variety of impacts on nature, and nature's contribution to people, these interactions shape well-being for societies, and its evolution, including through governance motivations and choices.

As a result of increasing global connections, local impacts on nature and people are influenced by interactions at long distances, in some cases with significant time lags and with cumulative effects. The social-ecological changes from these accumulating interactions, from local to global levels, can occur in highly unpredictable ways due to varied conditions characteristic of complex systems, including: nonlinear processes underlying the outcomes; interdependence between distant places; changes with cascading effects; and both positive and negative feedback loops that can exacerbate or reduce the impact of changes on nature and people. All of this greatly affects future trajectories.

Below, we consider a few of the interactions and iterations that have such influences, starting with an illustration of varied correlations among indirect and direct drivers. With variations, by context, each indirect driver that we described can have both immediate and more distant causal impacts upon any number of actions that directly affect nature and, thereby, influences upon direct drivers.

2.1.18.1 Illustrating interconnections

Complex interactions and resulting interconnections between indirect and direct drivers may be partially summarized using statistical tools **(Figure 2.1.17)**. This does not sort out causal links involved, yet it does raise various questions about exactly how these specific correlations have come about.

The direct drivers – land/seascape change, resource extraction, pollution, invasive alien species (climate change was not included as it operates at very different spatial and temporal scales) – strongly correlate with multiple indirect drivers, in terms of the current levels for the indicators measured for each of the different countries **(Figure 2.1.17a)**. In particular, direct drivers correlate with total population, which also correlates with changes in nature (Biodiversity Intactness Index) and environmental footprint. Economic and lifestyle drivers (e.g., gross domestic product per capita, and domestic material consumption per capita) are also correlated with most of the direct drivers, nature and footprint indicators. Functioning institutions and governance (e.g., protection of key biodiversity areas, the absence of conflict) are correlated with some indicators of direct drivers, nature and footprint, though the processes involved are complex and cannot easily be identified from these correlations. Differences across IPBES regions are suggested for some direct drivers.

Looking at country variations in rates of change (1990–2010, **Figure 2.1.17b**), instead of levels variations, again the direct drivers were quite correlated with demographic, economic and lifestyle drivers, confirming the above observed patterns, and additional suggestive correlations were also found. Rates of change in urban populations were correlated with land-use changes, highlighting the indirect effects of urbanization. Human migration was correlated with increases in alien species, highlighting the roles of increased movements of people and goods on these non-native species. In addition, merchandise-export values were correlated with amounts of resources extracted, confirming paramount roles of trade in extraction of living and nonliving materials from nature. These broad patterns support more detailed assertions above and pose future research questions.

Related research is growing. Social–ecological literature has seen an exponential development in the last 15 years **(Figure 2.1.18)**, with a great deal of research on some actions (e.g., agriculture) with direct impacts on nature, plus how they link to climate change, land/sea-use change and economic and governance drivers. While such a map also cannot communicate causal links, as it does not reflect the content of the analyzed papers but rather the frequency of occurrence of terms linked to any of the indirect and direct drivers, it highlights research gaps. For instance, less was found on invasive and alien species, values, or trade-offs and inequalities.

2.1.18.2 Evolving economic and environmental interactions

2.1.18.2.1 Growing globalization

The world is ever more global, leading the environmental footprints of consuming nations to be spread ever farther from where the consumption occurs. Networks across continents, including flows of people, information, ideas, capital and goods, have been growing in the last decades at similar rates for all countries, while being clearly higher for the high income countries **(Figure 2.1.4)**. As a result, the footprint of nations is also growing globally, i.e., fractions of the total land use change, due to consumption, that occurred outside country boundaries have increased **(Figure 2.1.19)**. While high income countries were exporting a large fraction of their footprint even before 1990, even the poorest countries now have a large fraction of their footprints beyond their boundaries.

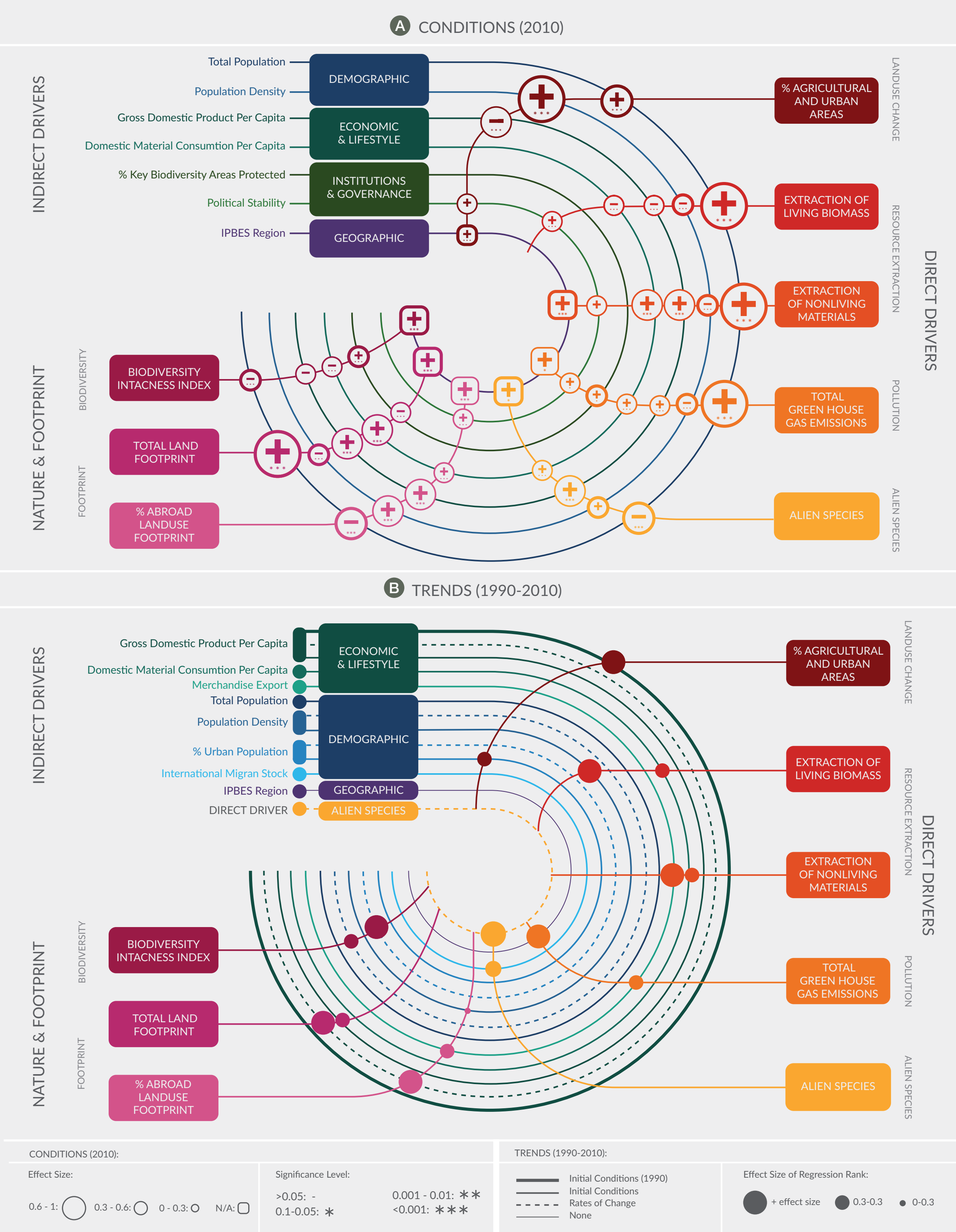


Figure 2 1 17 **Correlations between indirect drivers and direct drivers, as well as indicators of nature and footprint.**

A Correlations between current conditions of countries, (2010). B Correlations between trends of change in country values for 1990-2010. Multiple regression analysis was used as a way of summarizing correlations for current conditions, while regression trees were used for the correlations of the trends. Data used for correlations are by country. Corresponding average trends for development level categories are shown in Figures 2.1.4 and 2.1.12.

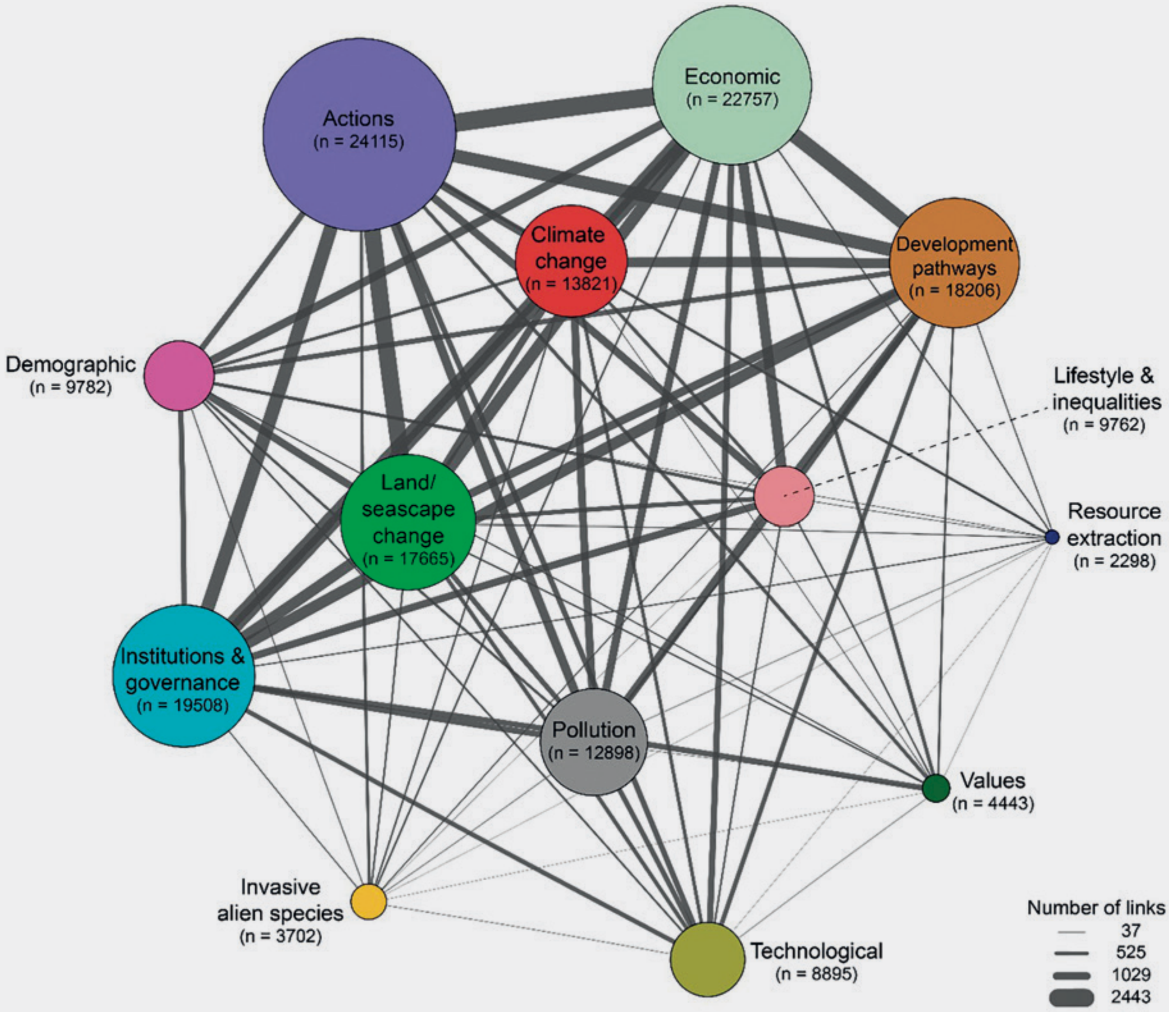


Figure 2 1 18 **Current state of knowledge on interactions among drivers from a systematic literature review.**

The number of papers that address each of the topics (circles) and that address two of them of (lines) are depicted. The literature surveyed was identified using keywords extracted from the Second Order Draft of this chapter, and using the bibliometrix R package, following Mazor *et al.* (2018) Sources: www.webofknowledge.com; www.bibliometrix.org.

2.1.18.2.2 Spreading spillovers

Spillovers from responses to environmental policies – even across borders – can undermine net impacts of governance efforts (see, for example, the case of palm oil, within **Box 2.1.4** below). Understanding and taking into account spillovers is important for evaluations, and for planning. Conservation efforts have expanded: legal limits, including protected areas and other restrictions; as well as positive incentives intended to discourage the degradation of nature (Chape *et al.*, 2005; Jenkins & Joppa, 2009), such as many programs using payments as compensation for protecting and restoring ecosystems (Albers & Grinspoon, 1997; Chen *et al.*, 2009; Daily & Matson, 2008; Uphoff & Langholz, 1998). Yet spillovers from these efforts, nearby or distant, are far from being understood and seldom taken into account (Meyfroidt *et al.*, 2018).

Responses to governance efforts across space and over time can hurt or help policies' objectives – environmental and economic. PAs, for instance, might not change land-use but just displace it (Hansen & DeFries, 2007), raising deforestation elsewhere (Robalino *et al.*, 2017 for local context and heterogeneous impact) while potentially also lowering local wages (Robalino, 2007). Yet context matters: with tourism, wages may rise (Robalino & Villalobos, 2015); and in cases, PAs lower deforestation nearby (Herrera Garcia, 2015) – including by dissuading local investments in economic development (Herrera Garcia, 2015). That

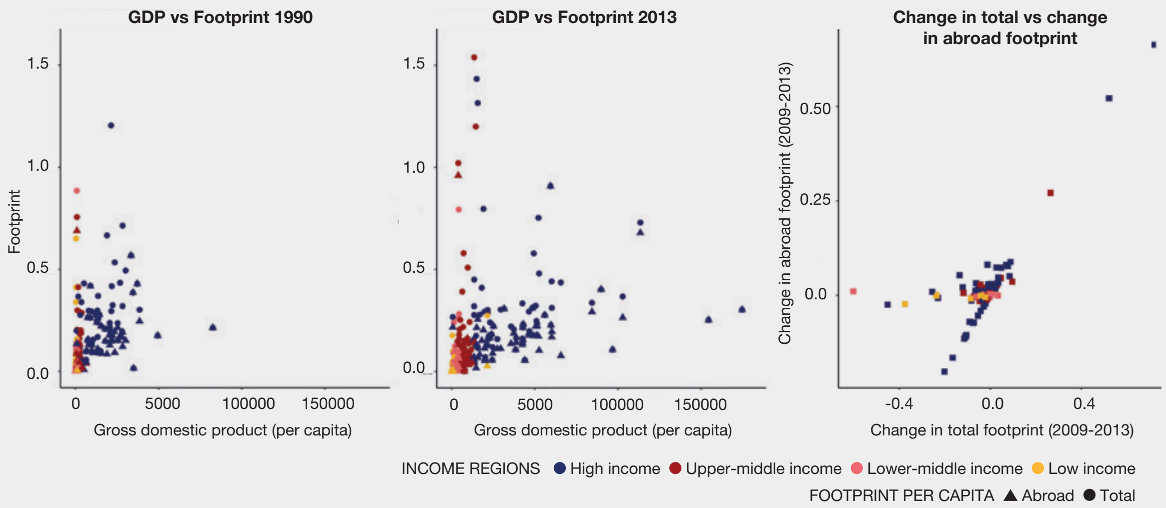


Figure 2 1 19 **Increasing total footprint of nations and exports of footprint: 1990-2013.**

Data shown is the footprint of individual countries, which is the sum of all land uses that occurs around the world to ultimately serve that specific nation's consumption. This land use footprint usually has a portion that occurs within the nation's own border (domestic), and a portion that occurs in within the borders of other countries (triangles), and the sum of these two components form the total footprint (circles). Countries are colored using World Bank's income categories. (Source: own calculations using Eora database, https://worldmrio.com/). The population and GDP data that were used for normalising the results were obtained from the Food and Agriculture Organization of the United Nations (FAO, 2016a; Wiedmann *et al.*, 2015).

may involve deforestation in other regions, if there exist broader spatial spillovers (DeFries *et al.*, 2010; Lambin & Meyfroidt, 2011; Rudel *et al.*, 2009b; Viña *et al.*, 2016; Zhu & Feng, 2003).

Understanding spillovers is essential to formulate policies. While there are studies of displacing land use (Lambin & Meyfroidt, 2011; Meyfroidt & Lambin, 2009; Pfaff & Walker, 2010) and deforestation (DeFries *et al.*, 2010; Liu *et al.*, 2012; Meyfroidt & Lambin, 2009; Verburg *et al.*, 2002; Wassenaar *et al.*, 2007), in policy formulation the consideration of human-nature interactions across spaces often is lacking. That could involve global scales, if prices rise in distant markets when one country lowers logging effort (Sedjo & Sohngen, 2000). Alternatively, it could be local, e.g., reduced motivations to conserve, for those who conserved voluntarily, if external interventions are perceived as a public overreach (Cardenas *et al.*, 2000).

Different spillover mechanisms yield different outcomes (Pfaff & Robalino, 2017). If PES for afforestation leads neighbors to learn that afforestation raises private profits, then others might start such practices in other locations – while those now receiving PES may continue practices after PES (Pagiola *et al.*, 2016 for Latin America). Such spatial and temporal spillovers benefit nature. Another potential spillover mechanism is that private or public conservation actions change the relative net benefits of conservation nearby. While Robalino & Pfaff (2012) find deforestation yields more private deforestation by neighbors, with tourism this can imply that conservation of nature yields neighboring conservation via local incentives to keep forest (Robalino *et al.*, 2017).

Moving to natural resources, many middle income countries possess stocks of oil and for some non-OECD high income countries, fossil fuels constitute a large share of their wealth. In such settings, discoveries can have spillovers through local incomes (Lange *et al.*, 2018b, p. 98) and prices. They can also bring 'the resource curse' (Barma *et al.*, 2012; van der Ploeg, 2011): although some resource-rich countries benefit from their natural wealth, in other countries it has been associated with bad macroeconomic performance and growing inequality among its citizens, with negative effects on other sectors of the economy due to concentrated growth. Further, as fossil fuels are nonrenewable, their extraction has effects upon the future.

Spillovers also imply gains from integration in the planning of development and conservation, for instance as related to transport investments. Consider a leading development policy, roads, and a leading conservation policy, protected areas. Roads increase profits in agriculture and, thereby, pressures for deforestation. That raises the impacts from well-implemented PAs (Pfaff *et al.*, 2016, 2009). Successful protection, in which PAs block the pressures, can in turn have positive spillovers through both agencies' interactions and private responses, as strong PA signals may lower expectations about economic prospects within any region. That has yielded reduced roads investments and in-migration (Herrera Garcia, 2015). Optimal policies could

Box 2 1 4 **Palm oil illustrates multiple forms of interaction across national borders.**

Palm oil production doubled in 2006-2016 to a global economic value of USD 65.7 billion in 2015. Demands in food (frying and cooking oils, baking fats, margarines, animal feed, confectionery filling, coffee whiteners, ice creams), oleo-chemicals (soaps, detergents, greases, lubricants and candle), fatty acids (to produce pharmaceuticals, water-treatment products and bactericides), and energy (biodiesel) fueled this increase, all encouraged by international capital (Borras Jr *et al.*, 2016) as well as the World Bank (Deininger *et al.*, 2011) and UNEP (Segura-Moran, 2011). States involved envision jobs and revenues to help mitigate high unemployment and to help supplement declining revenues, given falling commodity prices.

About 80% of production is in Indonesia and Malaysia – with the rest across Latin America and West Africa, e.g., growing in Cameroon (Hoyle & Levang, 2012) and Gabon (FAO, 2016a) – and consumption is highest in India, Indonesia, EU, China, Pakistan, Nigeria, Thailand, Bangladesh and USA. This generates tropical deforestation (Borras Jr *et al.*, 2011; Gibbs *et al.*, 2010), reduces soil fertility, raises water and air pollution (through fires) and biodiversity loss, pollutes with pesticides, and blocks communities from soil and water for livelihoods (Edwards *et al.*, 2010; Koh *et al.*, 2011; Temper *et al.*, 2015), while increasing human infections and premature deaths (Burrows, 2016; Fornace *et al.*, 2016).

In response to this, the EU voted to ban palm oil-based biofuels by 2021, while the Roundtable for Sustainable Palm Oil (RSPO) platform of principles, criteria, indicators and certification is followed voluntarily in Indonesia and Malaysia. RSPO has certified ~12 million metric tons (19% of output) with members in 91 countries and Indonesia proposed a Peatland Restoration Agency for 2 million ha, froze concessions, and started to work closely with large consumers.

Yet major plantation companies are shifting investments to Africa, where local values, nutrition, culture and markets in Congo Basin countries are disrupted as doubled prices fuel investment in medium-sized (5-50 ha) plantations in forested areas (Yemefack *et al.*, 2005). This growth has been linked to 'land grabbing' – both there and in the Guinea forest ecosystem, where several land acquisition deals by multinationals are reported (see www.landmatrix.org).

Consciously managing for multiple objectives, is important. One option is further agroecology. Agroforestry has potential for increasing productivity (and profit) and maintaining or enhancing ecosystem services. This requires multiple forms of support, including monetary incentives, technical training and other investment (Minang, 2018) to enhance the ability to manage land.

build from such non-cooperative interactions to pursue the coordination of roads and protection.

Similarly, concessions are a leading development policy in forests, awarding extraction rights. That alone can create incentives for private firms to defend forest assets from illegal invasions. Further, such a strong defense of rights may be a necessary condition for adding conservation influences of global consumer preferences as expressed through certifications (Rico *et al.*, 2017). Thus, further coordination across agencies could optimally locate concessions and protections. Protection also interacts with investment in hydropower, which has led to eliminations of PAs ('PADDD') but could be better coordinated to achieve multiple objectives (Tesfaw *et al.*, 2018).

2.1.18.2.3 Causing conflicts

Social instability is at the heart of environmental, social, economic or geopolitical threats (World Economic Forum, 2017, 2018) (see Figures S31–33). More than 2,500 conflicts over fossil fuels, water, food and land are currently occurring across the planet (including at least 1,000 environmental activists and journalists killed between 2002 and 2013. A report by the NGO Global Witness argues that 913 citizens were killed in their attempt to protect the environment between 2002 and 2013; and that the rate of such killing has been increasing (Global Witness, 2014).

While violent conflict may be decreasing (Lacina & Gleditsch, 2005), conflicts that destabilize social systems can have adverse environmental impacts, which in turn may cause or affect conflicts. Resource scarcities and/or unequal appropriations have triggered conflicts over fossil fuels, water, food, and land. Those conflicts undermine governance, in turn generating further shifts in threats to ecosystems in a harmful social-ecosystem feedback loop.

Links between resource scarcity and conflicts are not clearly established (Bernauer *et al.*, 2012; Koubi *et al.*, 2013), but clear examples, such as the role played by water scarcity in triggering violence in Syria, are available today. Water scarcity is exacerbated by contamination of local sources, the appropriation of water by agriculture, changes within land rights, food insecurity, unemployment, and political instability (Gleick, 2014). Civil conflicts in areas where valuable natural resources are found have tended to last longer, as the access to natural resources creates an economic incentive for armed groups (Lujala, 2010). The control of natural resources (timber, gems or oil) and the revenues from resources finance and motivate conflicts (Le Billon, 2001).

Disputes over use rights relevant for nature can trigger violence and destruction, particularly with weak governance (Brown & Keating, 2015). Violent conflict further disrupts institutions, causing insecurities and distrust (Miteva *et al.*, 2017). For centuries, resources have been linked to warfare

(Feldt, 2007). Matthew *et al.* (2009) suggest that 40–60% of civil wars in the past 60 years were triggered, funded or sustained by natural resources. Renner (2002) highlights that legal or illegal resource exploitation helped trigger, exacerbate or finance ongoing violent conflicts about the control of sites rich in valuable commodities or the points they pass through going to markets. Schaffartzik *et al.* (2016)) document that growing metals demand has generated incentives for countries to seek revenue through exploiting natural resources and exporting primary commodities, with the expansion of extraction frontiers generating conflicts. Billions of dollars can then go to unscrupulous actors.

Controlling natural resources is part of state-based and civil conflicts and an element within the repression of riots and even assassination of activists (Global Witness, 2014). Food riots also rise if food prices rise from physical or constructed scarcities (Lagi *et al.*, 2011). Such violence – including assassinations – can occur if communities are pushed off their lands or threatened by the degradation of their natural resources (Schoenberger & Beban, 2018). Violence might also be used to discourage resistance to large-scale degradation (Blake & Barney, 2018). More generally, conflict can be one symptom of an unequal distribution (Downey *et al.*, 2010) and can affect conservation as more untouched ecosystems harbor groups targeted by military operations (DeWeerdt, 2008). Looking out over time, armed conflict can lead to the withdrawal of financial aid, which is rarely reinstated after a conflict (Glew & Hudson, 2007).

In Indonesia ~20 million people have been affected by forest conflicts (Dhiaulhaq *et al.*, 2015) and the Environmental Justice Organizations, Liabilities and Trade (or EJOLT, www.ejolt.org) documents almost 2000 active environmental conflicts (see **Figure 2.1.20**) – most related to land, minerals, water access and dams (Giordano *et al.*, 2005; Martinez-Alier *et al.*, 2016; Seter *et al.*, 2016) – while the Latin American Observatory of Mining Conflicts

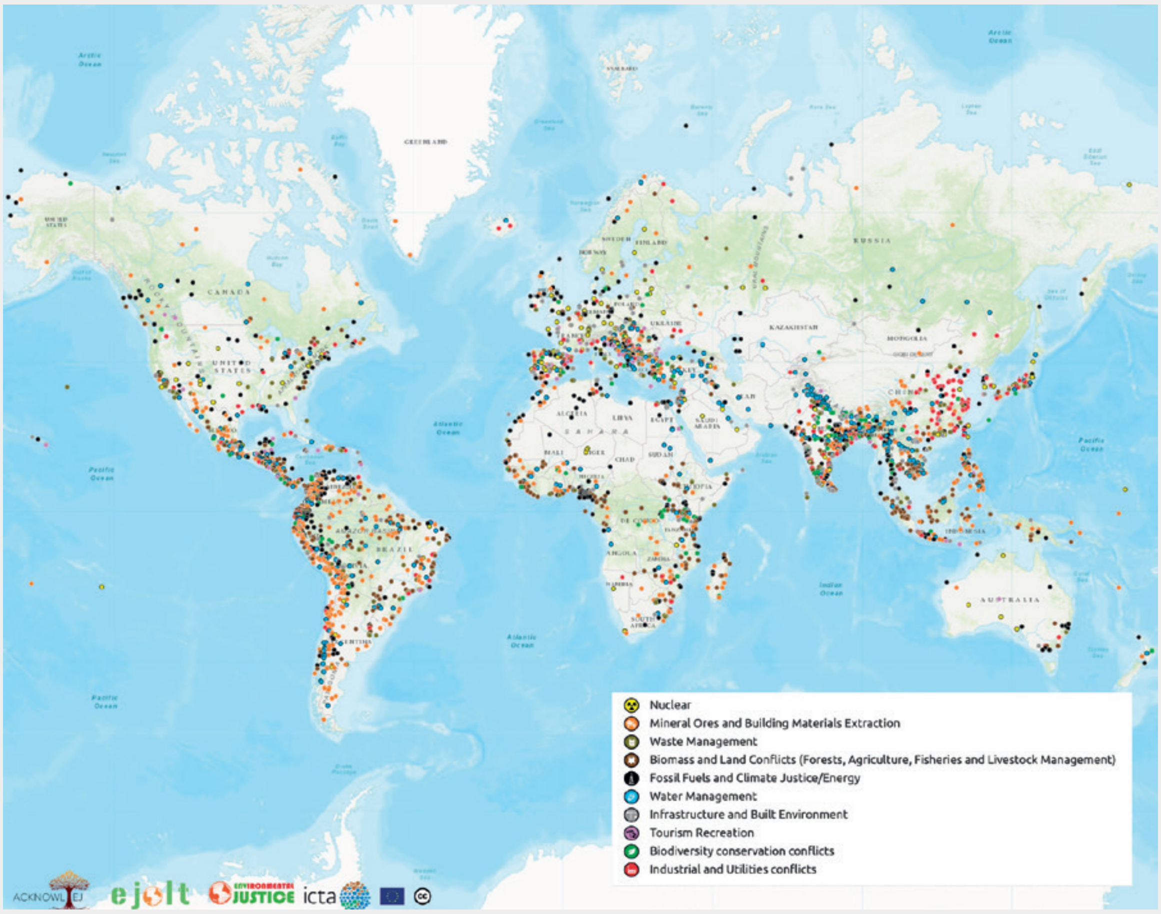


Figure 2 1 20 **Global map of environmental conflicts.**

The environmental justice atlas documents and catalogues social conflict around environmental issues, collecting the struggles of world communities to defend their land, air, water, forests and their livelihoods from damaging projects and extractive activities with heavy environmental and social impacts from around the world. Source: https://ejatlas.org/.

(www.conflictosmineros.net) notes over 150 active mining conflicts, most started in the 2000s after investments in mining in the 1990s (Urkidi & Walter, 2011; Walter, 2017). Butterman & Amey III (2005) suggest underlying international policy spillovers, i.e., that investment shifted due to environmental and labor regulations in Canada, and in the US, as well as due to political instabilities within the former Soviet Union, Asia and Africa. Some of the complex interactions involved in many such conflicts can be illustrated using the Nile Basin's example **(Box 2.1.5)**.

2.1.18.3 Evolving economic and environmental trade-offs

Across the globe, gains and burdens from nature are unequal for different sectors of society – and the trade-offs have evolved for all parties. For example, while a few firms are responsible for much of the fish harvesting around the globe (Österblom *et al.*, 2015), and a few countries are responsible for most of the carbon emissions (IPCC, 2013; Peters *et al.*, 2015), those who are most impacted by the consequences often are other groups that can include orders of magnitude more people with considerably less influence. In fisheries, FAO reports that 34 million people derive their livelihoods through fishing, while over 3 billion people get at least 15% of their protein intake from fish, especially in poor nations (FAO, 2014). Major ecological collapses have impacts upon international seafood market prices in markets (Smith *et al.*, 2017), but also upon the many small fish farmers and many consumers.

Environmental quality studies (Bowen *et al.*, 1995; Morello-Frosch *et al.*, 2001; Pastor *et al.*, 2002) find inequities can result from race and class barriers (e.g., **Box 2.1.3** above as well as **Box 2.1.6** above for including gender). In India, for instance, castes generate an important element of disproportionate pollution and other environmental stressors (Demaria, 2010; Parajuli, 1996). Tribal affiliation often counts in struggles against resource extraction processes, as in the case of Nigeria and other countries in which companies have shifted social and environmental costs of oil extraction onto Indigenous and poor local communities (Martinez-Alier *et al.*, 2014).

These inequalities have serious health consequences. A quarter of deaths and years of life lost are attributed to environmental degradation (Figure S31), with the highest fraction in low and middle income countries (WHO, 2016) given chemical or biological pollution of air, water and soil via agriculture, irrigation, and sanitation. Poor, rural communities are disproportionately affected (WRI, 2017). Negative effects of extreme events affect vulnerable communities in developing countries, who are least able to cope with the risks (Smit & Wandel, 2006), including of climate change (Mirza, 2003) and a likely multitude of primary and secondary effects (Adger, 2003).

Climate change, e.g., a 3°C warming with a 3% loss of GDP, will likely exacerbate inequalities (Mendelsohn *et al.*, 2000; Nordhaus & Boyer, 2000; Tol, 2002). Countries with higher initial temperatures, greater climate change levels, and lower levels of development, which often implies greater dependence on climate-sensitive sectors and in particular agriculture, are expected to bear the highest levels of impacts (Golden *et al.*, 2016, 2017; Marlier *et al.*, 2015; Myers *et al.*, 2014; Vittor *et al.*, 2006; Whitmee *et al.*, 2015).

More generally, losses of natural capital are unequally distributed across countries and regions (**Figure 2.1.21**, Lange *et al.*, 2018a). Further, these inequalities arise within countries as well, including along gender-based and race-based and income-based dimensions within developed countries.

Box 2 1 5 Nile basin's water allocation conflicts, with equity and efficiency considerations.

The Nile basin provides examples of conflicts concerning water allocation at the national scale, i.e., between nations, within an enormous region. This basin covers over 3 million km^2 with an annual discharge of 84 billion m^3 which supports over 200 million people within 10 countries: Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, Tanzania, South Sudan, The Sudan and Uganda. About 86% of the water from the Blue Nile originates from Lake Tana, which is within Ethiopia. Yet downstream 97% of the water needs in Egypt are fulfilled by the Nile, setting up potential tensions concerning the management of agroecosystems upstream.

Thus, not surprisingly, the decision by Ethiopia to build the Grand Renaissance Dam, which is now under construction, has created conflict with Egypt. Egypt says that the dam will reduce the flows to the lower Nile and that it will lose almost 3 billion m^3 to evaporation. Ethiopia responds that Egypt is losing 12 billion m^3 via the Aswan Dam, which is in Egypt (Di Nunzio, 2013).

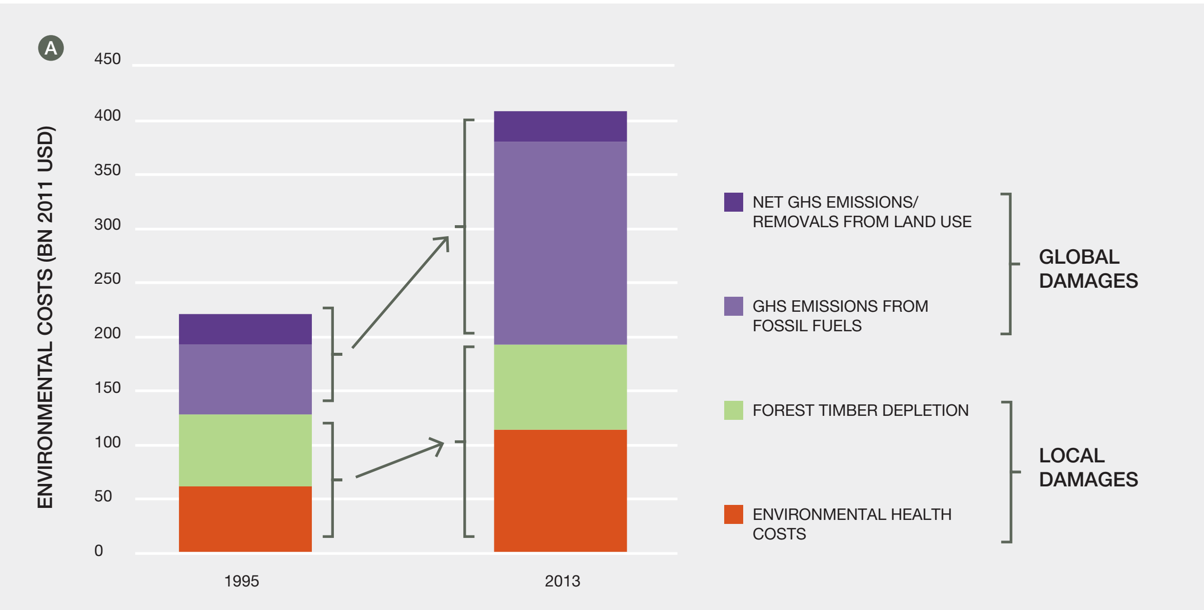
The region is rising in population and is modifying agroecosystems to meet needs for food, fuel and fiber. Given rising demand and its impacts on biodiversity, water resources and ecosystems, in order to work out rights structures for both sustainable management and fair utilization the Nile Basin Initiative was established in 1999 with support from each of the ten related countries. Only coordination can ensure sustainability for so many people and ecosystems (Swain, 2002).

Box 2 1 6 Scale, gender, and ecosystem-based differences for trade-offs within fisheries.

At the turn of the century, industrial fisheries and small-scale fisheries (SSFs) (Vásquez-León & McGuire, 1993) disagreed about inequitable relations including competition (Lawson, 1977; Vásquez-León & McGuire, 1993), preferential treatment by the state of the industrial fisheries (Panayotou, 1980; Pauly, 1997), access to specific fishing grounds (Begossi, 1995) and gear (Sunderlin & Gorospe, 1997). Conflict arose between fisheries, conservation and tourism (White & Palaganas, 1991) as well. SSFs were seen at odds with nonconsumptive uses of marine resources (Basurto *et al.*, 2017; Newman *et al.*, 2018). Agencies adopting mandates of conservation and protection were seen as against SSFs (Breton *et al.*, 1996). The conflicts were especially salient around endangered species and charismatic megafauna (Kalland, 1993). Jobs were said to be replaced in tourism and 'green' services yet fishers were skeptical (Young, 1999).

The literature has relied on technology to differentiate SSFs, often with unintended consequences (Basurto *et al.*, 2017). Definitions stress technical capacities, e.g., boat lengths, horsepower, and gear (Chuenpagdee *et al.*, 2006; FAO, 2009c; Smith *et al.*, 2017), excluding some SSF activities. To start, catching fish at sea is a predominately male activity (FAO, 2016b), while women play large roles in shore-side SSF efforts such as procuring ice, bait, food and fuel, accounting, managing, financing, fish processing, trading and marketing (Harper *et al.*, 2013; Thorpe *et al.*, 2014). These are labeled as supporting activities (Gereva & Vuki, 2010; Kleiber *et al.*, 2015; Tindall & Holvoet, 2008) or, when women are fishers (Béné *et al.*, 2009) in intertidal and shallow zones it is labeled as collection and gleaning and gathering (FAO, 2015a; Pálsson, 1989; Worldfish Center, 2010). Gender bias has implications for science, management, and the access to key resources. Most data measure only men's effort at sea from interviewing men (Kleiber *et al.*, 2015; Smith *et al.*, 2017), underestimating aggregate SSF economic contributions. Also, comprehensive ecosystem management – including of zones important for juvenile fish (e.g., seagrass beds, mangroves) – requires understanding all SSF practices (Kleiber *et al.*, 2015). Further, as women are often excluded from representing their concerns in the dominant fisheries governance processes (FAO, 2006; Okali & Holvoet, 2007; Porter, 2006), they are more vulnerable to tenure insecurity, marginalization and poverty (Harper *et al.*, 2013). Alternative SSF definitions are emerging. FAO's Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (SSF-Guidelines) defines SSFs with all activities along the relevant value chains – e.g., "pre-harvest, harvest and post-harvest" by men or by women (FAO, 2015a). Its implementation will shift SSF futures.

Challenges differ for inland fisheries facing agricultural runoff, introduced exotic species, and human uses (Youn *et al.*, 2014) such as hydropower, flood control, and irrigation (Baran *et al.*, 2007). In many developed countries, commercial fisheries have diminished in favor of alternative uses of freshwater, including recreational fishing, and scale again matters. Inland fisheries often feature small-scale harvesting (Bartley *et al.*, 2015) but large-scale, commercialized fisheries have large vessels and highly mechanized gear – e.g., the kilka fishery in the Caspian Sea (FAO, 1999), mechanized operations on lakes in Finland and the United States or estuaries in the Brazilian Amazon (Carolsfield, 2003; GLMRIS, 2012; Salmi & Sipponen, 2017) and long bag nets in the Tonle Sap Great Lake in Cambodia (Lamberts, 2001). Such operations may be more easily monitored and governed than dispersed fishers. Trade-offs between revenues and food security (Abila, 2003) arise for high-value exports (Lake Victoria Nile perch generated 250 million USD in 2012 (IOC, 2015)), given vulnerable stocks (Ermolin & Svolkinas, 2016).



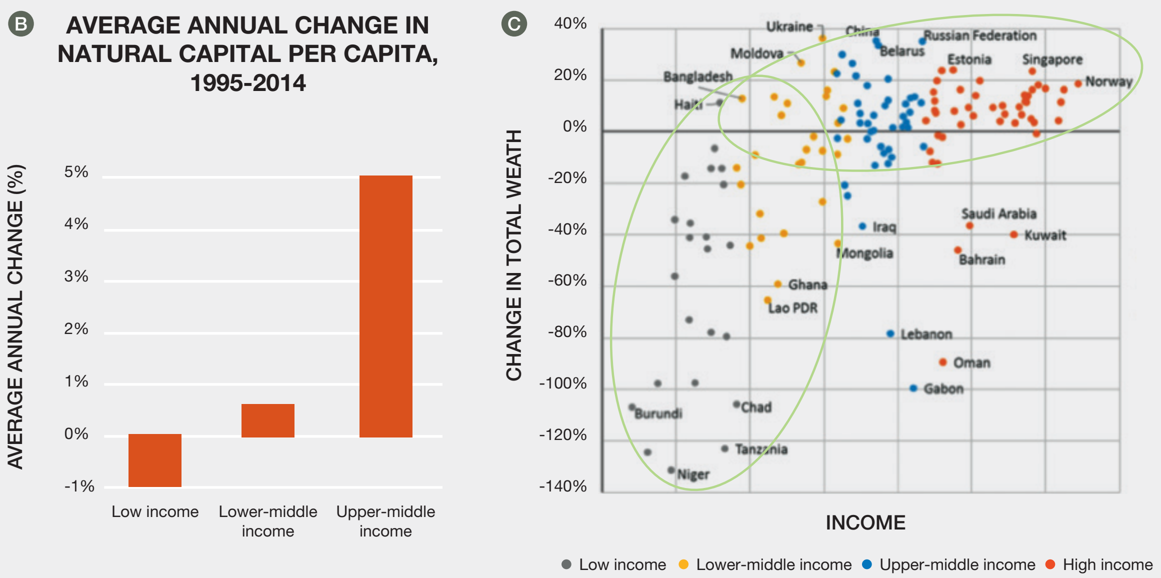


Figure 2 1 21 **Unequal gains and losses from changes in nature 1995-2014.**

A Increase in local and global environmental and societal costs, both global and local in billions of 2011 USD. B Average annual change in natural capital per capita for countries with contrasting levels of income, in average annual change in per cent. C Average annual changes in total wealth relative to changes in income per country; colors are used to distinguish countries of different income levels, using World Bank categories. Source: Lange *et al.* (2018a), see The Hidden Dimensions of Poverty (https://slideplayer.com/slide/11877123/).

2.1.18.4 Feedback loops and natural-social trajectories

Growing literature on social-ecological dynamics has largely explored actions (e.g. agriculture, fisheries, forestry, mining sectors) and the economic (e.g. trade, income, economic composition), and governance indirect drivers – alongside some work on positive and negative feedback loops, in a complex-systems sense of exacerbating or diminishing the forces going in a given direction.

Here we consider interactions and feedbacks that lead toward more or less desirable natural and social outcomes. This brings us full circle back to the trajectories highlighted in the Introduction.

The dynamics underlying development pathways described in the Introduction include feedback. Thus, as noted, initial conditions for the many consequential indirect drivers can lead to actions, aggregated impacts, changes in nature, shifts in NCP abundance or scarcity and, thus, changes in indirect drivers including values, prices, governance institutions, and more. Such feedback loops can push towards balancing or, instead, towards more extreme outcomes, both natural and social.

Below, we consider some relevant pieces of such feedback loops, although much remains to be studied concerning loops relevant for nature. First, we consider changes in trajectories, including abrupt changes, with feedback towards environmental degradation. Second, as part of responses to such trends, we consider individuals' and groups' feedback to governance responses. Finally, we scale upwards for possible feedback loops that lead in more desirable directions for nature.

2.1.18.4.1 Interactions, abrupt changes, and linked negative trends

Dramatic changes in nature can result from feedback that emerges from complex interactions between indirect and direct drivers – which can exacerbate the rates of degradation of nature. Regime shifts, for instance, are large, abrupt and persistent changes in the function and structure of systems (Scheffer & Carpenter, 2003). They occur at different spatial and temporal scales in marine and terrestrial systems (Rocha *et al.*, 2015). A 'regime shifts data base' documents over 30 different types of these abrupt changes (Figure S34) with >300 case studies based on a literature review of over 1000 scientific papers (Biggs *et al.*, 2015).

Regime shifts are increasingly observed. While they can occur naturally, under current trends of environmental forcing they might be more frequent and severe than observed. Climate change and food production have large forcing impacts (DeClerck *et al.*, 2016; Foley *et al.*, 2005;

Gordon *et al.*, 2008; Rocha *et al.*, 2015) and such shifts are expected to occur widely, but particularly in the Arctic (AMAP, 2012; Ford *et al.*, 2015; IPCC, 2013; Peterson & Rocha, 2016) where climate impact is felt relatively quickly. Another example of a regime shift is hypoxia in coastal systems, where oxygen levels fall low enough to produce 'dead zones' whose frequency and extent has risen across recent decades (Diaz & Rosenberg, 2008) and are more pronounced in the Northern Hemisphere, given common use of fertilizers. In the US only, more than 500 such 'lifeless' zones have been reported (Figure S35).

Shifts within the Arctic region have led communities to self-organize and to promote adaptive capacity (Huitric *et al.*, 2016), yet Arctic communities are, on their own, of course often limited in influencing the drivers of the regime shifts (Peterson & Rocha, 2016). Policies to manage many of the shifts that affect those communities require coordinated actions over scales which address the diversity of drivers (Rocha *et al.*, 2014).

Feedbacks between health and nature can arise when health and nature's status affect each other. The uses of antibiotics by humans (including over-use or mis-uses), for example, build resistance in nature (Laxminarayan *et al.*, 2013), thus contributing to negative impacts of nature on people. Chronic and infectious diseases and epidemic outbreaks shape household uses of nature, driving land management and dictating investments and policy. An E. coli outbreak changed landscape management in the US, for instance, as farmers eliminated hedgerows to avoid contamination by small mammal feces (Martin, 2006). In East Africa, poor health contributes to destructive and illegal fishing practices (Fiorella *et al.*, 2017), while sustainable agricultural practice is more common with improved access to anti-retroviral therapy (Damon *et al.*, 2015). Illnesses shift management of landscapes, e.g., malaria risk shapes tropical wetlands management (Malan *et al.*, 2009) while Zika control efforts include widespread insecticide use in the Americas and Pacific region (Blinder, 2016; Petersen *et al.*, 2016). Illness burdens – staggering globally and in sub-Saharan Africa and South Asia in particular – have implications for allocating budgets toward concerns deemed more immediate than nature. These kinds of interactions allow for unfortunate and linked trends in nature and human health.

2.1.18.4.2 Citizen feedback to governance

Well-informed citizens vote for representatives who share their views on the use of nature, in a democratic ideal. Yet, the fraction who vote has been well below 100%, globally. Voting may be irrational (Downs, 1957) and uninformed (Campbell *et al.*, 1960; Converse, 1964; Fiorina, 1981; Zaller, 1992), Studies find biases(Shogren & Taylor, 2008) and assess "nudges" around energy (Gillingham *et al.*, 2006; Sunstein & Reisch, 2014), including 'learning' via comparisons to neighbors (Allcott, 2011; Ayres *et al.*, 2013). In Ireland, real-time information affected behaviour (Gans *et al.*, 2013), although effects may decay without sustained information (Allcott & Rogers, 2014). 'Moral persuasion' (Ito *et al.*, 2018; Reiss & White, 2008) had effects only in the short-run, rising with income but lower for political conservatives (Costa & Kahn, 2013). Social identities matter (Bartels, 2002; Cassino & Lodge, 2007; Greene, 1999; Hillygus & Shields, 2014; Huddy, 2001; Kahneman & Tversky, 1979; Krosnick, 1991; Quattrone & Tversky, 1988). While values and identities may override (Kahan *et al.*, 2011; Layzer, 2006), so too do prior exposures and interactions (Brody *et al.*, 2008; Egan & Mullin, 2012). Framing around health (Myers *et al.*, 2012) and victims (Hart & Nisbet, 2012) can activate concerns and voting. Uncertain perceptions and a growing polarization and segmentation of media limits information (Hollander *et al.*, 2008).

Activists, firms, scientists and experts all inform both citizens and states (Keck & Sikkink, 1998), with influence via ideas and information, including from monitoring and connecting actors and setting agendas (Betsill & Corell, 2001; Wapner, 1995). Over time some NGOs have acquired roles in environmental regimes – nationally and internationally (Wapner, 1995). Some focus on facts: 'epistemic communities' (Sebenius, 1992) influence choice given uncertainties about social and physical processes (Adler & Haas, 1992) by developing knowledge or solutions, plus lobbying (Gough & Shackley, 2002). International learning can facilitate improved policies (Adler & Haas, 1992).

Free flow of information, civil liberties and regime receptiveness to citizen demands all suggest better environmental quality for democracies (Payne, 1995). Yet India – the largest democracy – faces severe environmental quality issues while Singapore ranks high alongside Norway and Sweden (EPI, 2018). Citizens can be aware of issues regardless of state-provided information, as they live with the problems (Arvin & Lew, 2011; O'Rourke, 2004; Winslow, 2005). Further, less democratic regimes do not restrict all information (King *et al.*, 2013 on censorship within China), even if any information that could galvanize collective action might be restricted. Participation modes for environmental actors have included protests in Vietnam and Myanmar to demand less degradation (Doyle & Simpson, 2006; O'Rourke, 2004). While that is not always effective, not all environmental participation is effective in democracies. Pavlinek & Pickles (2004) note the prioritization of the economy instead of environment in post-Soviet Central and Eastern Europe (CEE), yet Midlarsky (1998) sees "no uniform relationship between democracy and the environment" while Pellegrini and Gerlagh (2006) and Pellegrini (2011) suggest effects of democracy in decreasing degradation are overstated and that corruption could undermine all.

Leaders' incentives have mattered (Congleton, 1992; Ward *et al.*, 2014), e.g., private income gains from polluting and extracting (Deacon, 1999; McGuire & Olson, 1996; Olson, 1993). If the elites lose rents in stringent regulatory regimes, while the benefits of conservation are diffuse, leaders may not strengthen nature (Bernauer & Koubi, 2009; Cao & Ward, 2015). The time horizons matter too. Lasting institutions include legislatures (Gandhi, 2008; Gandhi & Przeworski, 2007; Svolik, 2012) and political parties (Brownlee, 2007), which can extend the temporal perspective.

In the 1970s, state policies were often varied command and control limits on pollution through output or technology requirements (Coglianese & Lazer, 2003). While relatively easy to implement, these have inefficiencies due to inflexibility (Jaffe *et al.*, 1995) and the distrust and adversarial legalism that often results. As Kagan (1991) describes, legal rules and adversarial procedures for resolving disputes often lead to costly winner-takes-all judicial battles with both cost and delays. This can result from a closed-door approach in which agencies ignore firm and local knowledge, lowering 'buy-in' (Beierle & Konisky, 2001; Coglianese & Lazer, 2003). This can create opportunities for 'capture' by interest groups (Oates & Portney, 2003) that have influence in traditional regulatory processes – often reflecting the power of concentrated production and finance. Recently, greater attention has been given to collaborative governance by public and private actors (Fiorino, 2006): "agencies directly engage non-state stakeholders in a collective decision-making process that is formal, consensus-oriented, and deliberative" (Ansell & Gash, 2008). Walker et al (2015) describe such approaches: first, the state informs and educates citizens via public meetings and notifications; second, regulating entities request public input on policies, as through comments, though technical complexity requires the agency to do more policy formulation; and third, more complete collaboration where agencies and private stakeholders equally construct new policies.

Water management provides some examples, from across the globe, of significant variation in such processes. In Singapore, a Public Utilities Board (PUB) manages electricity, gas and water supply plus legislation to address sewerage, effluents, drinking water quality and more (Luan, 2010). After focusing on construction and maintenance, it now also does 'demand management' to encourage citizens to conserve. India's National Water Policy is coordinated by the Ministry of Water Resources as a tool for planning and development of water resources. Adopted in 1987, this legislative pact was relaunched in 2012 to emphasize water as an 'economic good' and, thus, promotes efficient use and conservation. Beyond potable water access, a recent addition is flow in water channels to meet ecological needs. Canada also adopted a Federal Water Policy in 1987, noting intensive consultation with diverse stakeholder groups given two key objectives: improve the quality of the water resource; and advocate freshwater use in an efficient and equitable way, coherent with the social, economic and environmental needs of present and future generations.

2.1.18.4.3 Scaling up and extending positive responses

Multiple existing initiatives have both a positive potential and some potential to be scaled up for moderating negative impacts on nature and good quality of life, toward more sustainable futures. One compilation is the "Seeds of Good Anthropocenes" initiative[3] that aims to explore and articulate positive futures (Bennett *et al.*, 2016). Up to 500 initiatives which demonstrate elements of positive futures have been identified **(Figure 2.1.22)**, towards testing theories about how desirable transformative pathways can supported (Pereira *et al.*, 2018). They include social movements, ways of living or doing things, technologies and designs, and governance. For example, Yachay City of Knowledge is a "New City" under development in rural Ecuador, conceptualized to be a technological research and innovation hub containing research facilities, a working university, and bio-tech companies. "Tribal parks" are an example of Aboriginal people being recognized as co-managers of national parks in Canada[4]. The Foundation for Ecological Security is an Indian NGO which is working to reduce poverty by helping communities organize to restore their ecosystems while also enhancing their livelihoods in over 8,000 village institutions in 31 districts across 8 states, having already supported some form of restoration of over 1 million ha while training 350,000 people in both ecological restoration and management of village institutions[5].

Quite broadly, many voices have called for alternatives to current global development pathways (see also chapters 5 and 6). There are calls for 'degrowth', with changes in social and political priorities (Odum & Odum, 2006). Ecological sustainability and social justice are called out, e.g., "an equitable downscaling of production and consumption that increases human well-being and enhances ecological conditions at the local and global level" (Schneider *et al.*, 2010). Whether this will be widely embraced or scaled up as a goal remains to be seen.

Consumer-driven initiatives to demand sustainable land-use management and the restoration of degraded lands have arisen in recent decades (IPBES, 2018a). Companies have responded by committing to reduce impacts upon nature and the rights of local communities, including taking steps to, e.g., eliminate deforestation due to supply chains by

3. https://goodanthropocenes.net/
4. http://www.tribalparks.ca
5. http://fes.org.in

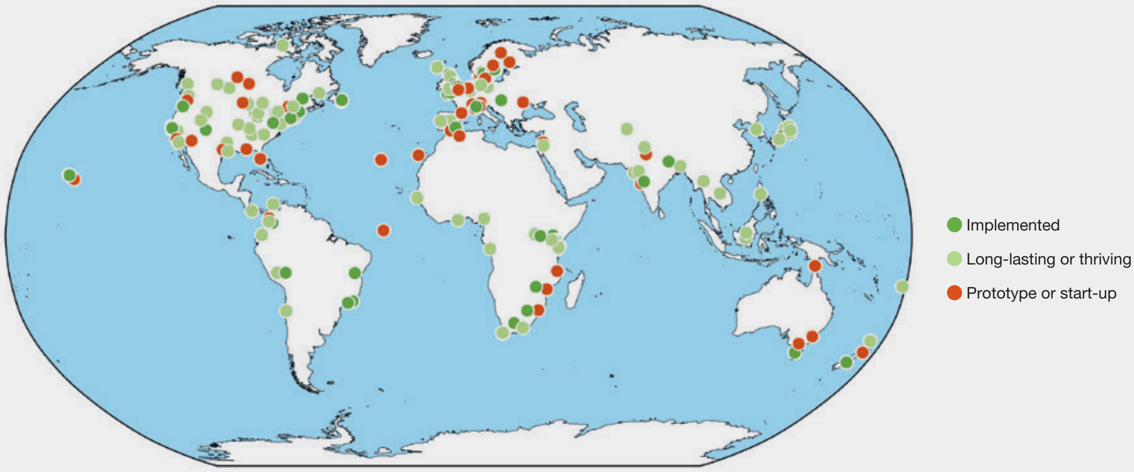


Figure 2 1 22 **Seeds of Good Anthropocenes.**

The Bright Spots team used an international participatory process to identify over 500 initiative globally, and gathered data on how they are established, grow, spread, or inspire positive change elsewhere.
Sources: Future Earth (2017), Pereira *et al.* (2018).

2020. State and civil-society groups have committed to restore hundreds of millions of hectares of degraded lands. Following all this, the finance sector is starting to make explicit commitments to reduce its environmental impacts.

Other alternatives to global development pathways have emphasized how nature's contributions are valued and currently marketed – versus how they could or should be. These have highlighted incentives and the potential from clear ownership and use rights, with private-market interactions that facilitate price feedbacks to address scarcities. For example, when an earthquake shuts down copper mines, the futures market quickly lowers expectations of supply, through higher prices, that in turn shifted any number of private plans, from computer wiring through kitchen redesign. Most generally, following signals of natural scarcities, relevant decisions have adjusted to help.

Industrial ecologists note that responses to environmental quality and natural resource scarcities have been considerably more complex, even if guided by a simple pursuit of profits. Paraphrasing Frosch & Gallopoulos (1989), the wastes from one industry can be the inputs for others, reducing the total usage of all raw materials as well as the generation of pollution into the environment. This has occurred in residences, too, with 'gray water' from apartments feeding urban roof gardens. While all of that requires coordination, in principle it is motivated by private costs or profits alone.

Limits on such useful feedback processes have included: information; rights; and transaction costs. Since the private payoffs from resource use and environmental degradation drive private choices, in many settings even commendable private responses have come up far short of social sensibility. The simple, obvious and pervasive reason for this is that private actors often have not taken into account how other people would lose (or gain) from those actors' choices concerning degradation. Sometimes actors did not know about effects on others, which suggests potential from initiatives such as efforts to communicate with relevant actors, e.g., via certifications of production processes. Yet often people simply have not in their daily decisions given equal attention to effects on others – even though, clearly, there exists both altruism and various private provisions of public goods. Thus, even if fully informed about effects on others, private actors were not bound to incur costs to benefit others, and often did not, raising questions about public roles concerning those affected.

When people affected by others' behaviours had the publicly defended right to clean air, or water, producers degrading others' environment and resources were forced to get consent and, at times, compensate the affected. That shifts private costs and benefits and, thus, plans. Given appropriate public frameworks, those signals of the need to adjust were stronger as scarcities in nature rose, shifting further the trade-offs for degrading production. Yet such frameworks often were lacking.

When rights were clear, and incentives aligned, actors gained in their own management decisions from information due to assessments – even by others. It appears as though larger fisheries, which tend to be more systematically assessed, are doing better in maintaining fish stocks, on average, than small, formally unassessed fisheries (Costello *et al.*, 2012). Even so, there can exist multiple stable points of equilibria within such fully informed social-ecological systems, given social and natural sources of feedback. Fishing effort responds often to the state of the fish stock, which is in turn affected by fishing-effort levels. If sustainability-oriented decision rules imply that the fishing effort falls as the scarcity of the fish rises, then they can stabilize stocks as can regulations informed by ecological and human response models (Yun *et al.*, 2017) **(Figure 2.1.23)**.

Notwithstanding the many types of past contributions to support nature, by many private actors, many outcomes in private contexts often have indicated a need for public responses to scarcities. Public actors with overarching mandates have not only set up appropriate frameworks to address trade-offs – leading to quantity and price policies – but also lowered solutions' transaction costs. For instance, states have required information, e.g., labeling with energy use for refrigeration or, more involved, certifications of legal sourcing for forest products, under which public rejections of illegally harvested timber

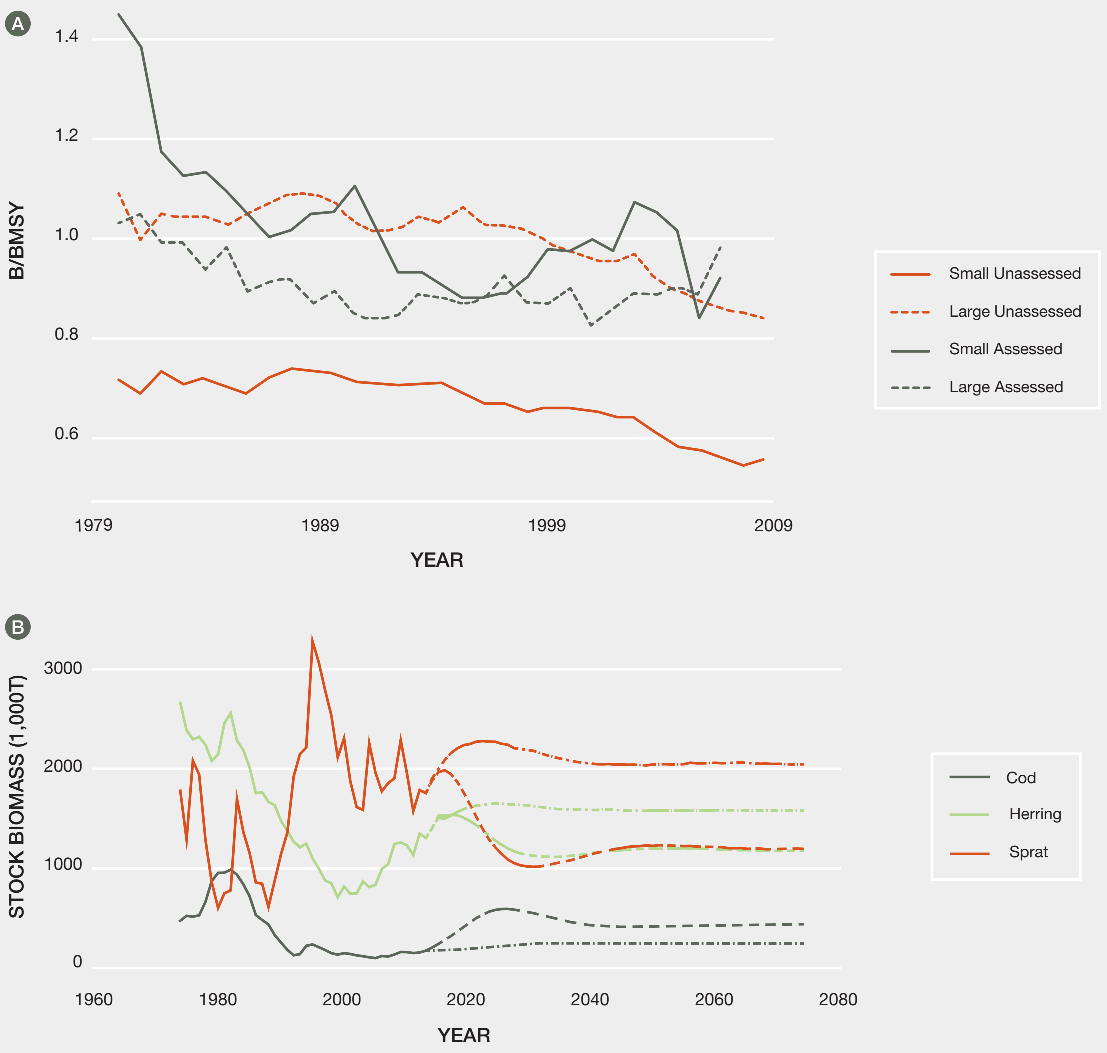


Figure 2 1 23 **Fisheries can show positive trends into the future when adequately managed and governed.**

A The ratio of observed biomass to the biomass that would provide maximum sustainable yield (B/Bmsy) has stabilized for small and large fisheries that are being constantly monitored (assessed). B Fisheries can stabilize at different equilibria level when managed for single-species (dashed lines), and under ecosystem-based management (dot-dash lines).
Sources: Costello et al. (2012), Yun *et al.* (2017).

have occurred (e.g., under the EU's FLEGT or the U.S. Lacey Act).

Further, many crucial incentives and empowerments of private actors involved the creation or the enforcement of some form of right, such as indigenous lands or smallholder land tenure or firms' concessions for timber harvesting or the right to clean air as implied by limitations on emissions. Like private choices, establishment of such limitations or rights has tended to respond to scarcity.

Stepping back, while in the past a large set of such institutions have generated social efficiency, as well as equity when attention has been given to that critical outcome as well, in practice there exist considerable institutional challenges. Just as private collective action to form institutions was not always successful – given multiple determinants of such coordination – public processes will not always effectively address environmental and resource scarcity. Some actors do not wish to do so. This suggests considerable attention is needed to environmental politics, alongside policy design.

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