Global trends in nature’s contributions to people

Supplementary Information

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Supplementary Table: Evidence and Trends in Nature’s Contributions to People

For each contribution of nature (rows) and for indicators of potential and realized contribution, environmental condition, and impact on quality of life (columns) we include a brief definition of the contribution. We then describe the chosen indicator(s) and their trends over the past 50 years. These indicators are not exhaustive; there are many additional ways that nature contributes to people, and even more ways that these contributions can be measured. These indicators were selected based on extensive review of each type of contribution to be representative of the major trends. When divergent trends occur for different indicators or types of indicator, more than one was selected. Evidence was evaluated using the IPBES four-box model for the qualitative communication of evidence, which considers both the quantity and quality of evidence, on a scale of low to robust, and the level of agreement among that evidence, on a scale of low to high.

| Key | Potential Contribution of Nature | Realized Contribution of Nature | Environmental Condition | Impact on Quality of Life |
|-----|---------------------------------|---------------------------------|-------------------------|--------------------------|
|     | Short general description of potential/realized/environmental condition/impact | Trend in chosen indicators (Worse, Little change, Better) | Text description of indicator, trend, and citations |                         |
| Habitat | Habitat that could support desired species. | Worse, regional differences | Significant global habitat declines with differing magnitudes across regions. Decreased biodiversity intactness. Well established. (1, 2) |                         |
| Potential Contribution of Nature | Realized Contribution of Nature | Environmental Condition | Impact on Quality of Life |
|---------------------------------|---------------------------------|--------------------------|--------------------------|
| **Pollination and seed dispersal** | The amount, quality and diversity of pollen and seeds that could be dispersed by fauna, indicated by (a) pollinator and (b) seed disperser diversity and abundance **Worse, uniform; Worse, uniform** | The extent of pollination and seed dispersal that actually occurs, indicated as the overlap between (a) pollinator and (b) seed disperser occurrence and dependent plants **Worse, uniform; Worse, uniform** | **Health associated with intake of pollinator-dependent foods**  
*Worse, regional differences*  
Decline in health due to declines in animal pollinated-food via micronutrient deficiency (18). Nutrition contribution from pollinator-dependent crops varies globally (19). Low-income groups have less ability to compensate. Impacts associated with declines in seed dispersal are mostly through impacts on other contributions of nature. Unresolved. |
| **Potential air pollutants retained in or by vegetation, indicated by carbon content of trees that could burn and leaf area of vegetation that could retain pollutants and protect soils, preventing dust** **Worse, regional differences** | Potential air pollutants retained in or by vegetation, indicated by carbon content of trees that could burn and leaf area of vegetation that could retain pollutants and protect soils, preventing dust **Worse, regional differences** | Actual retention of air pollutants in or by vegetation, indicated by lack of burning and actual entrainment of air pollutants **Worse, regional differences** | **Reduced morbidity and mortality related to air pollution**  
*Worse, regional differences*  
3.3 million premature deaths annually attributed to air pollution (24, 25). Increasing trend in Asia and decreasing in US and Europe (26). Increasing cost of healthcare and lost work (23). Overall impacts are well established, but impacts across user groups are mixed. |
| **Air Quality Regulation** | | Air quality **Worse, regional differences** | |
| Environmental Condition | Impact on Quality of Life |
|-------------------------|--------------------------|
| Reduction in mortality, morbidity, and cost related to climate-driven phenomena |
| Increase in economic cost of climate-driven extreme events leading to deaths, proliferation of diseases, agricultural disease outbreaks, and property damage |

### Potential Contribution of Nature
- **Climate Regulation**
  - Potential greenhouse gas sequestration by existing ecosystems; potential direct effects on regional climate
    - Worse, regional differences
  - Actual greenhouse gas sequestration by existing ecosystems, including management effects; direct effects on regional climate
    - Worse, regional differences
    - Would be more sequestration with no anthropogenic land management (33). Increase in methane and nitrous oxide emissions from land management (29). Precise contributions of ecosystems incomplete.

### Realized Contribution of Nature
- Actual greenhouse gas sequestration by existing ecosystems, including management effects; direct effects on regional climate
  - Worse, regional differences
  - Would be more sequestration with no anthropogenic land management (33). Increase in methane and nitrous oxide emissions from land management (29). Precise contributions of ecosystems incomplete.

### Reduction of greenhouse gas concentrations in the atmosphere, regional climate
- Worse, uniform
  - Increase in emissions, mostly in developed countries, China, and India, leading to increase in greenhouse gas concentrations in the atmosphere (34, 35). Well established.

### Ocean Acidification Regulation
- Potential carbon dioxide sequestration by existing ecosystems
  - Little change, uniform
  - Stable but spatially variable emissions and sequestration of carbon dioxide from land use terrestrial ecosystems (27). Warming of upper ocean increases range of nitrogen-fixing phytoplankton, increasing ocean net primary productivity (31, 32). Well established.

### Actual carbon dioxide sequestration by existing ecosystems, including management effects
- Worse, regional differences
  - Would be more sequestration with no anthropogenic land management (33). Precise contributions of ecosystems incomplete.

### Ocean acidification
- Worse, uniform
  - Ocean acidification is increasing (36) and marine calcification has dramatically declined (36, 37). Well established.

### Nutrition and income from shellfish and coral reefs
- Worse, uniform
  - Decline in shellfish availability (37). Increasing economic damage of coral reef loss, estimated to be US$500 to 870 billion by 2100 (36). Established but incomplete.
| Water Quantity and Flow Regulation | Potential Contribution of Nature | Realized Contribution of Nature | Environmental Condition | Impact on Quality of Life |
|-----------------------------------|----------------------------------|----------------------------------|--------------------------|--------------------------|
| Potential modulation of water flow by existing ecosystems | Potential modulation of water flow by existing ecosystems | Actual modulation of water flow by ecosystems, including land management effects and water availability | Available water | Water available to people relative to demand |
| Worse, regional differences | Worse, regional differences | Worse, regional differences | Little change, regional differences | Worse, uniform |
| Increased runoff quantity and flow speed due to deforestation, expanding rainfed cropland, and urbanization (38, 39). Impact of ecosystem change on water regulation established but incomplete (40). | Management combined with deforestation, expanding rainfed cropland, and urbanization increases runoff quantity and flow (38, 39), exacerbated by paths and roadways in (41). | Global river discharge constant over past 50 years but spatially variable (42, 43). Groundwater increases in some regions, decreased in others (44). Well established. | Globally, increasing human water demand increases water scarcity; well established (43, 45). Regional variation and impacts vary depending on adaptation capacity, but all are affected (46). Direct linkages from water scarcity measures to impacts are inconclusive. Overall, impact to people is thus established but incomplete. |

| Water Quality Regulation | Extent of ecosystems that could filter or add constituents to water | Actual removal of pollutants or addition of desired constituents by ecosystems | Ambient water quality | (a) Health cost of exposure to polluted water and (b) monetary cost of treatment |
|--------------------------|---------------------------------------------------------------|-------------------------------------------------|---------------------|-------------------------------------------------|
| Worse, uniform | Worse, uniform | Worse, uniform | Worse, regional differences | Better, uniform; Worse, uniform |
| Decreased filtration potential due to increased impervious surfaces and vegetation removal (47-49). Mechanisms well established, potential magnitude of impact established but incomplete (47, 48). | Increased in pollutants needing removal but less vegetation to intercept it. Filtration effectiveness varies widely among studies, so unresolved (47, 48). | Nutrient pollution and pathogens increasing, regionally variable trends in industrial waste (50). Few globally consistent water quality measurements and indicators (51). Overall trends well established, however. | Global decrease in the prevalence of water-borne disease, though at different rates (50, 52). Water-borne disease is well studied, well established (53). Extent, quality, and spending on water treatment and sanitation increasing (53). Extent and expansion of infrastructure is well monitored and established (53). |
| Potential Contribution of Nature | Realized Contribution of Nature | Environmental Condition | Impact on Quality of Life |
|----------------------------------|---------------------------------|--------------------------|---------------------------|
| **Soil Formation and Protection** | Potential to create and maintain soil fertility, reflects changes in ecosystem type  
Worse, regional differences | Soil quality, reflects land use patterns  
Worse, regional differences | Soil fertility, ability to use soil  
Worse, regional differences  
Global decline in soil fertility (54-56). Well established.  
Global decline in soil organic carbon, increasing soil degradation, regional variation, improvement in North America (54-57). Well established. | Health and income impacts of reduced soil fertility  
Worse, regional differences  
Declining crop yield due to soil degradation; regional variation (58, 59). Variable capacity to compensate using substitutes like mineral fertilizer (60). Well established. |
| **Hazard Regulation** | Existence of ecosystems that could regulate hazards  
Worse, regional differences | Actual reduction of hazards by ecosystems  
Worse, regional differences | Incidence and severity of hazards  
Worse, uniform  
Intersection of actual hazard occurrence with nature that could regulate it, e.g. overlap of mangroves, corals, and seagrass with high water events (62). Few actual studies, inconclusive. | Health and income impacts of hazards  
Worse, uniform  
Increasing number of people and value of impacted property (63). More impact on less robust institutions and on more vulnerable social groups (65, 66). Hazard occurrence and impact is well studied, but hazard regulation inconclusive (61, 63), so established but incomplete. |
| **Pest Regulation** | The number and diversity of pests that could be controlled, indicated by diversity and abundance of pest enemies  
Worse, uniform | Actual control of pests  
Worse, uniform | (a) Pest-driven damage and (b) incidence of vector-borne disease  
Little change, uniform; Worse, uniform  
Decline of natural pest enemies means less potential for control, even as pest abundance has likely increased due to increased drivers e.g. pests tolerant of chemical control (68, 69). However, limited studies globally, so evidence is inconclusive. | (a) Health impacts of vector-borne disease and (b) cost of pest-driven damage  
Better, regional differences; Worse, uniform  
Globally, food spoilage and crop loss due to pests has not changed significantly (70, 71). Well established. Risk of disease transmission has increased (69, 72). Well established. |
| | Decline of natural pest enemies and competent hosts of vector-borne and zoonotic diseases in all regions, with larger declines in the tropics and sub-tropics (67). Decreased natural habitat in agriculture to support pest predators (68). Well established. | | | |
| Potential Contribution of Nature | Realized Contribution of Nature | Impact on Quality of Life |
|---------------------------------|--------------------------------|--------------------------|
| **Energy**                      |                                |                          |
| Extent of (a) agriculture and (b) forest land for bio-energy production | Bio-energy harvested | Income and energy security from bio-energy |
| Better, regional differences; Worse, regional differences | Better, regional differences | **Better, uniform** |
| Increasing extent of agricultural land, though varies regionally (74). Well established. Global decrease in forested area to provide fuelwood, though varies regionally (20, 28). Well established. | Increased energy production by biofuel crops (7) and fuelwood (75). Slow growth and some decline in traditional biomass, primarily for cooking and heating, with changing technology. Well established. | Increasing income from biomass energy (76). Biofuels key to household income (77, 78). Biomass energy, including timber and crop residues, provides energy security to more than two billion people (79). Well established. |
| **Food and Feed**               |                                |                          |
| Extent of (a) food and feed producing land and (b) ocean food and feed stocks | (a) Amount and (b) nutrition of food and feed | (a) Hunger and malnutrition and (b) income from food and feed |
| Better, regional differences; Worse, regional differences | Better, uniform/Worse, uniform | Better, regional differences; Worse, regional differences |
| Increase in harvested area, with regional variation (74). Well established. Decrease in fish catch potential (80), though variable across regions (81). Established but incomplete. | Increasing global production of food (74). Increased global fish catch and cultured (farmed) fish production over the past 50 years (82). Well established. Current food production largely meets global caloric needs but fails to provide dietary diversity, notably fruits, nuts, and vegetables, for a healthy diet (83). Well established. | Decrease in hunger since 1970, though small increasing trend in past decade (84). Obesity has increased since 1970, countered in many regions by decreasing undernutrition (84). Well established. The global ex-vessel fish price increased between 1950 and the late 1980s but has since declined (85). Employment in marine fisheries has declined whereas aquaculture increased then stabilized (82). Well established. |
| Potential Contribution of Nature | Realized Contribution of Nature | Impact on Quality of Life |
|----------------------------------|---------------------------------|--------------------------|
| **Materials**                    |                                 |                          |
| Extent of (a) agriculture and (b) forest land for material production | Amount and quality of materials produced |
| Better, regional differences; Worse, regional differences |
| Increasing extent of agricultural land, though varies regionally (74), area of cotton was stable. Well established. Global decline in forest area; spatial variation (20, 28). Well established. |
| Production of a majority of material resources has increased globally, though there is considerable diversity among materials (75). Increased timber production (75). Well established. |
| (a) Numbers employed and (b) income from material production |
| Better, regional differences; Better, uniform |
| Globally, employment in forestry has probably increased since 1970 and reported employment has remained stable over the past 20 years (75, 86). Established but incomplete. Increasing revenue from forestry (87). Well established. |
| **Medicine**                     |                                 |                          |
| Potentially medicinal species, indicated by an overlap of (a) a wide diversity of species and (b) intimate knowledge of their properties | Medicinal species in use |
| Worse, uniform; Worse, regional differences |
| Declining measures of phylogenetic diversity (88). Well established. Declining fraction of known medicinal species due to ILK decline, loss of access to customary territories by IPLCs; reduces capacity to identify new drugs from nature (89). Established but incomplete. |
| Increase in medicines based on natural products (90, 91). 30,000 new compounds from oceans (92, 93). Gene bank accession and genetic resources have increased (94) and the capacity to mimic natural molecules and test the latter on diseases has increased. Well established. |
| Health impacts from natural or bio-derived medicines |
| Better, regional differences |
| Increased health attributable to nature-based medicines; more than 50% of global population relies almost exclusively on natural medicines (95, 96). Established but incomplete. |
| Potential Contribution of Nature | Realized Contribution of Nature | Impact on Quality of Life |
|---------------------------------|---------------------------------|---------------------------|
| **Learning** | **Diversity of nature and proximity of people who could learn from it** | **Actual learning from nature** | **Income and quality of life from bio-inspired production** |
| | *Worse, uniform* | *Worse, uniform* | *Better, regional differences* |
| | Declining diversity of life from which to learn, measured as phylogenetic diversity (88). Declining population living in direct proximity to nature due to urbanization and migration (97). Reduced human-nature interactions (98, 99). Established but incomplete. | Global decrease in biodiversity in conjunction with fewer people living in proximity to nature leads to fewer ideas and products mimicking or inspired by nature (e.g. images of nature in children’s media (100, 101). Inconclusive. | The overall value of bio-inspired goods is increasing, although it is concentrated within few very large industries (102). Established but incomplete. |
| **Experience** | **Existence of natural and traditional land and seascapes and proximity of people who could experience it** | **Actual physical and psychological experiences in nature for (a) wealthy and urbanized people and (b) poor and rural people** | **Nature-driven improvements in care, awareness, mental and physical health, life satisfaction and cultural security for (a) wealthy and urbanized people and (b) poor and rural people** |
| | *Worse, uniform* | *Better, regional differences; Worse, uniform* | *Better, regional differences; Worse, regional difference* |
| | Declining area of natural and traditional landscapes and seascapes due to urbanization and land use change (103, 104). Declining population living in direct proximity to nature due to urbanization and migration (97). Well established. | Nature visitation rates have risen in some areas and fallen in others (105, 106). Established but incomplete. Daily exposure to nature has decreased as urbanization has increased (98, 99, 107). Established but incomplete. | Wealthy, urban interest in nature seems to have increased (21), but evidence is inconclusive. Rural migration and land use change have decreased quality of life from nature exposure (108), particularly for the poor (109), but again evidence is inconclusive. Indications of positive mental and physical health impacts from exposure to nature, but findings are inconclusive (110, 111). |
| Identity | Potential Contribution of Nature | Realized Contribution of Nature | Impact on Quality of Life |
|----------|---------------------------------|---------------------------------|--------------------------|
| Identity | Potential of nature to influence identity, indicated by stability of land use and land cover<br>
*Worse, uniform*<br>
Stable human environments provide culture with the possibility to attribute value to it and form identities (111-113). Increased globalization, urbanization, and environmental degradation had decreased stability of land use and land cover (114, 115). Well established. | Actual role of nature in shaping identity for (a) wealthy and urbanized people and (b) poor and rural people<br>
*Better, regional differences; Worse, regional differences*<br>
In urban areas, increasing consciousness of nature and its contributions (116). For rural and indigenous and local people, decreasing local resource-based economies and loss of traditional knowledge and lifestyle and thus identities (117, 118). For both groups, little global-scale evidence, so inconclusive. | Nature-driven improvements in care, awareness, mental and physical health, life satisfaction and cultural security for (a) wealthy and urbanized people and (b) poor and rural people<br>
*Better, regional differences; Worse, regional differences*<br>
Increasing youth interest in nature’s contribution to identity (119), and nature has become engrained in some national cultural identities, livelihoods, and national economies (111). Rural migration and land use change decrease identity linked to nature (108, 111). For both groups, little global-scale evidence, so inconclusive. |
| Options | Amount and diversity of nature to support quality of life in the future<br>
*large decrease, uniform*<br>
Increasing species extinction rates; major regional variation (120, 121). Decreasing phylogenetic diversity (88). Trends based on data but the places and species for high diversity loss are established but incomplete. | | |
References

1. Butchart SHM, et al. (2010) Global Biodiversity: Indicators of Recent Declines. *Science* 328(5982):1164.
2. Newbold T, et al. (2016) Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. *Science* 353(6296):288-291.
3. Potts SG, et al. (2016) Safeguarding pollinators and their values to human well-being. *Nature* 540:220.
4. Regan EC, et al. (2015) Global Trends in the Status of Bird and Mammal Pollinators. *Conservation Letters* 8(6):397-403.
5. Cameron SA, et al. (2011) Patterns of widespread decline in North American bumble bees. *Proceedings of the National Academy of Sciences* 108(2):662.
6. Carvalheiro LG, et al. (2013) Species richness declines and biotic homogenisation have slowed down for NW-European pollinators and plants. *Ecology Letters* 16(7):870-878.
7. Koh LP & Ghazoul J (2008) Biofuels, biodiversity, and people: Understanding the conflicts and finding opportunities. *Biological Conservation* 141(10):2450-2460.
8. Aizen MA & Harder LD (2009) The Global Stock of Domesticated Honey Bees Is Growing Slower Than Agricultural Demand for Pollination. *Current Biology* 19(11):915-918.
9. Garibaldi LA, Aizen MA, Klein AM, Cunningham SA, & Harder LD (2011) Global growth and stability of agricultural yield decrease with pollinator dependence. *Proceedings of the National Academy of Sciences* 108(14):5909.
10. Aslan CE, Zavaleta ES, Tershy B, & Croll D (2013) Mutualism Disruption Threatens Global Plant Biodiversity: A Systematic Review. *PLOS ONE* 8(6):e66993.
11. Fontúrbel FE, et al. (2015) Meta-analysis of anthropogenic habitat disturbance effects on animal-mediated seed dispersal. *Global Change Biology* 21(11):3951-3960.
12. Garibaldi LA, et al. (2016) Mutually beneficial pollinator diversity and crop yield outcomes in small and large farms. *Science* 351(6271):388.
13. Chapman CA & Chapman LJ (1995) Survival without Dispersers: Seedling Recruitment under Parents. *Conservation Biology* 9(3):675-678.
14. Peres CA, Emilio T, Schietti J, Desmoulière SJM, & Levi T (2016) Dispersal limitation induces long-term biomass collapse in overhunted Amazonian forests. *Proceedings of the National Academy of Sciences* 113(4):892.
15. Pérez-Méndez N, Jordano P, García C, & Valido A (2016) The signatures of Anthropocene defaunation: cascading effects of the seed dispersal collapse. *Scientific Reports* 6(1):24820.
16. Biesmeijer JC, et al. (2006) Parallel Declines in Pollinators and Insect-Pollinated Plants in Britain and the Netherlands. *Science* 313(5785):351.
17. Aizen MA, et al. (2019) Global agricultural productivity is threatened by increasing pollinator dependence without a parallel increase in crop diversification. *Global Change Biology* 25(10):3516-3527.
18. Smith FP, Gorddard R, House APN, McIntyre S, & Prober SM (2012) Biodiversity and agriculture: Production frontiers as a framework for exploring trade-offs and evaluating policy. Environmental Science & Policy 23:85-94.
19. Chaplin-Kramer R, et al. (2014) Global malnutrition overlaps with pollinator-dependent micronutrient production. Proceedings of the Royal Society B: Biological Sciences 281(1794).
20. Keenan RJ, et al. (2015) Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015. Forest Ecology and Management 352:9-20.
21. Keeler BL, et al. (2019) Social-ecological and technological factors moderate the value of urban nature. Nature Sustainability 2(1):29-38.
22. Janhäll S (2015) Review on urban vegetation and particle air pollution – Deposition and dispersion. Atmospheric Environment 105:130-137.
23. OECD (2016) The Economic Consequences of Outdoor Air Pollution.
24. WHO (2016) Ambient air pollution: a global assessment of exposure and burden of disease (World Health Organization, Geneva) (en).
25. Amann M, Klimont Z, & Wagner F (2013) Regional and Global Emissions of Air Pollutants: Recent Trends and Future Scenarios. Annual Review of Environment and Resources 38(1):31-55.
26. Lelieveld J, Evans JS, Fnais M, Giannadaki D, & Pozzer A (2015) The contribution of outdoor air pollution sources to premature mortality on a global scale. Nature 525:367.
27. Le Quéré C, et al. (2018) Global Carbon Budget 2017. Earth Syst. Sci. Data 10(1):405-448.
28. Song X-P, et al. (2018) Global land change from 1982 to 2016. Nature 560(7720):639-643.
29. Tian H, et al. (2016) The terrestrial biosphere as a net source of greenhouse gases to the atmosphere. Nature 531(7593):225-228.
30. Zhu J-W & Zeng X-D (2016) Influences of the interannual variability of vegetation LAI on surface temperature. Atmospheric and Oceanic Science Letters 9(4):292-297.
31. Morán XAG, López-Urrutia Á, Calvo-Díaz A, & Li WKW (2010) Increasing importance of small phytoplankton in a warmer ocean. Global Change Biology 16(3):1137-1144.
32. Duarte CM (2017) Reviews and syntheses: Hidden forests, the role of vegetated coastal habitats in the ocean carbon budget. Biogeosciences 14(2):301-310.
33. Erb K-H, et al. (2017) Unexpectedly large impact of forest management and grazing on global vegetation biomass. Nature 553:73.
34. WMO (2018) World Meteorological Organization Greenhouse Gas Bulletin: The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2017.
35. IPCC (2014) Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. ed Core Writing Team RKPaLAMe (IPCC, Geneva, Switzerland), p 151.
36. Brander LM, Rehdanz K, Tol RSJ, & Van Beukering PJH (2012) The economic impact of ocean acidification on coral reefs. *Climate Change Economics* 03(01):1250002.
37. Kroeker KJ, Kordas RL, Crim RN, & Singh GG (2010) Meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms. *Ecology Letters* 13(11):1419-1434.
38. Sterling SM, Ducharme A, & Polcher J (2013) The impact of global land-cover change on the terrestrial water cycle. *Nature Climate Change* 3(4):385-390.
39. Trabucco A, Zomer RJ, Bossio DA, van Straaten O, & Verchot LV (2008) Climate change mitigation through afforestation/reforestation: A global analysis of hydrologic impacts with four case studies. *Agriculture, Ecosystems & Environment* 126(1–2):81-97.
40. van Dijk A & Keenan RJ (2007) Planted forests and water in perspective. *Forest Ecology and Management* 251(1-2):1-9.
41. Harden CP (1992) Incorporating roads and footpaths in watershed-scale hydrologic and soil erosion models. *Physical Geography* 13(4):368-385.
42. Milliman JD, Farnsworth KL, Jones PD, Xu KH, & Smith LC (2008) Climatic and anthropogenic factors affecting river discharge to the global ocean, 1951–2000. *Global and Planetary Change* 62(3–4):187-194.
43. Haddeland I, et al. (2014) Global water resources affected by human interventions and climate change. *Proceedings of the National Academy of Sciences* 111(9):3251-3256.
44. Rodell M, et al. (2018) Emerging trends in global freshwater availability. *Nature* 557(7707):651-659.
45. Brauman KA, Richter BD, Postel S, Malsy M, & Flörke M (2016) Water depletion: An improved metric for incorporating seasonal and dry-year water scarcity into water risk assessments. *Elementa* 4.
46. WWAP (United Nations World Water Assessment Programme) (2015) *The United Nations world water development report 2015: water for a sustainable world* (UNESCO, Paris).
47. Mayer PM, Reynolds SK, McCutchen MD, & Canfield TJ (2007) Meta-Analysis of Nitrogen Removal in Riparian Buffers. (Translated from English) *Journal of Environmental Quality* 36(4):1172-1180 (in English).
48. Sweeney BW & Newbold JD (2014) Streamside Forest Buffer Width Needed to Protect Stream Water Quality, Habitat, and Organisms: A Literature Review. *JAWRA Journal of the American Water Resources Association* 50(3):560-584.
49. Seto KC, Güneralp B, & Hutyra LR (2012) Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences* 109(40):16083.
50. UNEP (2016) *A Snapshot of the World’s Water Quality: Towards a global assessment*. (United Nations Environment Programme, Nairobi, Kenya), p 162.
51. GEMS/Water (2018) Progress on Ambient Water Quality – Piloting the monitoring methodology and initial findings for SDG indicator 6.3.2. (UN Environment on behalf of UN-Water,).
52. Pruss A, Kay D, Fewtrell L, & Bartram J (2002) Estimating the Burden of Disease from Water, Sanitation, and Hygiene at a Global Level. *Environmental Health Perspectives* 110(5):537-542.
53. WHO & UNICEF (2017) Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. (World Health Organization (WHO) and the United Nations Children’s Fund (UNICEF), Geneva).
54. IPBES (2018) Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental Science- Policy Platform on Biodiversity and Ecosystem Services. eds Scholes R, Montanarella L, Brainich A, Barger N, Brink Bt, Cantele M, Erasmus B, Fisher J, Gardner T, Holland TG, et al. (IPBES secretariat., Bonn, Germany), p 44.

55. FAO & ITPS (2015) Status of the World’s Soil Resources (SWSR) – Main Report. (Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy).

56. UNCCD (2017) Threats to Soils: Global Trends and Perspectives. in Global Land Outlook Working Paper., eds Pierzynski GM & Brajendra (United Nations Convention to Combat Desertification.).

57. Paustian K, Larson E, Kent J, Marx E, & Swan A (2019) Soil C Sequestration as a Biological Negative Emission Strategy. Frontiers in Climate 1:8.

58. Bakker MM, Govers G, Jones RA, & Rounsevell MDA (2007) The Effect of Soil Erosion on Europe’s Crop Yields. Ecosystems 10(7):1209-1219.

59. Lal R (2004) Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. Science 304(5677):1623.

60. Blanco-Canqui H & Lal R (2008) Soil Erosion and Food Security. Principles of Soil Conservation and Management, eds Blanco-Canqui H & Lal R (Springer Netherlands, Dordrecht), pp 493-512.

61. Renaud FG, Sudmeier-Rieux K, & Estrella M (2013) The role of ecosystems in disaster risk reduction (United Nations University Press).

62. Arkema KK, et al. (2017) Linking social, ecological, and physical science to advance natural and nature-based protection for coastal communities. Annals of the New York Academy of Sciences.

63. Guha-Sapir D, Hoyois P, & Below R (2016) Annual Disaster Statistical Review 2016: The Numbers and Trends. (CRED, Brussels).

64. Van Aalst MK (2006) The impacts of climate change on the risk of natural disasters. Disasters 30(1):5-18.

65. Kahn ME (2005) The Death Toll from Natural Disasters: The Role of Income, Geography, and Institutions. The Review of Economics and Statistics 87(2):271-284.

66. UN-Habitat (2004) The challenge of slums: global report on human settlements 2003. Management of Environmental Quality: An International Journal 15(3):337-338.

67. Jones KE, et al. (2008) Global trends in emerging infectious diseases. Nature 451(7181):990-993.

68. Letourneau DK, Jedlicka JA, Bothwell SG, & Moreno CR (2009) Effects of Natural Enemy Biodiversity on the Suppression of Arthropod Herbivores in Terrestrial Ecosystems. Annual Review of Ecology, Evolution, and Systematics 40(1):573-592.

69. Keesing F, et al. (2010) Impacts of biodiversity on the emergence and transmission of infectious diseases. Nature 468(7324):647-652.

70. Oerke EC (2006) Crop losses to pests. The Journal of Agricultural Science 144(1):31-43.

71. Savary S, et al. (2019) The global burden of pathogens and pests on major food crops. Nature Ecology & Evolution 3(3):430-439.
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72. Whitmee S, et al. (2015) Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation–Lancet Commission on planetary health. The Lancet 386(10007):1973-2028.
73. WHO (2014) Global Brief on Vector-Borne Diseases. (World Health Organization, Geneva).
74. Alexandratos N & Bruinsma J (2012) World agriculture towards 2030/2050: the 2012 revision. in ESA Working paper No. 12-03 (FAO, Rome).
75. FAO (2018) The State of the World’s Forests 2018 - Forest pathways to sustainable development. (Food and Agriculture Organization, Rome).
76. Goldemberg J (2000) World Energy Assessment: Energy and the challenge of sustainability (United Nations Development Programme New York^ eNY NY).
77. Dovie DBK, Witkowski ETF, & Shackleton CM (2004) The Fuelwood Crisis in Southern Africa — Relating Fuelwood Use to Livelihoods in a Rural Village. GeoJournal 60(2):123-133.
78. Rajagopal D (2008) Implications of India’s biofuel policies for food, water and the poor. Water Policy 10(S1):95-106.
79. Schiermeier Q, Tollefson J, Scully T, Witze A, & Morton O (2008) Energy alternatives: Electricity without carbon. Nature News 454(7206):816-823.
80. Cheung WWL, et al. (2009) Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. Global Change Biology 16(1):24-35.
81. Srinivasan UT, Cheung WWL, Watson R, & Sumaila UR (2010) Food security implications of global marine catch losses due to overfishing. Journal of Bioeconomics 12(3):183-200.
82. FAO (2016) The state of world fisheries and aquaculture 2016. (Food and Agriculture Organization of the United Nations, Rome, Italy), pp 1-204.
83. Haddad L, et al. (2016) Food systems and diets: Facing the challenges of the 21st century. (Global Panel on Agriculture and Food Systems for Nutrition, London, UK).
84. FAO (2017) The future of food and agriculture–Trends and challenges. (Food and Agriculture Organisation Rome).
85. Sumaila UR, Marsden AD, Watson R, & Pauly D (2007) A Global Ex-vessel Fish Price Database: Construction and Applications. Journal of Bioeconomics 9(1):39-51.
86. Whitman A, Wickramasinghe A, & Piña L (2015) Global trends in forest ownership, public income and expenditure on forestry and forestry employment. Forest Ecology and Management 352:99-108.
87. FAO (2014) Contribution of the forestry sector to national economies, 1990-2011. in Forest Finance Working Paper (FAO) eng no. 09, eds Lebedys A & Yanshu L (Food and Agriculture Organization of the United Nations, Rome, Italy).
88. Faith DP, Veron S, Pavoine S, & Pellens R (2018) Indicators for the Expected Loss of Phylogenetic Diversity. Phylogenetic Diversity: Applications and Challenges in Biodiversity Science, eds Scherson RA & Faith DP (Springer International Publishing, Cham), pp 73-91.
89. Richerzhagen C (2013) Protecting biological diversity: the effectiveness of access and benefit-sharing regimes (Routledge).
90. Newman DJ, Cragg GM, & Snader KM (2003) Natural Products as Sources of New Drugs over the Period 1981–2002. Journal of Natural Products 66(7):1022-1037.
91. Newman DJ & Cragg GM (2012) Natural Products As Sources of New Drugs over the 30 Years from 1981 to 2010. Journal of Natural Products 75(3):311-335.
92. Horta A, Alves C, Pinteus S, & Pedrosa R (2015) The marine origin of drugs. Phycotoxins, eds Botana LM & Alfonso A, pp 293-316.
93. Alves C, et al. (2018) From Marine Origin to Therapeutics: The Antitumor Potential of Marine Algae-Derived Compounds. (Translated from eng) Front Pharmacol 9:777-777 (in eng).
94. Tanksley SD & McCouch SR (1997) Seed Banks and Molecular Maps: Unlocking Genetic Potential from the Wild. Science 277(5329):1063.
95. WHO (2013) Traditional medicine strategy: 2014-2023 (World Health Organization, Geneva).
96. Romanelli CC, D.; Campbell-Lendrum, D.; Maiero, M.; Karesh, W.B.; Hunter, D.; Golden, C.D. (2015) Connecting global priorities: biodiversity and human health: a state of knowledge review. (WHO/CBD), p 344p.
97. WHO (2016) Global Health Observatory (GHO) data: urban population growth. (World Health Organization, Geneva).
98. Soga M & Gaston KJ (2016) Extinction of experience: the loss of human–nature interactions. Frontiers in Ecology and the Environment 14(2):94-101.
99. Cox DTC, Hudson HL, Shanahan DF, Fuller RA, & Gaston KJ (2017) The rarity of direct experiences of nature in an urban population. Landscape and Urban Planning 160:79-84.
100. Prévot-Julliard A-C, Julliard R, & Clayton S (2014) Historical evidence for nature disconnection in a 70-year time series of Disney animated films. Public Understanding of Science 24(6):672-680.
101. Williams Jr JA, Podeschi C, Palmer N, Schwadel P, & Meyler D (2012) The Human-Environment Dialog in Award-winning Children’s Picture Books*. Sociological Inquiry 82(1):145-159.
102. Richerzhagen C (2011) Effective governance of access and benefit-sharing under the Convention on Biological Diversity. Biodiversity and Conservation 20(10):2243-2261.
103. Seto KC & Shepherd JM (2009) Global urban land-use trends and climate impacts. Current Opinion in Environmental Sustainability 1(1):89-95.
104. Seto KC, Fragkias M, Güneralp B, & Reilly MK (2011) A Meta-Analysis of Global Urban Land Expansion. PLOS ONE 6(8):e23777.
105. Balmford A, et al. (2009) A Global Perspective on Trends in Nature-Based Tourism. PLOS Biology 7(6):e1000144.
106. Balmford A, et al. (2015) Walk on the Wild Side: Estimating the Global Magnitude of Visits to Protected Areas. PLOS Biology 13(2):e1002074.
107. Vining J, Merrick MS, & Price EA (2008) The Distinction between Humans and Nature: Human Perceptions of Connectedness to Nature and Elements of the Natural and Unnatural. Human Ecology Review 15(1):1-11.
108. Claval P (2005) Reading the rural landscapes. Landscape and Urban Planning 70(1):9-19.
109. United Nations Human Settlements Programme (2003) The Challenge of Slums: Global Report on Human Settlements, 2003 (Earthscan Publications).
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110. Bowler DE, Buyung-Ali LM, Knight TM, & Pullin AS (2010) A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health* 10(1):456.

111. Daniel TC, *et al.* (2012) Contributions of cultural services to the ecosystem services agenda. *Proceedings of the National Academy of Sciences* 109(23):8812.

112. Stephenson J (2008) The Cultural Values Model: An integrated approach to values in landscapes. *Landscape and Urban Planning* 84(2):127-139.

113. Plieninger T, *et al.* (2015) Exploring ecosystem-change and society through a landscape lens: recent progress in European landscape research. *Ecology and Society* 20(2).

114. Plieninger T, *et al.* (2015) The role of cultural ecosystem services in landscape management and planning. *Current Opinion in Environmental Sustainability* 14:28-33.

115. Milcu AI, Hanspach J, Abson D, & Fischer J (2013) Cultural Ecosystem Services: A Literature Review and Prospects for Future Research. *Ecology and Society* 18(3).

116. Wood SA, Guerry AD, Silver JM, & Lacayo M (2013) Using social media to quantify nature-based tourism and recreation. *Scientific Reports* 3(1):2976.

117. Kaltenborn BP (1998) Effects of sense of place on responses to environmental impacts: A study among residents in Svalbard in the Norwegian high Arctic. *Applied Geography* 18(2):169-189.

118. Pascua Pa, McMillen H, Ticktin T, Vaughan M, & Winter KB (2017) Beyond services: A process and framework to incorporate cultural, genealogical, place-based, and indigenous relationships in ecosystem service assessments. *Ecosystem Services* 26:465-475.

119. King K & Church A (2013) ‘We don't enjoy nature like that’: Youth identity and lifestyle in the countryside. *Journal of Rural Studies* 31:67-76.

120. Pimm SL, *et al.* (2014) The biodiversity of species and their rates of extinction, distribution, and protection. *Science* 344(6187):1246752.

121. Ceballos G, Ehrlich PR, & Dirzo R (2017) Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. *Proceedings of the National Academy of Sciences*. 

