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72191 Global Environmental Studies

Assignment 1

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Task 1: Definition

1 Ecosystem

An ecosystem is an ecological system which is described by a habitat, the organisms which live in it and the interactions between the two (Nebel & Wright, 1993). Dependent on geological features, a given ecosystem may encompass different environments, micro-climates, and habitats, thus enabling complementary niches that support greater biodiversity, i.e. a larger variety of interdependent species. In some ecosystems disturbances are common that lead to a successive change in the composition of the system, which over time favours a different community of species (cf. Chapin III, Matson, & Vitousek, 2011, p. 351). Next to natural ecosystems such as forests, lakes, or even the bodies of animals, there are also artificial systems that either emulate the mutual dependencies of natural ecosystems (e.g. aquaria, garden ponds, sustainable gardens) or are subject to ecosystem processes (e.g. transformed farmland).

Groups of organisms constitute functional units that provide ecosystem services as a result of their life processes, such as the production of organic material from sunlight (producers), nutrient cycling (e.g. grazers), recycling of waste (decomposers), and population control (predatory consumers) (Nebel & Wright, 1993). Some species, like some aquatic insects, assume different functional feeding roles throughout their life histories (cited in Mihuc & Toetz, 1994) or may move from one feeding group to another (MacNeil, Dick, & Elwood, 1997).

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Task 2: On the interdependence of humans and the environment

1 Introduction

All life on Earth depends on functional ecosystems and the services they provide. The natural processes of healthy ecosystems ensure that the Earth's finite materials required for life processes of all life forms are not lost as waste but instead are perpetually fed back into the system. Human activities—including fairly recent industrial processes as well as more traditional agricultural practises—disturb these cycles by overloading them or by modifying their rate. Unchecked population growth and the increase of the ecological footprint in wealthier nations in recent decades further exacerbate the impact on ecosystems and their services. Unbalancing natural processes has serious implications for humans and other members of the community of life alike. In the following paragraphs I will highlight a few of the ways by which ecosystems sustain life on Earth and investigate how human activities have impaired their processes.

2 How ecosystems sustain life

With respect to nutrients, the Earth is a closed system. Extraterrestrial inputs of chemical elements required for life on Earth are rare and too small to replenish stocks at the rate that is required for the growth of populations. As a result, life can only be sustained as long as elements that were bound as biomass are released and made available for reuse. Such services are provided by healthy ecosystems, enabling them to maintain equilibrium and prevent the loss of nutrients over time. Ecosystem processes result from the interactions of populations of plants, animals, and microbes with the abiotic geological features and properties of their environment. The species inhabiting the different habitats belonging to an ecosystem are linked through a food web. All organisms fulfill at least one of these functions: producers, consumers, and decomposers (Nebel & Wright, 1993, p. 23). Primary producers—vegetation capable of photosynthesis—convert light, atmospheric gases, and nutrients into organic molecules incorporated in their tissue. Primary consumers feed on vegetation and are in turn fed upon by carnivorous consumers on higher trophic levels. Detritivores and other decomposers break down dead organic matter into their elementry form. In the process of respiration, all organisms convert complex, energy-rich molecules into simpler molecules and heat (Nebel & Wright, 1993, p. 29).

In addition to cycling through the biosphere, chemical elements also interact with the abiotic environment, i.e. the atmosphere, lithosphere, and hydrosphere, where they are deposited in sediments or stored in reservoires, and eventually assimilated by the biosphere again (Nebel & Wright, 1993). Likewise, biota have an influence both on the composition of their chemical environment and geophysical processes (Gadd, 2010), such as the rate of evaporation and transpiration of water, or the climate by changing the characteristics of the land surface (Steffen, 2005, 24 ff). According to Hooper et al. (2005), there is consensus among scientists that ecosystem properties depend largely on biodiversity. The functional characteristics of species and the size and distribution of populations determine the flow of energy and materials through ecosystems. Biodiversity also provides for functional redundancy in ecosystems, thereby increasing their resilience in the case of disturbances. These interactions of the biosphere with the non-living environment lie at the root of global biogeochemical cycles, such as the global carbon and nitrogen cycles. As these cycles connect different ecosystems through their effect on shared resources, the biosphere can be considered a global ecosystem governed by global cycles (Nebel & Wright, 1993, p. 20).

Even from these grossly simplified descriptions of ecosystem processes two principles of sustainability that govern life on earth arise: *(i)* energy from the sun is captured in the form of complex organic molecules by producers and as such flows through the biosphere; and *(ii)* elementary nutrients are fixed in the tissue of organisms and later freed for reuse as decomposers process wastes.

3 Human impact

The impact human activities have had on biodiversity and natural ecosystem functions is well-documented. Harmful human activities generally fall into one of three categories (see figure 1): *(i)* land transformation and degradation; *(ii)* activities affecting global biogeochemistry by overloading nutrient cycles or altering their rate; and *(iii)* activities that result in biotic additions (species invasions) and losses (hunting and fishing).

Pre-industrial human impacts on the environment were mostly a result of land-use and land-cover changes. Data derived from the analysis of sediments and pollen is evidence for significant anthropogenic changes in vegetation cover as early as 5300 years before present (Vorren, Mørkved, & Bortenschlager, 1993). Some apparently natural ecosystems may actually be the result of human interference and land management (Oldfield & Dearing, 2003). After mapping the extent of anthropogenic land modification from 1700 to 2000 Ellis, Klein Goldewijk, Siebert, Lightman, and Ramankutty (2010) concluded that more than half of all biomes are now predominantly anthropogenic with only about 25 percent remaining in a wild state. When matching areas of degrading land with global land cover data, crop-land and forests make up the bulk of degrading areas (Z. G. Bai, Dent, Olsson, & Schaepman, 2008). Land transformation is a primary driver of biodiversity loss, as it affects biota directly by destroying habitats and indirectly by fragmenting ecosystems (Vitousek, Mooney, Lubchenco, & Melillo, 1997). Much of the land that has not been transformed is likely affected by fragmentation (Vitousek, Mooney, et al., 1997). Fragmented ecosystems suffer from increased edge effects and a lack of connectivity, both of which are likely to exacerbate threats to biodiversity (Fischer & Lindenmayer, 2007). A loss of biodiversity in turn degrades ecosystem

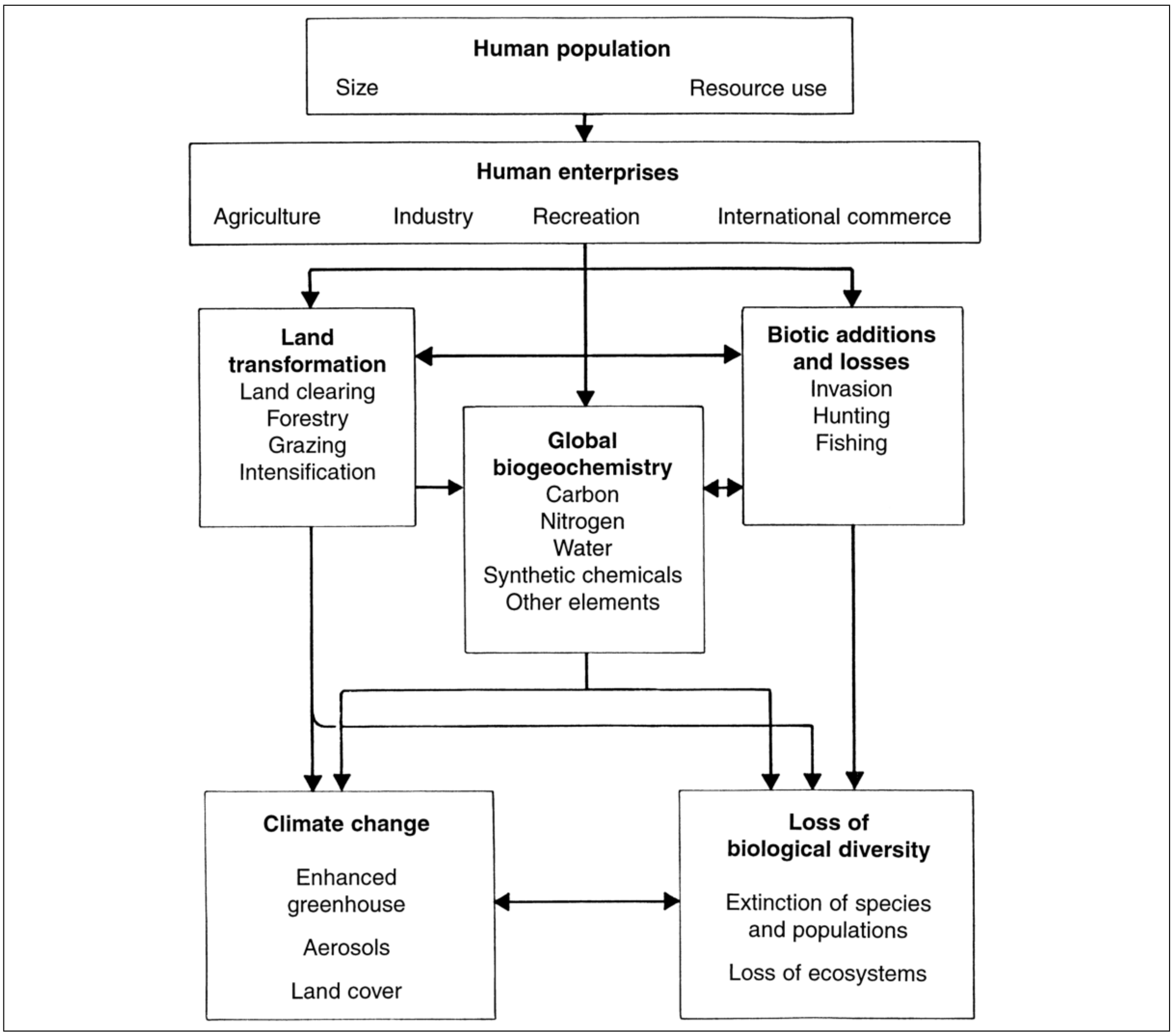

Figure 1: Illustrating the direct and indirect impact of human activities on global ecosystems. Reproduced from Vitousek, Mooney, Lubchenco, and Melillo (1997).

functions as primary productivity, CO_2 fixing, and retention of nutrients and water are reduced (Naeem, Thompson, Lawler, Lawton, & Woodfin, 1994).

The effects of land use and transformation go beyond the loss of biodiversity. According to Houghton (2010), land use and land-use changes from 1850 to 2000 are estimated to have contributed 28 to 40 percent to total anthropogenic CO_2 emissions. Vitousek, Aber, et al. (1997) attribute the mobilisation of more than 30 teragrams of nitrogen per year—more than a quarter of the natural terrestrial fixation—to land clearing and conversion, and the drainage of wetlands. These observations warrant a closer look at the impact of human activities on biogeochemical cycles. Representative for the many biogeochemical cycles that have been affected by human activities I will concentrate on the global nitrogen cycle.

Despite making up the majority of Earth's atmosphere, nitrogen is a limiting factor for the growth of organisms, as it must be fixed—i.e. converted to reactive forms available to most organisms—before it can be assimilated by cells to synthesize amino and nucleic acids (McNeill & Unkovich, 2007). Biological fixation on land (110 teragrams per year) and in the ocean (140 teragrams) is the primary natural source of reactive nitrogen. According to Gruber and Galloway (2008), the yearly anthropogenic fixation of nitrogen in the 1990s through industrial production of fertilizers, fossil fuel combustion, and growing of nitrogen-fixing crops was in excess of 160 teragrams. The increase in fixation and mobilisation of nitrogen has effects on the atmosphere, as well as terrestrial and aquatic ecosystems.

The effect on the atmosphere is mostly due to an increase of emissions of nitrogen gases caused by microbial activity in fertilised soils (Vitousek, Aber, et al., 1997). Nitrous oxide is not only a greenhouse gas contributing to global warming but, according to research by Ravishankara, Daniel, and Portmann (2009), is the most important ozone-depleting substance today. While about 40 percent of global emissions of nitrous oxide are human-caused, human activities such as burning of biomass and fossil fuel contribute more than 80 percent to the global emissions of nitric oxide—the main component of acid rain (Vitousek, Aber, et al., 1997).

Although increased plant productivity due to the enrichment of ecosystems with nitrogen can serve as a CO_2 sink (Gruber & Galloway, 2008), the harmful effects weigh heavier. Nitrogen deposition favours fast-growing nitrogen-demanding grasses whose dominance suppresses other plants, thus leading to large biodiversity losses in mature communities (Y. Bai et al., 2010). These effects have been confirmed in grass- and heathlands all over the world (Vitousek, Aber, et al., 1997; Y. Bai et al., 2010). Anthropogenic inputs of nitrogen are not restricted to the land, as nitrogen enters aquatic ecosystems through sewage discharge and agricultural run-off. There it contributes to nutrient depletion through acidification (Horswill, O'Sullivan, Phoenix, Lee, & Leake, 2008), and eutrophication, both of which result in the loss of biodiversity (Vitousek, Aber, et al., 1997). In addition to humanity's impact on the nitrogen cycle, human activities largely shape the cycles of carbon, water, sulphur, phosphorus, and other chemicals (Vitousek, Mooney, et al., 1997).

Species introductions and the effect of hunting or fishing belong to the third category of human impacts on ecosystems. Since humans populated New Zealand about 1000 years ago, thousands of plant and animals species have been introduced for various reasons: some species like the pacific rat were accidental introductions, other species were introduced by European colonists for sport or out of nostalgic sentiments (Veitch & Clout, 2001). The introduction of rats to New Zealand has lead to the dramatic decline of many native species, including giant snails, skinks, and unique plants such as *Dactylanthus taylorii*, and has been implicated in the extinction of numerous species of endemic birds (Towns & Broome, 2003).

The impact of human activities is generally accepted to be a function of population, affluence measured in GDP per capita, and technology. Recent efforts to quantify the actual proportion of these factors suggest that both population size and affluence are the principal drivers of the human ecological footprint (Rosa, York, & Dietz, 2004; Dietz, Rosa, & York, 2007). This makes intuitive sense when, for example, considering nitrogen mobilisation, deposition and fixation as it relates to food production which in turn is a function of population size (Vitousek, Mooney, et al., 1997).

4 Conclusion

An overwhelming body of evidence gathered throughout the last century has shown that human activities—even seemingly innocuous ones as the application of fertilizers—have had and still have destructive effects on ecosystems worldwide. By altering the rate of natural cycles, overloading them with pollutants, and by displacing nutrients from their original deposits, human activities have lead to the loss of ecosystem functions, lowered the quality of ecosystem services, and dramatically accelerated the rate of species extinctions. As human populations grow unchecked, the demand for food and arable land increases, and with it ecosystem stresses. Despite this negative impact, research indicates that humans depend on ecosystem goods and services now even more than in past decades (Guo, Zhang, & Li, 2010). Although the human ecological footprint in almost all countries is projected to increase by 2015 (Dietz et al., 2007) and continued degradation is likely to occur, there is some evidence that global ecosystems could recover from degraded states at a faster rate than previously assumed, giving hope that it may not yet be too late for sustainable ecosystem management (Jones & Schmitz, 2009).

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