Understanding the link between biodiversity loss and technology life cycles

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The efforts to increase society's environmental sustainability focus on four major challenges that need to be addressed: climate change, natural resource dissipation, environmental pollution, and biodiversity loss.

Impacts on climate change are relatively straightforward to characterize through CO_2 emissions. We even have ways to convert emissions of other greenhouse gases like methane and laughing gas, into CO_2 equivalents, so we can calculate the overall impact on the climate in tons of CO_2.

However, a similar approach does not apply to biodiversity loss, despite broad consensus among researchers that the biodiversity crisis is a significant and global problem. Professor Peter Fantke, DTU Sustain, and his research group aim to find quantifiable ways to measure biodiversity loss for use in life cycle assessment (LCA).

"Biodiversity loss is incredibly complex. It's not just about counting the number of species. Equally important is knowing that genetic variation is considered, as well as the interaction between species and their respective functions within an ecosystem—for example, a lake or a forest. This complexity is difficult to measure and quantify," explains Peter Fantke.

Biodiversity loss has complex causes

Quantifying biodiversity loss requires understanding the contribution of various stressors via their different pathways and effect mechanisms, such as chemical and plastic emissions, models to translate laboratory and field test data on individual organisms to loss on species, genetic and functional diversity, and the combination of extensive datasets.

Such datasets include information on stressors (e.g., various chemical properties), ecotoxicological tests on different species, and monitoring data of environments on land or in water (i.e., terrestrial and aquatic environments) on stressor concentrations as well as counts of species

(species richness) and individuals within each species (species abundance).

"The release of chemicals and plastics into the environment can have a negative effect on biodiversity. Yet, to understand this link, there are many other factors that need to be considered. This includes, for example, water and soil chemistry and temperature, background metal concentrations, inputs of nutrients and organic matter, and the season of monitoring data collection, with typically fewer species in winter and more in summer.

Due to the complex interaction of these factors, we are not yet fully able to map out the boundaries of each individual ecosystem with respect to its sensitivity to chemical and plastic emissions from our products and technology life cycles," says Peter Fantke.

Ecosystems have limited capacity for human-induced impacts

The research group has developed first concepts for linking impacts from chemical emissions on aquatic and terrestrial species to loss on species, genetic and functional diversity loss, and to define local-to-global capacity limits of ecosystems for coping with such impacts. The next steps are to combine methods and data from environmental chemistry, ecology and Earth systems science to quantify each specific aspect and to ultimately link chemical pollution to damage on ecosystem services, i.e., the tasks that ecosystems perform for the benefit of humans, for example producing oxygen via photosynthesis.

"The goal of our work is to integrate the quantification of biodiversity damage from chemicals and other stressors into life cycle assessment to evaluate and minimize such environmental impacts when developing new products or technologies. LCA already has measurable figures for the damage on other areas that we aim to protect, such as human health, but we still need to develop relevant metrics for addressing damage on biodiversity," says Peter Fantke.

It is not an easy task, as each ecosystem is unique and must be assessed as such. It is not possible simply to aggregate the pollution across different ecosystems, as they all have their own capacity limits for pollution inputs, depending on their individual environmental conditions, species composition and background loadings.

"As a starting point, we focus on data-rich freshwater ecosystems, for which we want to have quantifiable biodiversity loss measures. The next steps will be to determine the fraction of ecosystems globally that are affected by chemical pollution above their respective capacities, and to link biodiversity loss to damage on ecosystem services. This includes, for example, pollination of flowering plants including food crops by various insect species or microorganisms processing organic waste to benefit the nutrients in the soil where our food grows," says Peter Fantke.

The ultimate goal is to be able to quantify what biodiversity can withstand in terms of human-induced impacts from local farm scale to the largest scale—the Earth's biosphere, and how to attribute both impacts and impact capacities to individual product and technology life cycles, to support a more sustainable technology development worldwide.

Natural to work at a technical university

It may seem a bit off to work at a technical university on quantifying the complex link between chemical or plastic pollution and biodiversity loss. But for Peter Fantke, it is a natural consequence of what his work is intended for.

"If we want to reduce impacts on biodiversity, we need to understand how emissions along product and technology life cycles affect our ecosystems. This can be done using life cycle assessment, which takes a whole life cycle perspective. Today, engineers can design new materials, products, and technologies for a specific purpose. We need to ensure that technological development is not harmful to the environment, and therefore, quantifying the link between technology life cycles and related impacts on humans, natural resources and biodiversity are crucial. To protect ecosystems, we need to understand them first," explains Peter Fantke.

The first results of the group's work have been published in the journals *Science of The Total Environment*, *Environmental Science & Technology*, and *Environment International*. The hope is that within the next three to five years, it will be possible to contribute a range of quantifiable measures for understanding and minimizing negative impacts of products and technologies on biodiversity from local to global scale.

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