

## Environmental Science

### Query paper:

**Title:** Biodiversity loss and its impact on humanity

**Abstract:** The most unique feature of Earth is the existence of life, and the most extraordinary feature of life is its diversity. Approximately 9 million types of plants, animals, protists and fungi inhabit the Earth. So, too, do 7 billion people. Two decades ago, at the first Earth Summit, the vast majority of the world's nations declared that human actions were dismantling the Earth's ecosystems, eliminating genes, species and biological traits at an alarming rate. This observation led to the question of how such loss of biological diversity will alter the functioning of ecosystems and their ability to provide society with the goods and services needed to prosper.

### Candidate papers:

1. **Title:** The functional role of producer diversity in ecosystems

**Abstract:** Over the past several decades, a rapidly expanding field of research known as biodiversity and ecosystem functioning has begun to quantify how the world's biological diversity can, as an independent variable, control ecological processes that are both essential for, and fundamental to, the functioning of ecosystems. Research in this area has often been justified on grounds that (1) loss of biological diversity ranks among the most pronounced changes to the global environment and that (2) reductions in diversity, and corresponding changes in species composition, could alter important services that ecosystems provide to humanity (e.g., food production, pest/disease control, water purification). Here we review over two decades of experiments that have examined how species richness of primary producers influences the suite of ecological processes that are controlled by plants and algae in terrestrial, marine, and freshwater ecosystems.

2. **Title:** Plant species richness and ecosystem multifunctionality in global drylands

**Abstract:** Experiments suggest that biodiversity enhances the ability of ecosystems to maintain multiple functions, such as carbon storage, productivity, and the buildup of nutrient pools (multifunctionality). However, the relationship between biodiversity and multifunctionality has never been assessed globally in natural ecosystems. We report here on a global empirical study relating plant species richness and abiotic factors to multifunctionality in drylands, which collectively cover 41% of Earth's land surface and support over 38% of the human population. Multifunctionality was positively and significantly related to species richness. The best-fitting models accounted for over 55% of the variation in multifunctionality and always included species richness as a predictor variable. Our results suggest that the preservation of plant biodiversity is crucial to buffer negative effects of climate change and desertification in drylands.

3. **Title:** Partitioning selection and complementarity in biodiversity experiments

**Abstract:** The impact of biodiversity loss on the functioning of ecosystems and their ability to provide ecological services has become a central issue in ecology. Several experiments have provided evidence that reduced species diversity may impair ecosystem processes such as plant biomass production. The interpretation of these experiments, however, has been controversial because two types of mechanism may operate in combination. In the 'selection effect',

dominance by species with particular traits affects ecosystem processes. In the ‘complementarity effect’, resource partitioning or positive interactions lead to increased total resource use. Here we present a new approach to separate the two effects on the basis of an additive partitioning analogous to the Price equation in evolutionary genetics. Applying this method to data from the pan-European BIODEPTH experiment<sup>4</sup> reveals that the selection effect is zero on average and varies from negative to positive in different localities, depending on whether species with lower- or higher-than-average biomass dominate communities. In contrast, the complementarity effect is positive overall, supporting the hypothesis that plant diversity influences primary production in European grasslands through niche differentiation or facilitation.

4. **Title:** Plant diversity and productivity experiments in European grasslands

**Abstract:** At eight European field sites, the impact of loss of plant diversity on primary productivity was simulated by synthesizing grassland communities with different numbers of plant species. Results differed in detail at each location, but there was an overall log-linear reduction of average aboveground biomass with loss of species. For a given number of species, communities with fewer functional groups were less productive. These diversity effects occurred along with differences associated with species composition and geographic location. Niche complementarity and positive species interactions appear to play a role in generating diversity-productivity relationships within sites in addition to sampling from the species pool.

5. **Title:** Biodiversity effects increase linearly with biotope space

**Abstract:** Understanding the influence of environmental variation on the relationship between biodiversity and ecosystem functioning is of theoretical and practical interest. We predicted that the strength of this relationship should increase with available biotope space (the physical space associated with a species’ niche) due to increased niche complementarity between species. In this study, biotope space specifically refers to soil volume which is associated with the niche dimension of nutrient acquisition. We tested our prediction by growing plant communities on a gradient of increasing soil depth and volume, offering increased rooting space to species. Our results provide support for a linear increase of the magnitude of positive biodiversity effects on above- and belowground community biomass with increasing biotope space. This increase was caused by complementarity effects between species. Soil erosion may thus reduce intercropping benefits.

6. **Title:** Species diversity: from global decreases to local increases

**Abstract:** Current patterns of global change can strongly affect biodiversity at global, regional and local scales. At global scales, habitat destruction and the introduction of exotic species are contributing to declines in species diversity. At regional and local scales, evidence for declines in diversity is mixed, and recent work suggests that diversity might commonly be increasing. In spite of these trends, considerable research continues to consider explicitly the effects of declines in diversity on processes that operate at regional and local scales (such as ecosystem functioning), without explicitly considering the converse set of questions, namely the effects of increases in diversity. Here, we examine evidence that indicates how species diversity is changing across spatial scales and argue that global decreases in diversity are commonly contrasted by increases in diversity at regional and local scales.

**Exemplary analysis:**

1. **Relevance:** The query paper discusses the alarming rate of biodiversity loss and its potential impact on ecosystems and human prosperity. Citing this paper supports the argument that biodiversity is crucial for maintaining ecosystem services such as food production, pest control, and water purification.

**Reason for Citation:** This paper is likely cited because it provides foundational knowledge on how biodiversity, specifically the diversity of primary producers (plants and algae), influences ecological processes essential for ecosystem functioning.

2. **Relevance:** This is particularly relevant given that drylands cover a significant portion of the Earth's land surface and support a large human population. The findings underscore the importance of preserving plant biodiversity to mitigate the effects of climate change and desertification, aligning with the query paper's theme of biodiversity's importance to humanity.

**Reason for Citation:** The citation of this paper supports the query paper's concern about biodiversity loss by providing empirical evidence of the positive relationship between plant species richness and ecosystem multifunctionality in drylands.

3. **Relevance:** Understanding these mechanisms is crucial for interpreting how biodiversity loss might alter ecosystem processes. The query paper leverages this information to build a case for the nuanced ways in which reductions in biodiversity can impair ecosystems' ability to provide services to humanity.

**Reason for Citation:** This paper is cited to introduce the mechanisms through which biodiversity affects ecosystem functioning, namely the selection effect and the complementarity effect.

4. **Relevance:** It reinforces the query paper's argument by showing that loss of plant diversity leads to reduced ecosystem productivity, which can have direct and indirect impacts on human well-being. The emphasis on functional groups and geographic variability adds depth to the discussion of biodiversity's role in ecosystem functioning.

**Reason for Citation:** The citation of this paper provides concrete experimental evidence of the relationship between plant diversity and primary productivity in grasslands across Europe.

5. **Relevance:** It supports the query paper's narrative by demonstrating that more available space (e.g., soil depth and volume) enhances biodiversity's positive effects on ecosystem biomass through niche complementarity. This finding is relevant for understanding how changes in land use and soil erosion might affect biodiversity's contributions to ecosystem services.

**Reason for Citation:** This paper is likely cited for its exploration of how environmental variation (specifically, biotope space) influences the biodiversity-ecosystem functioning relationship.

6. **Relevance:** This nuanced view is important for the query paper's discussion of biodiversity loss and its impacts, as it highlights the complexity of biodiversity changes and their implications for ecosystems and human societies across different scales.

**Reason for Citation:** This paper is cited to provide a broader perspective on biodiversity trends, acknowledging that while global biodiversity is decreasing, local and regional diversity might be increasing.

**Exemplary ranking:** Ranked order: paper 3, paper 2, paper 1, paper 4, paper 5, paper 6

1. **Explanation:** This paper provides foundational knowledge on the role of primary producers in ecosystems. Understanding this role is key to assessing the broader impacts of biodiversity loss, as primary producers are at the base of the trophic pyramid and their diversity is critical for the overall functioning of ecosystems.
2. **Explanation:** Given the global extent of drylands and their vulnerability to biodiversity loss, this paper's empirical evidence on the relationship between plant species richness and ecosystem functionality is vital. It directly supports the exploration of biodiversity's importance for sustaining ecosystem services in areas that are both ecologically and socioeconomically significant.
3. **Explanation:** This paper is crucial for understanding the fundamental mechanisms (selection and complementarity effects) through which biodiversity impacts ecosystem functioning. For a follow-up study, a deep dive into these mechanisms would be essential to explore how biodiversity loss might alter these processes and the subsequent effects on ecosystem services.
4. **Explanation:** This paper offers concrete experimental evidence on how plant diversity affects ecosystem productivity. For a follow-up study, such evidence can be pivotal in arguing for the conservation of plant diversity as a means to maintain or enhance ecosystem services that are directly linked to human well-being.
5. **Explanation:** The exploration of how environmental variation affects the biodiversity-ecosystem functioning relationship is crucial for understanding how changes in land use and habitat fragmentation might impact biodiversity's contributions to ecosystem services. This paper's findings can inform discussions on land management practices that support biodiversity conservation.
6. **Explanation:** While providing a broader perspective on biodiversity trends, this paper is ranked last because its focus on the complexity of biodiversity changes across scales might be more supplementary to a focused investigation on the impacts of biodiversity loss. However, it remains relevant for discussing the varied implications of biodiversity trends for ecosystems and human societies.