

Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

- | | |
|-------------------------------------|--|
| n/a | Confirmed |
| ☐ | ☒ The exact sample size (<i>n</i>) for each experimental group/condition, given as a discrete number and unit of measurement |
| ☐ | ☒ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly |
| ☐ | ☒ The statistical test(s) used AND whether they are one- or two-sided
<i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i> |
| ☐ | ☒ A description of all covariates tested |
| ☐ | ☒ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons |
| ☐ | ☒ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals) |
| ☐ | ☒ For null hypothesis testing, the test statistic (e.g. <i>F</i> , <i>t</i> , <i>r</i>) with confidence intervals, effect sizes, degrees of freedom and <i>P</i> value noted
<i>Give P values as exact values whenever suitable.</i> |
| ☒ | ☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings |
| ☐ | ☒ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes |
| ☐ | ☒ Estimates of effect sizes (e.g. Cohen's <i>d</i> , Pearson's <i>r</i>), indicating how they were calculated |

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

- | | |
|-----------------|--|
| Data collection | Plot Digitizer version 2.0 (Department of Physics at the University of South Alabama, Mobile, AL, USA) |
| Data analysis | The data analysis was conducted in R (v. 4.3.2), using packages including 'taxize', 'V.PhyloMaker', 'FD', 'metafor', 'lme4', 'lmerTest', 'multcomp', 'ggplot2' and 'cowplot'. The R scripts needed to reproduce the results are archived in Figshare (10.6084/m9.figshare.27316062). |

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

Data

Policy information about [availability of data](#)

- All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:
- Accession codes, unique identifiers, or web links for publicly available datasets
 - A description of any restrictions on data availability
 - For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

The source data underlying Figs. 2–5, Extended Data Figures and Supplementary Tables are archived in Figshare (10.6084/m9.figshare.27316062). The plant trait data are available from the TRY Plant Trait Database ([www.try-db.org/](#)).

Research involving human participants, their data, or biological material

Policy information about studies with [human participants or human data](#). See also policy information about [sex, gender \(identity/presentation\), and sexual orientation](#) and [race, ethnicity and racism](#).

Reporting on sex and gender N/A

Reporting on race, ethnicity, or other socially relevant groupings N/A

Population characteristics N/A

Recruitment N/A

Ethics oversight N/A

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description

We conducted a global meta-analysis based on observations from 452 studies with paired observations of plant mixtures and corresponding monocultures, to evaluate net biodiversity effects and the components, i.e., complementarity effects and selection effects across global biodiversity experiments. We used mixed-effect meta-regression models to investigate the important drivers for the complementarity effects and selection effects among potential factors, including species richness, phylogenetic diversity, functional diversity, presence of contrasting N-fixing plants, species biomass inequality, community-weighted-mean of functional traits, stand age, ecosystem types, and climatic factors.

Research sample

In total, we obtained 4680 paired observations of biomass of all species in plant mixtures and corresponding monocultures from 452 studies across different ecosystem types, including grasslands (60 studies), forests (112 studies), wetlands (3 studies), croplands (42 studies), containers (213 studies), and aquatic systems (25 studies) (Extended Data Fig. 1; Supplementary Table 8); and plant types, including woody plants, herbaceous plants, and mixtures with both woody and herbaceous plants. We obtained plant biomass, species identity, species richness, species proportion, stand age, geographical location (latitude and longitude), ecosystem type, plant type and climates for each observation (Extended Data Fig. 9; Supplementary Table 9). The biomass of each species in mixtures and monocultures was recorded or calculated as the mean value across replicates. We included several studies that reported annual biomass productivity (or growth rate) of trees, which is strongly and positively related to their biomass at a young age. The biomass was estimated as the total or aboveground biomass or productivity, the carbon stock of the trees, the volume of wood or the basal area in the original studies. The biomass measured for individuals was converted to area-based with the density of the species in individual plots. The designed proportions of species in the plant mixtures were recorded as the proportions of seedlings or seeds. The plant mixtures with both non-N-fixing plants and N-fixing plants, including Fabaceae species and N-fixing actinorhizal plants, were marked as the mixing of N-fixing and non-N-fixing species. Inequality was indicated as the coefficient of variation (CV) of species biomass of their corresponding monocultures. Stand age referred to the years between the establishment of the stand or the beginning of the experiment and the measurement of biomass. For field experiments, the mean annual temperature (MAT) was recorded from the literature if available; otherwise, it was derived from the WorldClim version 2.1 dataset. To indicate the climatic water condition of each experimental location, we derived the aridity index, i.e., the ratio of the mean annual precipitation to mean annual potential evapotranspiration, from the WorldClim dataset.

Sampling strategy

To ensure the quality of the dataset, we established several criteria to determine whether each study can be included in our dataset: (a) The effects of plant diversity or mixture are isolated from other factors or treatments. (b) The planting densities of plant mixture and monoculture were constant following the substitutive design. For example, if a species was planted as 120 ind m⁻² in its monoculture, it should be planted as 40 ind m⁻² in a 1:1:1 three-species mixture. (c) No barrier between plant individuals was set up in plant mixtures or monocultures. (d) Biomass of each species in mixtures and corresponding monocultures are available in text, tables or figures. (e) The data were recorded only once if they were repeatedly reported in multiple papers. To investigate as various species combinations as possible, we included not only studies focusing on BEFs but also studies examining interspecific competition or interactions, even between species of the same genus, as long as their experimental designs fell in our data selection criteria as above.

Data collection

We followed the guidelines of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) to build up the dataset for net biodiversity effect, complementarity effect, and selection effect in manipulated plant mixture or diversity experiments (Extended Data Fig. 1a; Supplementary Table 5). Specifically, we first searched for all peer-reviewed journal articles and theses for

related studies using the Web of Science (Core Collection; <http://www.webofknowledge.com>), Google Scholar (<http://scholar.google.com>), and the China National Knowledge Infrastructure (CNKI; <https://www.cnki.net>) until December 1, 2023. We employed different combinations of keywords, including (species diversity OR species richness OR plant mixture OR plant diversity OR tree mixture OR mixed plantation OR pure and mixed) AND (biomass OR growth OR productivity OR basal area OR overyielding OR complementarity effect OR selection effect OR sampling effect OR competition). Additionally, we investigated all studies citing de Wit (1960), whose replacement series design is widely used in plant mixture or diversity manipulation experiments. We also examined the datasets of previous syntheses and meta-analyses with related topics as supplementary data sources (Supplementary Table 6). Two of the three authors independently followed the guidelines of PRISMA, searched the different combinations of keywords, and examined each related literature against the data selection criteria. 37 studies that were only selected by one of the authors were more carefully and interactively examined by the two authors to determine their inclusion following data selection criteria. All the unselected literature was listed with the reasons for exclusion (Extended Data Table 7).

Timing and spatial scale	The publications included in the dataset ranged from 1962 to 2023. The observations were distributed across the globe.
Data exclusions	Observations were excluded if not following our established criteria: (a) The effects of plant diversity or mixture are isolated from other factors or treatments. (b) The planting densities of plant mixture and monoculture were constant following the substitutive design. For example, if a species was planted as 120 ind m ⁻² in its monoculture, it should be planted as 40 ind m ⁻² in a 1:1:1 three-species mixture. (c) No barrier was established between plant individuals in mixtures or monocultures. (d) Biomass of each species in mixtures and corresponding monocultures are available in text, tables or figures. (e) The data were recorded only once if they were repeatedly reported in multiple papers. As outliers are present in diversity manipulation experiments and affect the validity of the conclusions from a meta-analysis, any ΔY , CE and SE with a standardized residual value exceeding the absolute value of three were removed as outliers.
Reproducibility	All attempts to repeat the analysis and results were successful.
Randomization	N/A
Blinding	Blinding was not possible in the data analysis.
Did the study involve field work?	☐ Yes ☒ No

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Plants

Seed stocks	N/A
Novel plant genotypes	N/A
Authentication	N/A