

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 |
|-------------------------------------|--|
| <input type="checkbox"/> | <input checked="" type="checkbox"/> The exact sample size (n) for each experimental group/condition, given as a discrete number and unit of measurement |
| <input type="checkbox"/> | <input checked="" type="checkbox"/> A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly |
| <input type="checkbox"/> | <input checked="" type="checkbox"/> 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> |
| <input type="checkbox"/> | <input checked="" type="checkbox"/> A description of all covariates tested |
| <input type="checkbox"/> | <input checked="" type="checkbox"/> A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons |
| <input type="checkbox"/> | <input checked="" type="checkbox"/> 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) |
| <input type="checkbox"/> | <input checked="" type="checkbox"/> For null hypothesis testing, the test statistic (e.g. F , t , r) with confidence intervals, effect sizes, degrees of freedom and P value noted
<i>Give P values as exact values whenever suitable.</i> |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes |
| <input type="checkbox"/> | <input checked="" type="checkbox"/> Estimates of effect sizes (e.g. Cohen's d , Pearson's r), 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 From Web of Science (<http://webofscience.com>), Google Scholar (<https://scholar.google.com>) and the National Knowledge Infrastructure Database (<http://cnki.net>) using GetData.

Data analysis Data analysis was performed using the 'Taxonstand', 'V.PhylMaker2', 'phytools', 'stats', 'smatr', 'randomForest' and 'metafor' packages in R (3.6.1).

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 raw datasets generated during this study will be deposited in the Figshare repository and assigned a permanent DOI upon article acceptance. Processed data

supporting the key findings are included in the Supplementary Information. Raw datasets are available from the corresponding author on reasonable request during the peer review process.

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	Not applicable.
Reporting on race, ethnicity, or other socially relevant groupings	Not applicable.
Population characteristics	Not applicable.
Recruitment	Not applicable.
Ethics oversight	Not applicable.

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	In this study, we integrate a global dataset (520 species, 98 families) to reveal how plants have evolutionarily shifted N allocation from cell wall toward photosynthetic efficiency since their colonization of land. We identify a distinct evolutionary trajectory in leaf N allocation, with early-diverging seed plants preferentially investing in cell walls, while recently evolved species allocate more N to photosynthesis. This pattern is fundamentally constrained by deep evolutionary history and further shaped by recent environmental factors. Our findings further refine the leaf economics spectrum, demonstrating that conservative-strategy species favor structural components (cell walls), whereas acquisitive-strategy species invest heavily in metabolic gain (photosynthesis). These strategies are clearly partitioned across functional groups: herbaceous plants and AM-associated woody plants typically employ an acquisitive strategy with high photosynthetic N investment, while EcM-associated woody plants generally adopt a conservative strategy, allocating more N to cell walls.
Research sample	This is not applicable to our study because this work is not an "experimental" study but an integrated data analysis based on the published peer-reviewed literatures.
Sampling strategy	This is not applicable to our study because this work is not an "experimental" study but an integrated data analysis based on the published peer-reviewed literatures.
Data collection	To explore the N functional allocation strategy of plant leaves, we conducted a systematic search of the published peer-reviewed literatures that investigated the leaf N allocation among multiple functions. Here, we mainly focus on the allocation of leaf N to a range of photosynthetic and defense-related functions, including ribulose-1,5-bisphosphate carboxylase-oxygenase enzyme (Rubisco, PR), bioenergetics (i.e., electron transport, PB), light absorption by chlorophyll (PL), and cell wall structure (Pcw). The literatures were collected from Web of Science (http://webofscience.com) and Google Scholar (https://scholar.google.com) according to the following searches: ((TS=(leaf)) OR TS=(foliar)) AND (((TS=(nitrogen allocation)) OR TS=(nitrogen fraction)) OR TS=(nitrogen partitioning)). For each study, the data was directly obtained from the text, tables, and supplementary materials of the literature, or acquired from graphics using GetData Graph Digitizer v2.26. After systematic screening, a total of observations for 520 species from 98 families were included in our database. The final dataset was derived from 157 literature.
Timing and spatial scale	Timing scale: 1970-2025; Spatial scale: global terrestrial ecosystems
Data exclusions	In order to minimize publication bias caused by different data sources, we only considered studies that have at least two types of leaf N components in this study.
Reproducibility	Our results can be reproduced when following the described methods and data.
Randomization	This is not applicable to our study because this work is not an "experimental" study but an integrated data analysis based on the published peer-reviewed literatures.

Blinding

This is not applicable to our study because this work is not an "experimental" study but an integrated data analysis based on the published peer-reviewed literatures.

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 | Involvement in the study |
|-------------------------------------|--|
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Antibodies |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Eukaryotic cell lines |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Palaeontology and archaeology |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Animals and other organisms |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Clinical data |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Dual use research of concern |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Plants |

Methods

- | n/a | Involvement in the study |
|-------------------------------------|---|
| <input checked="" type="checkbox"/> | <input type="checkbox"/> ChIP-seq |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Flow cytometry |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> MRI-based neuroimaging |

Plants

- | | |
|-----------------------|-----------------|
| Seed stocks | Not applicable. |
| Novel plant genotypes | Not applicable. |
| Authentication | Not applicable. |