nature portfolio

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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 (*n*) 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 *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☒	☐ 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. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐ 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 *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	No software was used for data collection. All the data used in this study were downloaded through links available on publicly accessible websites.
Data analysis	All data analysis and figure production were completed using Matlab R2021a, and map production was done using ArcGIS 10.8

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

Vegetation data: We utilized the Global Inventory Modeling and Mapping Studies third generation (GIMMS-3G+) Normalized Difference Vegetation Index (NDVI) dataset to extract the GUDs of vegetation in the permafrost region. The GIMMS-3G+ NDVI dataset is publicly available at https://ecocast.arc.nasa.gov/data/pub/gimms/3g.v1/. This dataset has a spatial resolution of 0.0833 degrees and supports a wide array of vegetation monitoring applications.Climate data: Historical near-

surface meteorological conditions, including air temperature, precipitation, and downward shortwave radiation, were obtained from the ERA5-Land monthly mean datasets. These data can be accessed from the Copernicus Climate Data Store at https://cds.climate.copernicus.eu/. Soil moisture data, available from the same source, was extracted for analyses in this study.Vegetation root attributes: Data on the mean 95% root depth were extracted from the International Satellite Land Surface Climatology Project, Initiative II (ISLSCP II) dataset, which is available at https://daac.ornl.gov/ISLSCP_II/guides/roots.html. This dataset provides insights into global root system characteristics and below-ground biomass distribution across various ecosystems.

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	This study investigates the impact of permafrost degradation on vegetation green-up dynamics in the Northern Hemisphere.
Research sample	The research sample includes satellite-derived NDVI data (GIMMS-3G+) and climate variables from the ERA5-Land dataset. These data span across the Northern Hemisphere's permafrost regions, from 1982 to 2018.
Sampling strategy	Sampling covers various permafrost regions. The sample size was determined based on available vegetation and climate data.
Data collection	Data were collected from the GIMMS-3G+ NDVI and ERA5-Land datasets, which are publicly available from respective repositories.
Timing and spatial scale	Data collection spanned from 1982 to 2018, covering the Northern Hemisphere's permafrost regions, with a unified spatial resolution of 0.25 degrees. Sampling was conducted on a monthly basis.
Data exclusions	This started with the application of a modified Savitzky-Golay filter to remove abnormal data points (i.e., outlier points),of original NDVI data, followed by the removal of snow-affected data. The snow-affected data were substituted with the most recent data of acceptable quality that were unaffected by snow.
Reproducibility	The study was based on publicly available datasets, and all analyses were performed using reproducible methods in Matlab R2021a.
Randomization	Sample groups were assigned based on geographical regions. Randomization was not applicable due to the nature of the study.
Blinding	Blinding was not applicable as the study relied on satellite-derived and publicly available datasets.

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	Not applicable
Novel plant genotypes	Not applicable
Authentication	Not applicable