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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 in data collection.
Data analysis	The data analysis in this study was performed using the following software tools: Python 3.10: Used for preprocessing satellite-based NDVI datasets and climate datasets. MATLAB R2020a: Used for extracting vegetation phenology, calculating the correlation, sensitivity, and contribution of climate to phenology, and generating some of the figures. ArcGIS 10.8.1: Used for spatial data mapping and visualization. RStudio 4.4.0: Primarily used for plotting figures.

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

1.The satellite-based NDVI datasets used in this study are publicly available. The GIMMS NDVI3g dataset (1982-2015) was obtained from the Global Inventory Modeling and Mapping Studies (GIMMS) database (https://ecocast.arc.nasa.gov/data/pub/gimms/3g.v0/). The MODIS NDVI dataset (2001-2022) was sourced from NASA's Land Processes Distributed Active Archive Center (LP DAAC) (https://lpdaac.usgs.gov/products/mod13c1v006/).
2.The climate data used in this study are from the ERA5 dataset, provided by the European Centre for Medium-Range Weather Forecasts (ECMWF), and can be accessed at https://confluence.ecmwf.int/display/CKB/ERA5.
3.The land cover data (MCD12C1) used in this study were obtained from the MODIS Land Cover Type product and are available at https://lpdaac.usgs.gov/products/mcd12c1v006/.
There are no restrictions on the availability of these datasets.

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	This study does not involve human participants, and therefore no sex- or gender-based data were collected or analyzed.
Reporting on race, ethnicity, or other socially relevant groupings	This study does not involve human participants, so no race, ethnicity, or other socially relevant groupings were collected or analyzed.
Population characteristics	This study does not involve human participants, and thus no population characteristics were collected or reported.
Recruitment	No human participants were recruited for this study.
Ethics oversight	As this study does not involve human participants, ethics oversight was not required.

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 global impact of climate change and vegetation growth carryover (VGC) on plant phenology, specifically focusing on the start-of-season (SOS) and end-of-season (EOS) phenological events. Using two satellite-based NDVI datasets spanning the past four decades, the study explores how temperature, radiation, and VGC influence these phenological stages. The analysis identifies regional differences between the Northern Hemisphere (NH) and Southern Hemisphere (SH), showing that advanced SOS is primarily driven by increasing temperature and radiation, while delayed EOS is influenced by temperature and VGCSOS. The study employs statistical models to assess the contribution of VGCSOS and climatic factors to phenology across various biomes. The findings provide insights into the evolving contribution of VGCSOS to global vegetation dynamics under warming scenarios, with significant implications for predicting vegetation growth and carbon sequestration in the context of climate change.
Research sample	The research sample consists of global satellite-derived Normalized Difference Vegetation Index (NDVI) data from two primary sources: the Global Inventory Modeling and Mapping Studies (GIMMS) NDVI3g dataset (1982-2015) and the Moderate Resolution Imaging Spectroradiometer (MODIS) NDVI dataset (2001-2022). These datasets provide vegetation phenology information on the start-of-season (SOS) and end-of-season (EOS) for both the Northern Hemisphere (NH) and Southern Hemisphere (SH). The study also incorporates climate data from the ERA5 reanalysis dataset (1982-2022), which includes variables such as temperature, precipitation, solar radiation, and potential evapotranspiration. The NDVI data were chosen for their extensive temporal and spatial coverage, allowing for a comprehensive analysis of vegetation dynamics and the influence of climate and vegetation growth carryover (VGCSOS) on phenological patterns at a global scale. The sample represents various biomes across the globe, excluding croplands, to focus on naturally occurring vegetation dynamics influenced by climate factors.

Sampling strategy	This study uses all available satellite-based NDVI and climate data from the GIMMS, MODIS, and ERA5 datasets, ensuring comprehensive temporal and spatial coverage. To ensure consistency between datasets with different spatial resolutions, we resampled all data to a uniform resolution of 0.1° using the nearest neighbor method. No sample size calculation was necessary as the study encompasses full datasets for the entire period.
Data collection	Data was downloaded from publicly available sources, including the NASA LP DAAC website for MODIS data, and the ECMWF website for ERA5 data. No field data collection was required as the study relies entirely on pre-existing datasets.
Timing and spatial scale	The data covers the period from 1982 to 2022, with NDVI data recorded every 15 days (GIMMS) and every 16 days (MODIS). The spatial resolution is approximately 8 km for GIMMS and 0.05° for MODIS and 0.1° for ERA5 climate data.
Data exclusions	No data were excluded from the analysis.
Reproducibility	The data used in this study are publicly available and have been widely validated in previous global vegetation and climate studies. The analysis can be reproduced using the same datasets and methodological approach.
Randomization	As the study is based on observational data, no randomization was required.
Blinding	Blinding was not relevant for this study as it involved publicly available satellite and climate 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	This study did not involve the use of seed stocks or other plant materials.
Novel plant genotypes	This study did not involve the generation or use of novel plant genotypes.
Authentication	This study did not involve the authentication of seed stocks or plant genotypes.