

Reporting Summary

Nature Research 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 Research 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 Data on yield were downloaded from the Global Yield Gap Atlas, GAEZ, and AgMIP websites. Data on crop distribution were downloaded from SPAM MAP, and data on crop area were download from FAOSTAT. All these sources are publicly available

Data analysis Data were analyzed using R and mapped using ArcGIS.

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 Research [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 list of figures that have associated raw data
- A description of any restrictions on data availability

Data on yield potential and actual yield from GYGA are available at www.yieldgap.org. Data on yield potential from AgMIP and GAEZ can be download from www.fao.org/nr/gaez/en and www.agmip.org, respectively.

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](https://www.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 assess the performance of two widely used “top-down” gridded frameworks (GAEZ and AgMIP) versus an alternative “bottom-up” approach that estimates extra production potential locally, for a number of representative sites, and then upscales the results to larger spatial scales (GYGA).
Research sample	Our comparison included a total of 1362 buffers located within 870 climate zones, with 422 buffers (within 249 CZs) for rainfed maize, 160 buffers (116 CZs) for irrigated maize, 93 buffers (66 CZs) for rainfed rice, 209 buffers (114 CZs) for irrigated rice, 400 buffers (274 CZs) for rainfed wheat, and 78 buffers (49 CZs) for irrigated wheat.
Sampling strategy	The top-down and bottom-up approaches were compared in a total of 67 countries, which together account for 74%, 67%, and 43% of global maize, rice, and wheat harvested areas, respectively.
Data collection	Data were downloaded from the GAEZ, AgMIP, and GYGA websites.
Timing and spatial scale	Comparison of the three databases was performed at three spatial levels: local (also referred as “buffer”), climate zone, and country. We also try to be consistent in terms of the time period for yield potential was simulated; however, this was not always possible because while GAEZ and AgMIP use weather data sets that cover the time period between 1961-1990 and 1980-2010, respectively, GYGA uses more recent weather data. This would, however, not biased the conclusions from the study as we are comparing long-term averages in all cases rather than specific years.
Data exclusions	No data were excluded from the analysis.
Reproducibility	Raw data inputs used for model simulations and other analyses are available upon request.
Randomization	Not applicable as we did not conduct field experiments.
Blinding	Not applicable.
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
☒	☐ Human research participants
☒	☐ Clinical data
☒	☐ Dual use research of concern

Methods

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