The Journal of Open Source Software

AgriFoodPy: a package for modelling food systems

Juan P. Cordero[1¶], **Kevin Donkers**[2], **Ian Harrison**[3], **Sarah L. Bridle**[1], **Angelina Frankowska**[4], **Michelle Cain**[4], **Neil Ward**[5], **Jez Frendenburgh**[5], **Edward Pope**[2], **Alana Kluczkovski**[6], **Ximena Schmidt**[7], **Jacqueline Silva**[8], **Christian Reynolds**[9], **Katherine Denby**[6], **Bob Doherty**[10], and **Aled Jones**[11]

1 Department of Environment and Geography Wentworth Way, University of York, Heslington, York, YO10 5NG, United Kingdom **2** Land, Environment, Economics and Policy Institute (LEEP), University of Exeter Business School, Exeter, United Kingdom **3** School of Physics and Astronomy, Cardiff University, Cardiff CF24 3AA, United Kingdom **4** Centre for Environmental and Agricultural Informatics, School of Water, Energy and Environment, Cranfield University, Cranfield MK43 0AL, United Kingdom **5** School of Environmental Sciences, University of East Anglia, Norwich, United Kingdom **6** Centre for Novel Agricultural Products (CNAP), Department of Biology, University of York, York, YO10 5DD, United Kingdom **7** Equitable Development and Resilience Research Group, College of Engineering, Design and Physical Science, Brunel University London, London, UB8 3PH, United Kingdom **8** Global Academy of Agriculture and Food Systems, The University of Edinburgh. Charnock Bradley Building, Easter Bush Campus, EH25 9RG. **9** Centre for Food Policy, City, University of London, Northampton Square, London, EC1V 0HB, United Kingdom **10** School for Business and Society, University of York **11** Global Sustainability Institute, Anglia Ruskin University, Cambridge CB1 1PT, United Kingdom ¶ Corresponding author

DOI: 10.xxxxxx/draft

Software

- Review
- Repository
- Archive

Editor: Open Journals

Reviewers:

- @openjournals

Submitted: 01 January 1970
Published: unpublished

Summary

`AgriFoodPy` is an open-source Python package for processing, simulation, and modeling of agrifood datasets and systems. By employing `xarray` (Hoyer & Hamman, 2017) as the primary data structure, `AgriFoodPy` provides methods to manipulate tabular data by extending `xarray` functionality via accessor classes. It acts as an accessibility and interoperability layer between data sources and external packages, and also bundles with a library of models for use without any additional requirements.

A separate repository, `agrifoodpy_data`, is actively maintained in parallel to provide access to local and global agrifood datasets, including geospatial land use and classification data (Morton, 2022), food supply (FAO, 2023), life cycle assessment (Poore & Nemecek, 2018), and population data (United Nations, 2022). The `AgriFoodPy` framework is region-agnostic and provides facilities to model and simulate processes and intervention impacts regardless of their geographic origin.

Features

Version 0.1 provides table manipulation methods to extend the coordinate dimensions of `xarray` Datasets and DataArrays, extract summary statistics, and includes charting methods to analyze and display data. It also includes a library of intervention models for supply and demand changes, afforestation and agroecology, and land carbon sequestration. These can be used to predict the effectiveness of systemic interventions through key metrics of the food system.

`AgriFoodPy` provides a framework to build interfaces to external tools and packages which can be used by the community to extend its functionality and widen the scope of the simulated

The Journal of Open Source Software

systems. This makes it the first multipurpose tool of its kind, allowing wide analysis of food systems data by integrating diverse datasets, models and indicators into a unified framework. This allows researchers to make informed decisions and identify opportunities for systemic change in all areas of food systems, ranging from production, consumption, and land use to food security, nutrition, health, and policy-making.

Future releases will provide access to more models and community-contributed datasets formatted using `xarray`. Additionally, `AgriFoodPy` will implement a pipeline manager to perform end-to-end simulations of agrifood systems, which can be used to speed up the comparison of multiple scenarios and build easily shareable and reproducible workflows.

Open-source code and community development will allow a transparent view into analysis choices and data sources, which can help provide trustworthy evidence-based support for data-driven policymaking. `AgriFoodPy` is developed and maintained by a diverse community of domain experts with a focus on software sustainability and interoperability.

Statement of need

Providing food for an ever-growing population while reducing the impact of human activity on the environment has become one of the main global challenges. Local and intergovernmental independent committees (https://www.theccc.org.uk/, https://www.ipcc.ch/) have reported the impact of food production on climate change. The scenarios and projections in their reports also highlight the need for precise and transparent modeling of different aspects of the food system to help stakeholders understand the effects of consumption patterns and farming practices.

Coordinated efforts to achieve a sustainable food system must originate from effective policy-making based on evidence, careful choice of metrics and indicators to describe the state of the food system, and accurate estimates of how these metrics change under different scenarios and decisions/interventions.

Existing datasets and analysis software usually rely on non-standardized data structures and predominantly closed-source code. This hinders research and independent scrutiny of food system intervention projections and the impact of policy on environmental, socio-economic, and health indicators. Moreover, this forces researchers to routinely expend significant effort replicating or re-developing existing code to reduce and analyze data. Additionally, the opacity of some data sources and analysis choices makes it difficult to draw conclusions from equivalent comparisons between different interventions and policy decisions.

Few open initiatives exist focused on analysis and modeling of agrifood and environmental related data, e.g., the Environmental Data Science book (https://edsbook.org/). The research community has developed open-source tools that address some individual aspects of modeling agrifood systems, such as geospatial imaging (e.g., `GeoPandas`, Jordahl et al., 2020; `Rasterio`, Gillies & others, 2013), atmospheric and climate modeling (`Fair`, Leach et al., 2021) in Python, and other open softwares in other languages, including agriculture and farming (`APSIM`, Holzworth et al., 2014) and life cycle assessment (`OpenLCA`, www.openlca.org).

`AgriFoodPy` provides a consistent standard for agrifood data distribution, while also allowing external models and packages to coexist and interoperate, which facilitates a holistic approach to agrifood modeling.

Plans for future use in research and communication include the FixOurFood agrifood calculator (https://fixourfood.streamlit.app/), an interactive modeling tool to evaluate the effect of food system transformations in the UK. There are also plans to publish a paper on global diets their social and environmental impacts.

Acknowledgements

JPC, SLB, AF, MC, KD, BD, AK and FixOurFood's work was supported by the UKRI Transforming Food Systems Strategic Priority Fund (grant number BB/V004581/1). KD was funded via a doctoral training grant awarded as part of the UKRI AI Centre for Doctoral Training in Environmental Intelligence (UKRI grant number EP/S022074/1). NW & JF are grateful for funding from the AFN Network+ (UKRI Agri-food for Net Zero Network+) Grant Award EP/X011062/1 CR was funded through Transforming the UK Food System for Healthy People and a Healthy Environment SPF Programme, Grant Award BB/V004719/1 Healthy soil, Healthy food, Healthy people (H3). This article has benefited from comments and suggestions of the following people: Daniel Lewis, Joe Kennedy, Nada Saidi, Adam Amara.

References

FAO. (2023). *FAO. 2023. Food balance sheets 2010–2021. Global, regional and country trends. FAOSTAT AnalyticalBrief series no. 72.* https://doi.org/10.4060/cc8088en

Gillies, S., & others. (2013). *Rasterio: Geospatial raster i/o for Python programmers*. Mapbox. https://github.com/rasterio/rasterio

Holzworth, D. P., Huth, N. I., deVoil, P. G., Zurcher, E. J., Herrmann, N. I., McLean, G., Chenu, K., van Oosterom, E. J., Snow, V., Murphy, C., Moore, A. D., Brown, H., Whish, J. P. M., Verrall, S., Fainges, J., Bell, L. W., Peake, A. S., Poulton, P. L., Hochman, Z., … Keating, B. A. (2014). APSIM - evolution towards a new generation of agricultural systems simulation. *Environmental Modelling & Software*, *62*, 327–350. https://doi.org/10.1016/j.envsoft.2014.07.009

Hoyer, S., & Hamman, J. (2017). Xarray: N-D labeled arrays and datasets in Python. *Journal of Open Research Software*, *5*(1). https://doi.org/10.5334/jors.148

Jordahl, K., Bossche, J. V. den, Fleischmann, M., Wasserman, J., McBride, J., Gerard, J., Tratner, J., Perry, M., Badaracco, A. G., Farmer, C., Hjelle, G. A., Snow, A. D., Cochran, M., Gillies, S., Culbertson, L., Bartos, M., Eubank, N., maxalbert, Bilogur, A., … Leblanc, F. (2020). *Geopandas/geopandas: v0.8.1* (Version v0.8.1). Zenodo. https://doi.org/10.5281/zenodo.3946761

Leach, N. J., Jenkins, S., Nicholls, Z., Smith, C. J., Lynch, J., Cain, M., Walsh, T., Wu, B., Tsutsui, J., & Allen, M. R. (2021). FaIRv2.0.0: A generalized impulse response model for climate uncertainty and future scenario exploration. *Geoscientific Model Development*, *14*(5), 3007–3036. https://doi.org/10.5194/gmd-14-3007-2021

Morton, C. G. ;O'Neil., R. D.;Marston. (2022). *Land cover map 2020 (1km summary rasters, GB and n. ireland)*. NERC EDS Environmental Information Data Centre. https://doi.org/10.5285/d6f8c045-521b-476e-b0d6-b3b97715c138

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, *360*(6392), 987–992. https://doi.org/10.1126/science.aaq0216

United Nations. (2022). *United nations, department of economic and social affairs, population division (2022). World population prospects 2022: Summary of results. UN DESA/POP/2022/TR/NO. 3.* https://population.un.org/wpp/