

# AgriFoodPy: a package for modelling food systems

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## Software

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## 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 systems. This makes it the first multipurpose tool of its kind, allowing wide analysis of food

43 systems data by integrating diverse datasets, models and indicators into a unified framework.  
44 This allows researchers to make informed decisions and identify opportunities for systemic  
45 change in all areas of food systems, ranging from production, consumption, and land use to  
46 food security, nutrition, health, and policy-making.

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

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

## 55 Statement of need

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

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

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

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

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

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

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## References

- FAO. (2023). *FAO. 2023. Food balance sheets 2010–2021. Global, regional and country trends. FAOSTAT Analytical Brief 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.aag0216>
- 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.*