

# GLASSNET Geospatial Data for Sustainability

## A Gridded Price-Adjusted Quantity Index for Total Production of Crops for Irrigated and Rainfed Farms for the Contiguous U.S.

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*Related references:*

Haqiqi, I., Bowling, L. C., Jame, S. A., Baldos, U. L., & Liu, J. Hertel, T. W., (2023). Global Drivers of Local Water Stresses and Global Responses to Local Water Policies in the United States. *Environmental Research Letters*. 18: 065007 <https://doi.org/10.1088/1748-9326/acd269>

Baldos, U. L. C., Haqiqi, I., Hertel, T., Horridge, M., and Liu, J. (2020). SIMPLE-G: A Multiscale Framework for Integration of Economic and Biophysical Determinants of Sustainability *Environmental Modelling & Software*, 133: 104805, [DOI: 10.1016/j.envsoft.2020.104805](https://doi.org/10.1016/j.envsoft.2020.104805).

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# A Gridded Price-Adjusted Quantity Index for Total Production of Crops for Irrigated and Rainfed Farms for the Contiguous U.S.

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## Keywords:

Agricultural economics; land use; irrigation; yields; crop production

## Data Items

A price-adjusted quantity index is introduced for the total production of crops for irrigated and rainfed farms for the Contiguous U.S. (without crop details) at 5 arc-min resolution. Here, the production of all crops in each grid cell is aggregated into two crop composites: irrigated (QCROP\_irr) and rainfed (QCROP\_rfd). Each composite may have a slightly different mix of crops with different prices. To consider price differences, a “corn-equivalent” index is generated for production. The dataset also represents the cropland area for irrigated (QLAND\_irr) and rainfed (QLAND\_rfd) around the year 2010 provided in NetCDF, GeoTIFF, CSV, and HAR file formats. This note describes the method and discusses the likely applications of this dataset.

**Table 1. Data items available in this dataset**

Variables*	Note	Resolution	Scope	Units
QCROP_irr: aggregate crop production, irrigated	Circa 2010	5 arc-min	CONUS	1000 metric ton
QCROP_rfd: aggregate crop production, rainfed	Circa 2010	5 arc-min	CONUS	1000 metric ton
QLAND_irr: cropland area, irrigated	Circa 2010	5 arc-min	CONUS	1000 hectare
QLAND_rfd cropland area, rainfed	Circa 2010	5 arc-min	CONUS	1000 hectare

\* Available in separate files in NetCDF and geoTIFF and combined in HAR and CSV formats. Here, CONUS stands for the Contiguous United States.

## Methods

For detailed description of methods and validations look at the Supplementary Information provided in Haqiqi et al (2023). The gridded cropland data is obtained from the United States Department of Agriculture Cropland Data Layer at 30 meters and aggregated to 5 arc-min around the year 2010 (Lark et al, 2015; Baldos et al., 2020). To split the cropland into irrigated and rainfed, the share of irrigated area is calculated for each 5 arc-min grid cell based on Moderate Resolution Imaging Spectroradiometer (MODIS) Irrigated Agriculture Datasets for the Conterminous

United States (MIrAD-US) averaged over 2007 and 2012 (Brown et al, 2019). Then, the crop yields and irrigation yield gaps are obtained from the Global Crop Water Model (GCWM) based on the simulation of crop yields (Siebert and Döll, 2010; Hoff et al, 2014) for 29 crop categories (an aggregation from 175 FAO categories) and aggregated to the two crop composites: irrigated and rainfed. The county level area is adjusted based on USDA Census of Agriculture (USDA, 2014). Different types of aggregation are implemented as described below.

Using GCWM simulation outputs for 29 crops at 5 arc-min, for each grid cell  $g$  and land type  $l$  (irrigated and rainfed), the production is calculated using the information about crop  $c$  associated with that grid cell. The production equation can be written as:

$$\begin{aligned} Q_{g,l} &= \sum_{c,t} N^{-1} Q_{g,c,l,t} P_c P^{-1} \\ &= \sum_{c,t} N^{-1} L_{g,c,l} Y_{g,c,l,t} P_c P^{-1} \end{aligned}$$

Where,  $N$  is the number of years;  $Q_{g,l}$  shows the production by grid cell and land type;  $Q_{g,c,l,t}$  shows the production by grid cell, land type, crop, and time (year);  $P$  is the price indexed by crop;  $L$  is the land area by crop, land type and grid cell; and  $Y$  is the yield by crop, land type, and grid cell. Note that the price is fixed over the period assuming a fixed weight in calculating the corn-equivalent production (and yields). Here, price of corn is \$226 per metric ton. Total production in the US is matched to FAO.

### Temporal aggregation

The year 2010 has been a relatively normal year for US agriculture. Thus, the spatial distribution of aggregate crop production around 2010 should be a good representative of spatial distribution of crop production in normal years for the United States. Other versions of the variables in this dataset are calculated for 2006 and 2017. This dataset provides useful information for economic studies on how land use and agriculture change over time.

The calculation is based on a biophysical model that simulates annual crop yields. To capture the average conditions, the dataset aggregates the annual data into 5-year periods. This way, the dataset can help economic models to analyze the medium-run and long-run effects. The critical biophysical information is the simulated irrigation yield gap for each location. The assumption is that the irrigated cropland does not face water stress. While both irrigated and rainfed production are affected by heat stress, the damage on irrigated crop production is smaller.

### Spatial aggregation

This dataset is designed to work at a 5-arc-min resolution based on USDA CDL (30 meters) and other high-resolution datasets (250m to 10 km). The advantage of the gridded corn-equivalent approach is that it can be readily aggregated to match agronomic or hydrologic models that may operate on the scale of sub-basins or soil types. This dataset can be aggregated to national, sub-national, county-level, agroecological zones, and river basins.

## Crop aggregation

This dataset provides an index for total crop production without crop details. It follows the SIMPLE-G-Allcrops model (Baldos et al., 2020). Aggregation to single-composite commodities is an appropriate approach when total land, water, and fertilizer uses are the focus of the analysis. For water quality analysis, the aggregation of crops can be redefined to include the important crops. For example, the SIMPLE-G-cornsoy model (Liu et al, 2018) is designed for water quality analysis in the US, with a composite of just two crops. While the data on production of individual crops could be helpful in some studies, it may not show the relative economic status of crop production. It would not be appropriate to aggregate various crops in tons (e.g., 10 tons of almonds may be worth more than 20 tons of beets).

## Application

This dataset is designed for long-run analysis of land use and land conversion when considering a production index for aggregating crops. This data has been used in multiple studies (Haqiqi et al., 2018; Baldos et al, 2020; Ray et al, 2023; Haqiqi et al, 2023). It was published first as one of the inputs of SIMPLE-G-US, on September 11, 2018, <https://mygeohub.org/tools/simpleus>, for version 1.0. However, users reported difficulty to extract the data from the HAR format and issues with very small values. Here, the data is made available in other formats for better access.

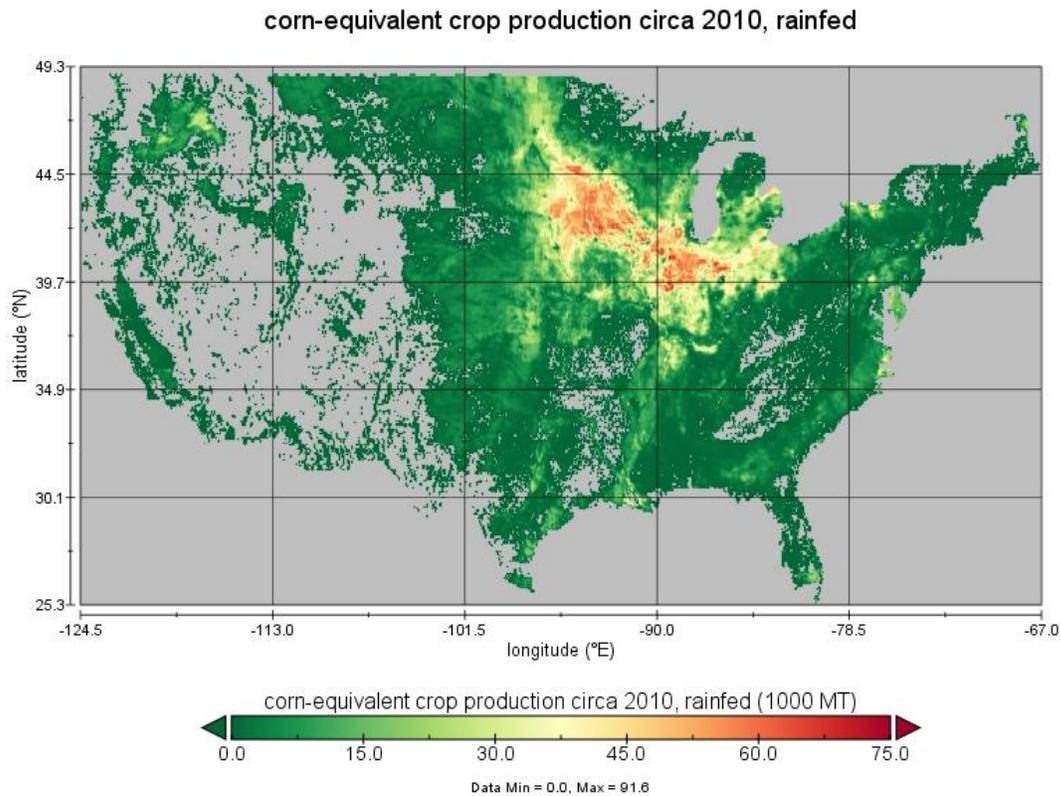


Figure 1. Rainfed corn equivalent crop production in 1000 metric tons per 5 arc-min grid cell over cultivated cropland around the year 2010. The gray coloring is not cultivated.

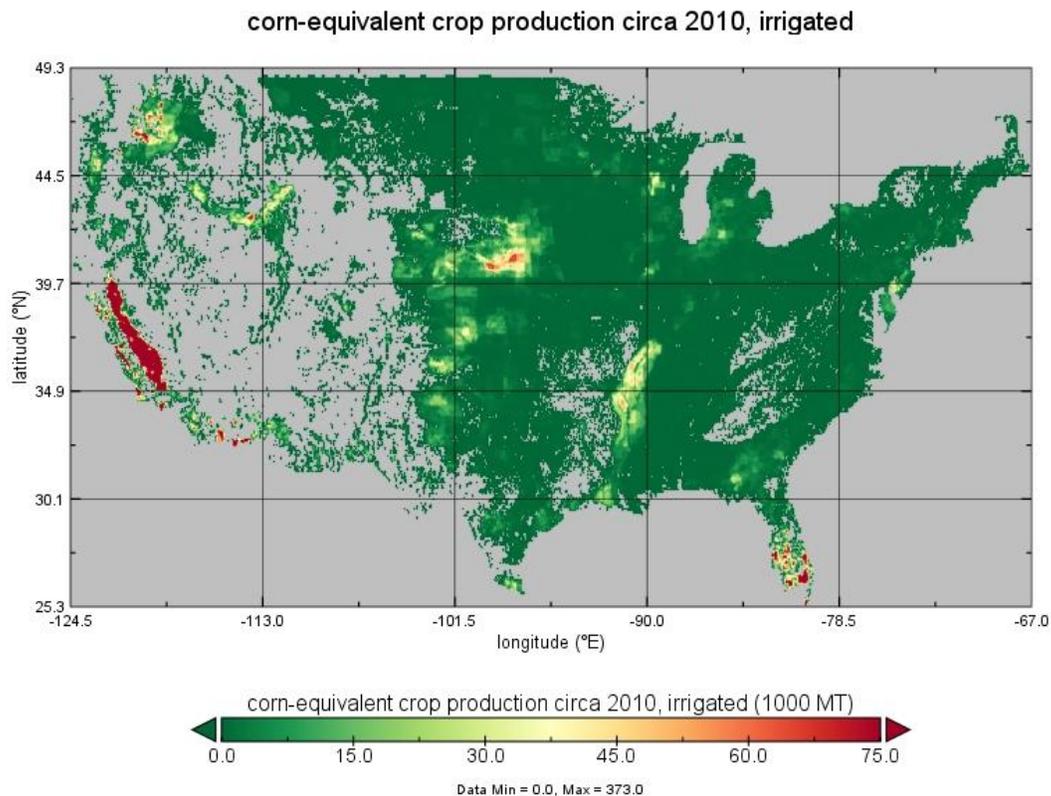


Figure 2. Irrigated corn equivalent crop production in 1000 metric tons per 5 arc-min grid cell over cultivated cropland around the year 2010. The gray coloring is not cultivated.

### How to read the HAR and CSV files

The CSV file includes 75,651 rows of data and one top row for labels. The columns x and y are the coordinates of the center of the grid cell in 5-arcmin, considering “+proj=longlat +datum=WGS84”. The FIPS column shows the US county codes. The sub-region column is the code for Farm Resource Regions as described in [Haqiqi et al \(2023\)](#).

Note that the LON and LAT headers in the HAR files are showing the coordinate values (longitude and latitude) for the center of the grid cell (in some versions they are multiplied by 120, and the user needs to divide them by 120 to get to the precise coordinates). A working GEMPACK is required to read the HAR files. A free version of GEMPACK software is available on the CoPS website (Harrison & Pearson, 1996; Horridge et al, 2018): [www.copsmodels.com/gpwingem.htm](http://www.copsmodels.com/gpwingem.htm) and [www.copsmodels.com/gpmark9.htm](http://www.copsmodels.com/gpmark9.htm).

## References

- Baldos, U.L.C., Haqiqi, I., Hertel, T.W., Horridge, M. and Liu, J., (2020). SIMPLE-G: A multiscale framework for integration of economic and biophysical determinants of sustainability. *Environmental Modelling & Software*, 133, p.104805, <https://doi.org/10.1016/j.envsoft.2020.104805>.
- Brown, J.F., Howard, D.M., Shrestha, D., and Benedict, T.D., (2019). Moderate Resolution Imaging Spectroradiometer (MODIS) Irrigated Agriculture Datasets for the Conterminous United States (MIrAD-US): U.S. Geological Survey data release, <https://doi.org/10.5066/P9NA3EO8>.
- Haqiqi, I., Bowling, L. C., Jame, S. A., Baldos, U. L., & Liu, J. Hertel, T. W., (2023). Global Drivers of Local Water Stresses and Global Responses to Local Water Policies in the United States. *Environmental Research Letters*. <https://doi.org/10.1088/1748-9326/acd269>
- Haqiqi, I., Bowling, L., Jame, S., Hertel, T.W., Baldos, U. and Liu, J., (2018). Global Drivers of Land and Water Sustainability Stresses at Mid-Century. Purdue Policy Research Institute (PPRI) Policy Briefs, 4(1), p.7. <https://docs.lib.purdue.edu/gpripb/vol4/iss1/7>
- Haqiqi, I., Perry, C.J. and Hertel, T.W., (2022). When the virtual water runs out: local and global responses to addressing unsustainable groundwater consumption. *Water International*, 47(7), pp.1060-1084, <https://doi.org/10.1080/02508060.2023.2131272>.
- Harrison, W. J., & Pearson, K. R. (1996). Computing solutions for large general equilibrium models using GEMPACK. *Computational Economics*, 9, 83-127.
- Hoff, H., Döll, P., Fader, M., Gerten, D., Hauser, S., & Siebert, S. (2014). Water footprints of cities - indicators for sustainable consumption and production. *Hydrology and Earth System Sciences* 18, 213-226, 2014. <https://doi.org/10.5194/hess-18-213-2014>
- Horridge, J. M., Jerie, M., Mustakinov, D., & Schiffmann, F. (2018). GEMPACK manual. *GEMPACK software*.
- Lark, T. J., Salmon, J. M., & Gibbs, H. K. (2015). Cropland expansion outpaces agricultural and biofuel policies in the United States. *Environmental Research Letters*, 10(4), 044003. <https://doi.org/10.1088/1748-9326/10/4/044003>
- Liu, J., Hertel, T.W., Bowling, L., Jame, S., Kucharik, C. and Ramankutty, N., (2018). Evaluating alternative options for managing nitrogen losses from corn production. Purdue Policy Research Institute (PPRI) Policy Briefs, 4(1), p.9. <https://docs.lib.purdue.edu/gpripb/vol4/iss1/9>
- Ray, S., Haqiqi, I., Hill, A. E., Taylor, J. E., & Hertel, T. W., (2023). Labor markets: A critical link between global-local shocks and their impact on agriculture. *Environmental Research Letters*. <https://doi.org/10.1088/1748-9326/acb1c9>.
- Siebert, S. & Döll, P. (2010). Quantifying blue and green virtual water contents in global crop production as well as potential production losses without irrigation. *Journal of Hydrology* 384, 198-217. DOI:10.1016/j.jhydrol.2009.07.031.
- USDA (2014). Farm Economics, 2012 Census of Agriculture Highlights. United States Department of Agriculture, National Agricultural Statistics Service. ACH12-2/May 2014.