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GLASSNET Geospatial Data for Sustainability

Water Supply Elasticity for US Agriculture: Using Groundwater Extraction and Recharge Rates

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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

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Water Supply Elasticity for US Agriculture: Using Groundwater Extraction and Recharge Rates

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Keywords

Agricultural economics; water resources; value of water; supply elasticity; irrigation; land use.

Summary

New estimates of downscaled gridded water supply elasticity are provided for 75,651 grid cells (at 5 arc-min resolution) for the United States agriculture given the groundwater irrigation and recharge rates around year 2010.

Data Items

Data items include long-run water supply elasticity, groundwater irrigation in million m3 per year per grid cell, groundwater recharge in million m3 per year per grid cell, and the ratio of irrigation to recharge. The data is provided for the Continental United States at 5 arc-min resolution.

Table 1. Data items and descriptions

Variables	Note	Resolution	Label	Units
water supply elasticity	The long run % change in water supplied to agriculture in response to 1% change in value of irrigation water	5 arc-min	Supply_elasticity	NA
groundwater extraction	Average annual volume of total groundwater extraction per grid cell	5 arc-min	Total_irrigation	Million m3
groundwater recharge rates	Average annual recharge of groundwater resources per grid cell	5 arc-min	Total_recharge	Million m3
irrigation to recharge	Ratio of groundwater extraction to groundwater recharge	5 arc-min	irrigToRchrg	ratio

Applications and related literature

The elasticities of water supply and demand are important for economic and multidisciplinary studies of water resources, sustainability policies, and climate impacts (Ward & Michelsen 2002; Griffin 2016). The water supply elasticity represents the economic response of water owners to changes in market price or value of water. When combined with estimated demand elasticities, this parameter can be used in economics and policy studies to provide insights on the likely agricultural economic responses to changes in water conditions or imposing new water policies and regulations. The spatial distribution of these parameters is also important in understanding the heterogenous responses to policies and shocks as well as in quantifying the leakages and spill-over effects. While many researchers have studies the water demand elasticities, there is no estimate available for spatially varying water supply elasticity (mostly due to data availability). There are two approaches in estimating water supply elasticity: empirical estimations and biophysical downscaling. The spatial regression would require economic information about the implicit and explicit value of water as well as volumetric information about crop water requirements and withdrawals. Depending on water right regimes, introducing new variables or a clustering might be required. To avoid endogeneity issues, the elasticities are estimated in a system of demand and supply (Haqiqi, 2023). The biophysical downscaling method assumes the supply elasticity of water follows a function with vertical and horizontal asymptotes (Baldos et al., 2020; Haqiqi et al, 2023).

Methods

The gridded water supply elasticity is estimated following Baldos et al (2020) assuming a non-linear relationship between water supply parameter and the ratio of extraction to recharge. The supply elasticity of water (ε) for each grid cell g is given by:

$$\varepsilon_g = \omega_0 + \frac{\omega_1}{\left(\omega_2 + R_g\right)^{\omega_3}}$$

where, R is the ratio of withdrawal to groundwater recharge; and ω represents the parameters that govern the curvature of the function. Here, ω_1 is 0.50, ω_2 is 0.30, ω_3 is 0.45. Also, ω_0 is set to zero for groundwater and -0.05 for surface water. Figure 1 illustrates the magnitude of water supply elasticity in the US.

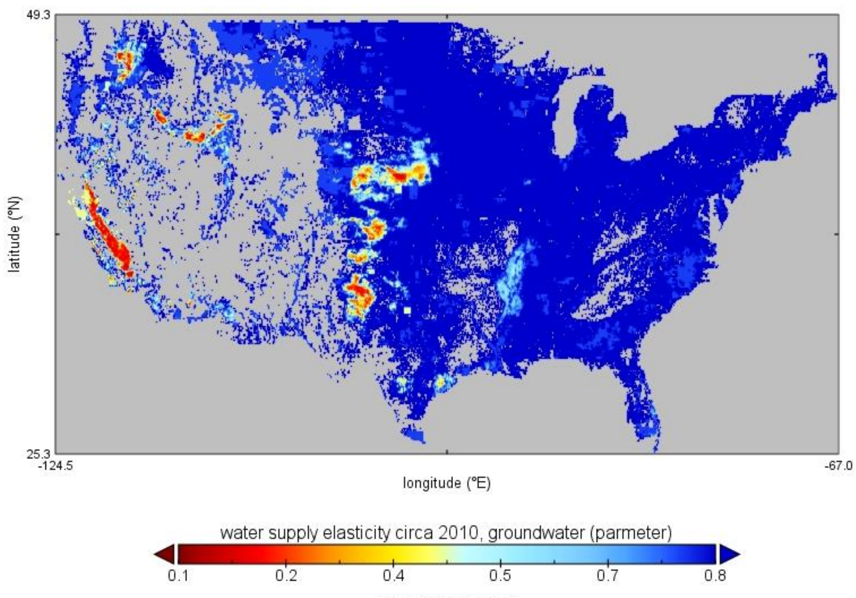

Figure1. Downscaled supply elasticity of water for irrigated crop production in the Unites States.

Data sources

The groundwater extraction and recharge ratios are obtained from United States Geological Survey (USGS) various sources (Bartolino & Cunningham 2003; Brown et al., 2019; Reitz et al., 2017). The calculations are compared with simulation model outputs of Water Balance Model (Vörösmarty et al., 2000; Wisser et al., 2008; Grogan et al. 2017; Liu et al., 2017; Grogan et al., 2022).

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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 (USDA, 2000).

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.

Bartolino, J. R., & Cunningham, W. L. (2003). Ground-water depletion across the nation. USGS Fact Sheet No. 103-03. https://doi.org/10.3133/fs10303

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.

Grogan, D. S., Wisser, D., Prusevich, A., Lammers, R. B., & Frolking, S. (2017). The use and re-use of unsustainable groundwater for irrigation: a global budget. *Environmental Research Letters*, *12*(3), 034017.

Grogan, D. S., Zuidema, S., Prusevich, A., Wollheim, W. M., Glidden, S., & Lammers, R. B. (2022). Water balance model (WBM) v. 1.0. 0: a scalable gridded global hydrologic model with water-tracking functionality. *Geoscientific Model Development*, *15*(19), 7287-7323.

Haqiqi, I. (2023). SIMPLE-G model, data, parameters, and implementation. 26th Annual Conference on Global Economic Analysis. Université de Bordeaux, Pey-Berland, June 14-16, 2023.

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

Liu, J., Hertel, T. W., Lammers, R. B., Prusevich, A., Baldos, U. L. C., Grogan, D. S., & Frolking, S. (2017). Achieving sustainable irrigation water withdrawals: global impacts on food security and land use. *Environmental Research Letters*, *12*(10), 104009.

Reitz, Meredith, Sanford, W.E., Senay, G.B., and Cazenas, Jeffrey, (2017). Annual estimates of recharge, quick-flow runoff, and ET for the contiguous US using empirical regression equations, 2000-2013: *U.S. Geological Survey data release*, https://doi.org/10.5066/F7PN93P0.

USDA (2000). Farm Resource Regions. United States Department of Agriculture, Economic Research Service, Agricultural Information Bulletin, Number 760. https://www.ers.usda.gov/publications/pub-details/?pubid=42299

Vörösmarty, C. J., Green, P., Salisbury, J., and Lammers, R. B. (2000). Global Water Resources: Vulnerability from Climate Change and Population Growth, Science, 289, 284–288, https://doi.org/10.1126/science.289.5477.284.

Wada, Y., Wisser, D., and Bierkens, M. F. P. (2014). Global modeling of withdrawal, allocation and consumptive use of surface water and groundwater resources, Earth Syst. Dynam., 5, 15–40, https://doi.org/10.5194/esd-5-15-2014.

Wisser, D., Frolking, S., Douglas, E. M., Fekete, B. M., Vörösmarty, C. J., and Schumann, A. H. (2008). Global irrigation water demand: Variability and uncertainties arising from agricultural and climate data sets, Geophys. Res. Lett., 35, L24408, https://doi.org/10.1029/2008GL035296.