Challenges predicting the spatial patterns of land conversion (And how GEOSHARE can help.)

Nelson Villoria and Jing Liu

Center for Global Trade Analysis
Department of Agricultural Economics
Purdue University

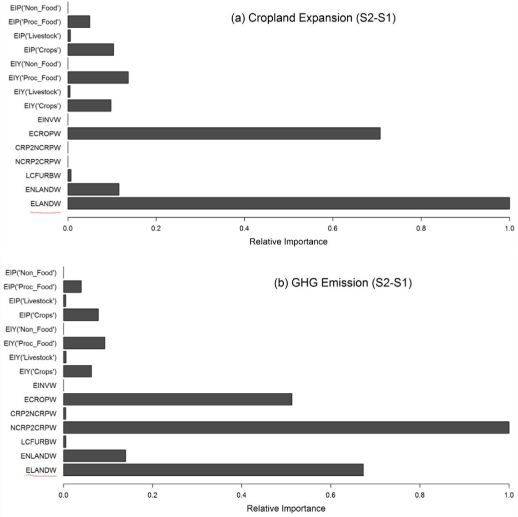
September 10, 2014

The author acknowledges support from the Electric Power Research Institute, GEOSHARE, and Purdue University's NSF GABBS project.

Introduction

- Increasingly, GTAP applications involve workflows starting with geospatial information (e.g., water scarcity but also biofuels).
- GTAP land use impacts are part of the CARB regulation of biofuels; model based analysis of land use change also plays an important role with EPAs regulations of biofuels.
- Land use change accounts for 17% of global GHG emissions.
- Yet tremendous uncertainty about where land use change is likely to occur. And how productive that land will be.
- Message: if want to improve this state of affairs, we need better data. Hence GEOSHARE. This presentation shows that link and how it can be exploited.

A key unknown, and a main source of model output uncertainty, are the land supply elasticities:



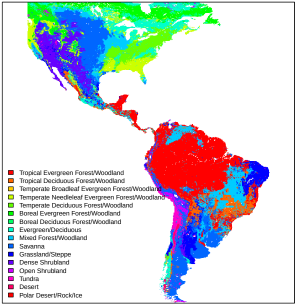
Lobell, Baldos, and Hertel (2013, Figure 6).

Land Supply Elasticity Defined:

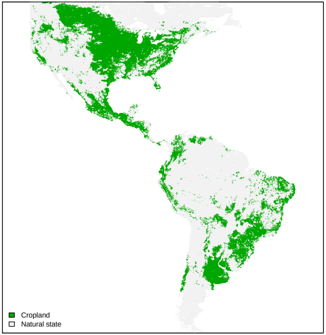
% change in land supplied from a commercial or natural state to agriculture (or vice versa) given a 1% change in relative returns.

Using spatial data to model the transition from natural vegetation to cropland

Maps of potential vegetation provide natural cover before land was converted to agriculture (Ramankutty and Foley, 1999):



Discrete choice: land is in agriculture, $Z=1$, $Z=0$ otherwise (Monfreda et al., 2008):



Regressors

Model land use decision (Z) as a logit function of land use drivers to infer transition probabilities from natural cover to cropland:

$$P(Z_i = 1|S_i) = \Lambda(\alpha_0 + \alpha_1 S_i + ... + \alpha_n S_n + \varepsilon_i). \qquad (1)$$

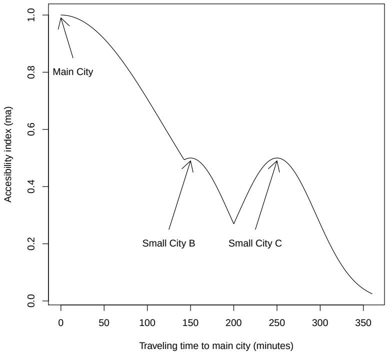
VARIABLES		UNITS	SOURCE
Biophysical	Potential Vegetation*	1-14	Ramankutty & Foley
	Soil Fertility Constraints	1-7	IIASA Global AEZ
	Average annual precipitation	mm	IIASA Global AEZ
	Elevation	meters	NOAA SAGE's Atlas
	Soil pH	0-14	SAGE
	Soil Carbon		SAGE
	Monthly temp (ave. 1961-1990)**	Degree Celsius	CRU
Socio-economic	Market Access	index	Verburg et al
	Area equipped for irrigation	% of gridcell	Siebert et al
	Built-up land	% of gridcell	Miteva, B.
	Protected Areas	0-2	GEONETWORK
Descriptive	GTAP 18 and 108 AEZs	AEZs	Uris Baldos

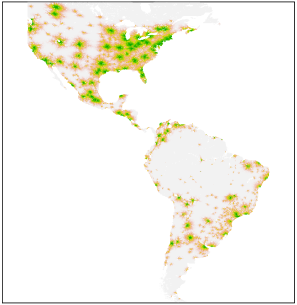
Land supply elasticities

- Require price, but we do not have gridded/subnational data on land returns or prices!
- Instead, we have measures of access to markets
- Model land returns as functions of market access (Von Thunen's model):

$$Returns_i = Access_i^{\gamma_1} \tag{2}$$

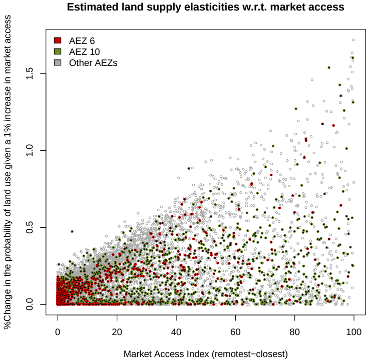
Market access index decreases with travel time from the location of a large market (Verburg, 2011)



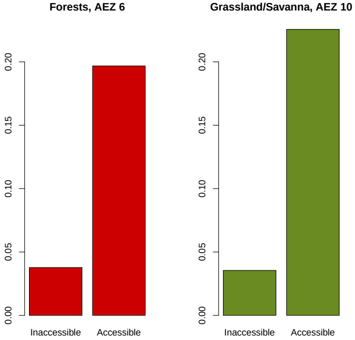


Land supply elasticities and land accessibility

Land supply elasticities for all the sample grids highlighting those in AEZs 6 and 10



Average land supply elasticity for forests in AEZs 6 and grasslands in AEZ 10



Accessible lands are those with market access greater than the 75th percentile. Inaccessible lands are below the 75% percentile. The elasticities on the right plot are weighted averages using predicted probabilities of land use as weights.

In sum:

- Using global grids of agricultural production and its determinants produce land supply elasticities that:
  - Are in line with previous literature using actual price changes.
  - Reject the hypothesis of homogeneous elasticities across countries/ AEZs.

These parameters are important because global land use models are used to answer questions about:

- The poverty effects of climate policy,
- the indirect land use effects of biofuels.
- the carbon mitigation possibilities of investments in agricultural productivity,
- etc.

How can GEOSHARE help?

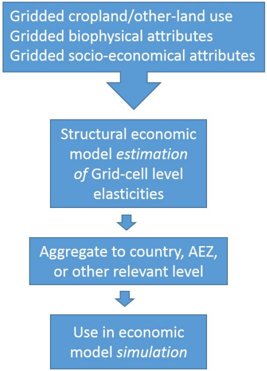
Spatial data has many advantages:

- Are global.
- Are gridded.
- Are comprehensive.

... but unfortunately...

- the data are dated.
- the assumptions underlying the final product are often opaque.
- the emphasis on biophysical attributes (as opposite to socio-economic variables.)

A GEOSHARE workflow (in progress):



Thank you!

nvillori@purdue.edu

Cited work:

Lubowski, Ruben (2002) Determinants of Land Use Transitions in the United States: Econometrics Analysis of Changes among the Major Land-Use Categories. PhD Dissertation, Harvard University: Cambridge, MA.

Barr, Kanlaya J., Bruce A. Babcock, Miguel A. Carriquiry, Andre M. Nassar, and Leila Harfuch. Agricultural Land Elasticities in the United States and Brazil. *Applied Economic Perspectives and Policy* 33, no. 3 (Autumn 2011): 449 462.

Eickhout, Bas, Hans van Meijl, Andrzej Tabeau, and Elke Stehfest. 2008. Chapter 9: The Impact of Environmental and Climate Constraints on Global Food Supply. In Economic Analysis of Land Use in Global Climate Change Policy. GTAP Working Paper No. 47.

Sohngen, Brent, and Robert Mendelsohn. 2007. A Sensitivity Analysis of Forest Carbon Sequestration. In Human-Induced Climate Change: An Interdisciplinary Assessment, edited by Michael E. Schlensinger, Haroon S. Kheshgi, Joel Smith, Francisco C. de la Chesnaye, John M. Reilly, Tom Wilson, and Charles D. Kolstad. Cambridge, UK: Cambridge University Press.

Rose, Steven K., Alla A. Golub, and Brent Sohngen. 2012. Total Factor and Relative Agricultural Productivity and Deforestation. American Journal of Agricultural Economics, December. doi:10.1093/ajae/aas113.

Lobell, David B., Uris Lantz C. Baldos, and Thomas W. Hertel. 2013. Climate Adaptation as Mitigation: The Case of Agricultural Investments. Environmental Research Letters 8 (1): 015012.

Golub, Alla, Thomas W. Hertel, and Brent Sohngen. 2009. Land Use Modelling in a Recursively Dynamic General Equilibrium Framework. In Economic Analysis of Land Use in Global Climate Change Policy, edited by T. W. Hertel, Steven Rose, and Richard Tol, 12354. London and New York: Routledge.

Ramankutty, Navin, and Jonathan A. Foley. 1999. Estimating Historical Changes in Global Land Cover: Croplands from 1700 to 1992. Global Biogeochemical Cycles 13 (4): PP. 9971027.

Monfreda, Chad, Navin Ramankutty, and Jonathan A. Foley. 2008. Farming the Planet: 2. Geographic Distribution of Crop Areas, Yields, Physiological Types, and Net Primary Production in the Year 2000. Global Biogeochemical Cycles, March, 1:19.