Crop Choice, Rotational Effects and Water Quality Consequence in Up-Mississippi River Basin: Connecting SWAT Model with Dynamic Land Use Model

Yongjie Ji	Iowa State University	yongjiej@iastate.edu
Sergey Rabotyagov	University of Washington	rabotyag@uw.edu
Catherine L. Kling	Iowa State University	ckling@iastate.edu

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Yongjie Ji, PhD1; Sergey Rabotyagov, PhD2; Catherine L. Kling, PhD1
1[Iowa State University], 2[University of Washington]

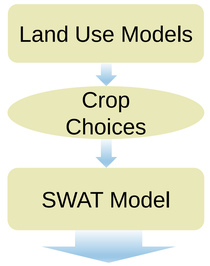
Center for Agricultural and Rural Development

Introduction

- Agricultural land use in Upper-Mississippi River Basin is one of major nutrient sources to the Gulf of Mexico, contributing to the formation of the hypoxic (dead) zone there.
- The land use decision is naturally dynamic, affected by the ever changing market incentives (prices and costs) and agronomical dynamics (soybean-corn rotation) . In future scenarios, these dynamics are also affected by climate changes in multiple ways, such as yield effects.
- We propose an integrated framework between a dynamic land use model and environmental consequences, i.e., water quality via SWAT model (USDA-ARS)

Roadmap

Market Incentives, Crop History, Yield Projections



Water Quality Measures: Nitrogen, Phosphorus, et al.

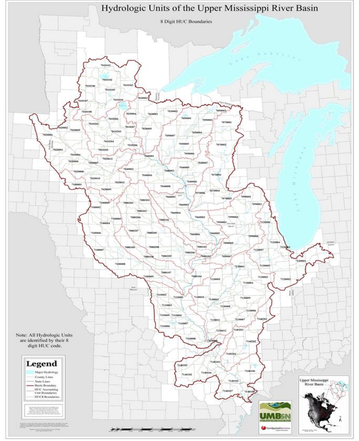
Method - Connect to SWAT

- The effect of climate change will be introduced to model via a modified yield function

$$Yield = f(weather\ variables|\cdot)$$

- Once with estimated parameters, we could simulate possible crop choice decisions under different scenarios, like price changes.
- An 8 digit HUC SWAT model covering whole Upper-Mississippi River Basin will be used to evaluate water quality effects of induced land use change under different scenarios.
- The two scenarios considered are
  - Future climate scenarios projected in IPCC and downscaled to UMRB.
  - Relative price change, the increase of corn price versus soybean price

Maps



- 131 sub-basins in UMRB
- 60 percent of the basin is cropland or pasture. Major cash crops include corn and soybeans.
- Contribute 43% nitrogen and 26% phosphorus to the Gulf of Mexico

Method-Land Use

- The farmer makes crop decision on a plot of cropland to maximize the flow of expected utility

$$Max \sum^{T} \beta^t [u(d_t|X_t) + \eta_{it}]$$

$$u(d_t|\cdot) = \begin{cases} \alpha_c + \theta_r R_{ict} + \theta_{c1} S1_{it} + \theta_{c2} S2_{it} + \theta_{c3} G1_{it} & if\ d_t = 1\ (Corn) \\ \alpha_s + \theta_r R_{ist} + \theta_{s1} S1_{it} + \theta_{s2} S2_{it} + \theta_{s3} G1_{it} & if\ d_t = 2\ (Sobyean) \\ \lambda Soil_i & if\ d_t = 3\ (Other) \end{cases}$$

Where

- $u(\ \ )$ utility function
- $R = P_{ijt} * Yield_{ijt} - C_{ijt}, j = 1,2$
- $X = (P, Yield, C, S1, S2, S3, Soil)$ a set of state variable
- $\beta\ discounting\ factor, \theta s, as\ and\ \lambda\ are\ unkown\ parameters$

This dynamic discrete choice model will be estimated through conditional choice probability with two-period-ahead dependence (Arcidiacono and Miller, 2011).

- Static model and State-dependent model added as comparison.

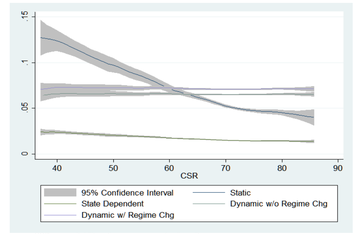
Results - Land Use

	Static Model		State Dependent Model		Dynamic Model I		Dynamic Model II	
Variable	Est	Std.Dev	Est	Std.Dev	Est	Std.Dev	Est	Std.Dev
Corn	1.8727	0.1245	2.2169	0.1653	-0.3100	0.1656	-0.4145	0.1661
Soybean	1.6317	0.1247	2.0192	0.1657	-0.6580	0.1875	-0.7604	0.1897
SLOPE	0.0326	0.0054	0.0195	0.0073	0.0161	0.0074	0.0159	0.0074
LCC	0.3969	0.0297	0.1748	0.0387	0.0603	0.0388	0.0552	0.0388
CSR	-0.0074	0.0011	-0.0047	0.0015	-0.0034	0.0015	-0.0033	0.0015
Revenue	0.0031	0.0001	0.0015	0.0001	0.0008	0.0001	0.0007	0.0001
S1:Corn			0.8060	0.0549	0.2631	0.0551	0.2399	0.0552
S2:Corn			-0.3000	0.0491	-0.3223	0.0493	-0.3233	0.0493
G1:Corn			-3.3945	0.0568	-3.4079	0.0572	-3.4103	0.0572
S1:Soybean			-1.2699	0.0575	-1.5527	0.0578	-1.5712	0.0578
S2:Soybean			1.3447	0.0484	1.3257	0.0488	1.3261	0.0489
G1:Soybean			-0.4723	0.0556	-0.4217	0.0563	-0.4242	0.0563
Log-llike	-47091		-31650		-32049		-32099	

Results-Climate Change

- We have access to several downscaled weather projections in UMRB at finer spatial resolution (1/8th degree). Coupled with the yield function, we can have different projected yield patterns for corn and soybean. Together with the estimation results, we could estimate future crop choices and their water quality consequences.

Results- Price Change



- CSR corn suitability rating, a measure of soil quality.
- The result is from Iowa part of UMRB, the result of the whole UMRB will be updated later.

- Water Quality Change
- The dramatic elasticity estimation implies different crop choice patterns and the associated water quality consequences. At this stage, the final analysis hasn't been finished yet.

Conclusions

- The dynamic models have better performance in modeling the land use data in recent years.
- In the price increasing scenario, dynamic models produce significant different elasticity estimation from the static model. That implies the different water quality consequences.
- In theory, the model could be used to predict land use change under different climate patterns. The analysis work will be done very soon.

References

1. Arcidiacono, Peter, and Robert A. Miller. 2011. "Conditional Choice Probability Estimation of Dynamic Discrete Choice Models With Unobserved Heterogeneity." Econometric 79 (6)
2. Silvia Secchi, Philip W. Gassman, Manoj Jha, Lyubov Kurkalova, and Catherine L. Kling 2011. Potential water quality changes due to corn expansion in the Upper Mississippi River Basin. Ecological Applications 21:1068–1084.