A Coupled Spatial Economic-Hydrological Model of

Cropland Transitions and Environmental Impacts

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Abstract

Agricultural land use change has long been of a considerable interest to agricultural and resource economists. With a focus on western Lake Erie basin, the objective of this paper is to identify the determinants of recent land use transitions from non-agricultural land into cropland and investigating the environmental impacts of these recent changes in terms of agricultural nutrient runoffs. Specifically, we analyze the transitions from non-crop rural land into different crop rotation patterns using a mixed logit model with error components that relaxes the IIA assumption. We then investigate the environmental effects of these changes using an existing watershed hydrological model – Soil Water Assessment Tool (SWAT) by translating the land use changes into changes in nutrient runoff into Lake Erie, focusing particularly on dissolved phosphorus.By analyzing the operators' field-level decisions of transitioning non-cropland into crop production and its environmental impacts, our model provides useful insights into recent trends of expanding agricultural production. This work also contributes to the literature on coupled economic-ecological models by offering the first SWAT application on land use transitions into and out of agriculture.

I. Introduction

Over the past decade corn and other agricultural commodity prices have seen a remarkable rise, which in part can be attributed to rising demand for U.S. grain exports from emerging economies like China (Gloy, Hurt, Boehlje, & Dobbins, 2011), as well as the federal energy policies that greatly increased demand for corn through renewable fuels standards and tax credits (Nickerson et al., 2012). These recent macroeconomic trends could alter the returns to private operators and provide a strong incentive to expand and/or intensify their agricultural production practices. In particular, rising commodity prices would propel some operators to convert land from non-cropland into cropland. However, reports have revealed that despite an upward adjustment in rental payments, the total acres in the Conservation Reserve Program are shrinking in Nebraska and other states (Stubbs, 2012). These recent trends raise questions about operators' responses to the rising commodity prices at the extensive margin: where, at what rates, and what types of land are these non-agricultural land transitioning into cropland? Are these land use transitions occurring uniformly over space or they are affected by parcel-specific spatial characteristics? What are the implications for land conservation and agricultural non-point nutrient runoffs?

Agricultural land use change has long been of a considerable interest to agricultural and resource economists. Stavins and Jaffe (1990) are among the first to provide a theoretical framework on agricultural land use that posits that private landowners would choose the use that yields the maximum discounted present value of net returns. Using sample points from Natural Resource Inventory (NRI) from

1982 to 1997 and a nested logit specification, Lubowski, Plantinga, and Stavins (2006) estimated the agricultural land use transitions between forests, cropland, grassland, and urban uses to derive the costs of forest-based carbon sequestration. Lewis and Plantinga (2007) and Lewis, Plantinga, Nelson, and Polasky (2011) combine this econometric model with a GIS-based landscape simulation that predicts the spatial pattern of land use change and effects of afforestation subsidies on habitat fragmentation. Despite their useful insights, these models treat agriculture as a broad land use category and rely on NRI which is only a selected sample of agricultural land parcels. A recent study by Wright and Wimberly (2013) analyzed the recent grassland conversion into corn or soybean cropping in Western Corn Belt using pixel data from USDA NASS Cropland Data Layer (CDL).

The objective of this paper is to identify the determinants of recent land use transitions from non-agricultural land into cropland and investigating the environmental impacts of these recent changes in terms of agricultural nutrient runoffs. Specifically, we analyze the transitions from non-crop rural land into different crop rotation patterns using a mixed logit model with error components that relaxes the IIA assumption. In addition to allowing for more general, nonproportional substitution patterns through mixed logit specification, our economic model also improves on previous studies in the following ways: first, we break the agriculture crop choices into several sub-categories based on crop rotation patterns – continuous corn, continuous soybean, corn-soybean, and corn-soybean-wheat rotation; second, our dataset is based on field boundaries by use of USDA FSA’s Common Land Unit data, which, in contrast to the 50 meter pixels used by Wright and Wimberly (2013), corresponds to the behavioral unit of operator decision making; finally, we account for the rich spatial heterogeneity across the landscape by including various measures of parcel and location characteristics, such as crop pirces, distance to grain elevator, soil texture, starting land use, soil erosion factor, and corresponding weather conditions. We then investigate the environmental effects of these changes using an existing watershed hydrological model – Soil Water Assessment Tool (SWAT) by translating the land use changes into changes in nutrient runoff into Lake Erie, focusing particularly on dissolved phosphorus.

We apply this model to the Maumee River watershed, which is part of the western Lake Erie basin and the largest in the Great Lakes Region. Specifically, we overlay each field boundary in this watershed with CDL raster data using ArcGIS, from which we identify the dominant land use from 2006 to 2012. Since we focus on transitions from non-cropland into cropland, we only keep fields with dominant non-cropland use in 2006-2009, which leads to 19,360 non-agricultural rural fields that span a total of 600, 000 acres within 28 counties in Ohio, Indiana, and Michigan. Descriptive statistics reveal that, besides the transitions out over 20% of the total non-crop acres, roughly over 140,000 acres, transitioned into crop production in 2010-2012, with corn-soybean rotation, continuous soybean, and other crop rotation being the dominant.

Preliminary results using a multinomial logit specification reveal that, relative to parcels that remained in a non-cropland use, parcel-specific spatial characteristics matter in explaining the conversion and crop rotation decisions. Specifically, a larger parcel size increases the chances of converting into continuous corn or corn-soybean rotation, while a greater runoff potential leads to a higher probability of transitioning into corn-soybean-wheat rotation or a crop rotation that includes hay. The location characteristics, the initial non-cropland use and long-term weather conditions also affect the transition probability. Specifically, being in close proximity to agricultural output markets such as an ethanol plant increases the transitions into continuous corn or corn-soybean rotations, while an initial land use of pasture in 2006-2009 or a higher mean daily maximum temperature tend increases the likelihood of conversion to a crop rotation with hay. Although this preliminary model does not relax IIA assumption, these results suggest that it is crucial to analyze the effects of parcel-specific spatial characteristics in shaping the land use transitions into cropland.

We've developed, calibrated and validated SWAT model for simulation of flow, sediment, and nutrients from Maumee River basin. By integrating a crop choice model and a SWAT model, Secchi, Gassman, Jha, Kurkalova, and Kling (2011) analyzed the water quality impacts resulting from price-driven corn acreage expansion in the Upper Mississippi River basin. However, our model differs from this previous study that we focus on not only on the transitions among different crop choice or crop rotations within agriculture, but on transitions into and out of agriculture, which to our knowledge haven't been analyzed using the SWAT model. Gebremariam et al. (2013) have shown that SWAT is the best of the existing hydrological models in predicting the impacts of agricultural management practices and conducting climate change analysis. Preliminary results suggest that row crop management practices and frequent intense storms are primarily to blame for the dissolved phosphorus loss in the watershed. We will extend the results of both the spatial land conversion and SWAT models by integrating them to examine the environmental impacts of under baseline and alternative future scenarios, including future changes in commodity prices and potential increase in temperature and precipitation.

As U.S. agriculture strives to meet future production goals under unprecedented pressures, the challenge of maintaining food supply and operator livelihood without compromising environmental quality has become increasingly important. By analyzing the operators' field-level decisions of transitioning non-cropland into crop production and its environmental impacts, our model provides useful insights into recent trends of expanding agricultural production. This work also contributes to the literature on coupled economic-ecological models by offering the first SWAT application on land use transitions into and out of agriculture.

II. Integrated economic-biophysical modeling framework

a) Econometric model of land use change

Following Lubowski et al. (2006), we first estimate a multinomial logit model of land use change in which private landowners are assumed to choose the land use j among K uses that yields the highest expected net returns. Specifically, for parcels already in other agricultural land use which is non-cropland, we analyze the probability of switching into agricultural production and more specifically different crop rotation patterns. Non-cropland farmers could switch into continuous corn rotation, corn-soybean rotation, corn-soybean-wheat rotation, or other crops that involves crops like hay, and could choose to stay as non-cropland in pasture or forest use.

However, the multinomial logit model imposes the property of “independence of irrelevant alternatives”, which implies the ratio of the probabilities of any two choices is independent of the other alternatives. Following Lewis et al. (2011), we address this problem by estimating a random parameters logit model which allows the estimated parameters to vary individually, and thus leading to a more flexible substitution patterns than the proportional substitution implied by multinomial logit.

b) Biophysical model – Soil and Water Assessment Tool (SWAT)

SWAT is a partially lumped watershed model. It was developed by the U.S. Department of Agriculture’s (USDA) Agricultural Research Service (ARS) for simulating flow, sediment, nutrients and pesticides leaving agricultural watersheds (Arnold, Srinivasan, Muttiah, & Williams, 1998). Having evolved out of various hydrology, crop growth, and chemical transport models that were developed by ARS during the past 30 years (White et al., 2011), SWAT has primarily been used to assess the benefits of conservation practices aimed at reducing sediment, nutrient, and chemical runoff from agricultural fields (Tuppad, Douglas-Mankin, Lee, Srinivasan, & Arnold, 2011). For this reason, SWAT offers a wide range of alternatives for simulating conventional and conservation farming practices. SWAT's sub-watersheds are divided into hydrological response units (HRUs) that have unique combinations of slope, land use, and soil type within the sub-basin, and form the basic land segment for computing flow and transport.

III. Data

Crop Data

We use two types of data to generate the parcel-level time-series data on agricultural land cover, which are the United States Department of Agriculture (USDA) Cropland Data Layer (CDL) for Ohio, Indiana, and Michigan from 2007 to 2012, and parcel data collected from individual counties' tax assessor offices and/or GIS departments. Annual parcel-level data on crop rotation (2007-2009, 2010-2012, and 2007-2012) are created based on these types of data.

Urban Influence

Urban influence variables represent the relationships between urban and agricultural areas, which are expected to influence the potential economic value of agricultural land. In this study, these variables are specified in terms of distances to nearest large city which has at least 100,000 population, distances to nearest highway ramp and railway point. For example, parcels which are close to urbanized areas with large population potentially have higher chance to get developed for urban use instead of using for agriculture. Being proximity to transportation systems may encourage producing certain types of crop since it would reduce transportation costs for delivering agricultural products. We collected spatial shapefiles on cities, highway ramps, and railway points from U.S. Census TIGER/Line, then calculated the distances from parcel centroids to the nearest interested points.

Agricultural Market Influence

We used distances to nearest agricultural delivery points as agricultural market influence, including ethanol plants, grain elevators, and agricultural terminals. The locations of these places are related to transportation costs and market information both of which may affect the usage of land parcels. Spatial shapefile data on ethanol plants, grain elevators and agricultural terminal ports were obtained from the Ohio Ethanol Council (2012), the Farm Net Services (2012) and the Ohio Licensed Grain Handlers List (2012).

Agricultural Productivity

Naturally, the value of parcel land for agricultural use is associated with land productivity, climate/weather characteristics, and proximity to major streams and rivers, which endogenously decide the amount and quality of agricultural products. We have rich data for Land productivity characteristics mainly in terms of soil quality variables, including available water capacity (SOL_AWC), saturated hydraulic conductivity (SOL_K), amount of organic carbon in the layer (SOL_CBN), USLE soil erodibility factor (USLE_K), soil components (percentages of clay, sand, silt, and rock), particle-size class (texture), runoff potential class, hydrologic group, drainage class, farmland class, land capability classification (SOL_LCC), and the slope of land. The soil quality data were extracted from the Soil Survey Geographic (SSURGO) database from NRCS. The average and representative values of these variables were assigned to parcels using the spatial analysis tool in ArcGIS. Slope data is based on the National Elevation Data (NED) 30 meter from the National Geospatial Management Center, which provides the seamless mosaic of best-available elevation data. .

Climate variables include temperature and precipitation, and also the indication of areas with flood risk. We requested these weather data from PRISM and the National Flood Hazard Layer (NFHL) data originated by the Federal Emergency Management Agency. Related to flood risk, the proximity to major streams and rivers is characterized as the distance from the parcel centroids to the nearest major streams or rivers, using river data from Ohio Department of Natural Resources.

Economic Return

The variables of economic return for each rotation type we created were estimated for parcels by partially looking at the approaches Lubowski et al. (2006) used for his county-level estimates of annual net returns per acre for each major land use, and also based on our specific situations of study region and data availability. Since we do not have data for costs, the economic variables we estimated are not the net return, but revenue. Different from Lubowski et al. (2006) who used the net return for crops, pasture, forest, range and urban uses directly in the model, our research calculated revenue variable for the six rotation types we created based on the dominant land use trajectory from 2007 to 2012. First of all, revenue for the major land use types were estimated, including corn, soybean, winter wheat, pasture, hay, forest, developed (urban) uses. A variety of different sources for these land uses was used, basically including market, county, or state- level price and yield from USDA National Agricultural Statistics Service, state forest service from Ohio, Indiana, and Michigan, Forest Inventory and Analysis (FIA) Program of the U.S. Forest Service, and 2010 US census bureau.

Rotation types were created for two periods, 2007 to 2009, and 2010 to 2012. We are looking at the land use change in terms of rotation types from period 2007-2009 to 2010-2012, thus return variables of the six rotation types were calculated for the period 2007-2009. The basic logic for this calculation is: first, identifying the most common dominant land use trajectories across 2007-2009 for each rotation type in each county; second, aggregating the parcel size based on the identified trajectories to get the area share for each most common identified trajectory; third, calculating the return for each most common land use trajectory using the corresponding price and yield data for each land use type; lastly, using the calculated returns in previous step and also the percentage of acres to get weighted average return for each parcel.

Variable	Mean	Std. Dev.	Min	Max
Parcel size	42.9531	32.9407	0.0000	992.3800
Parcel size squared	2930.0520	6466.9470	0.0000	984818.1000
Slope	0.1074	0.4224	0.0000	21.0000
Distance to city with 100,000 people	59780.7200	22292.1500	4396.3980	109658.1000
distance to nearest ethanol plant	37185.1800	18774.3900	240.1260	90290.4500
Distance to grain elevator	7428.5480	3951.1970	95.9606	41378.3900
Distance to river and stream	3223.6470	2581.4010	0.0131	25272.5300
Soil available water capacity	0.1385	0.0664	0.0000	0.4000
USLE erodibility factor	0.3173	0.1099	0.0000	0.6400
Farmland class	2.1476	1.0711	0.0000	5.0000
Clay content	31.1231	12.7849	0.0000	70.9107
Sand content	25.7957	16.2519	0.0000	95.9000
Silt content	38.4372	12.7837	0.0000	70.0980
Rock content	1.7056	1.8206	0.0000	84.6998
Soil capacity class	1.3763	1.2806	0.0000	8.0000
Drainage class	3.2417	2.9066	0.0000	7.0000
Hydrology group	1.9175	1.1270	0.0000	4.0000
Average daily max temp 1981-2010	21.6103	0.3405	20.2559	22.2135
Average daily min temp 1981-2011	9.7080	0.5371	7.9328	11.6886
Average daily precipitation 1981-2012	2.9040	0.0981	2.6617	3.1649
Average daily degree days over 30 Celcius degree	0.0458	0.0075	0.0201	0.0650

Table 1: Summary Statistics

IV. Estimation Results

a) Multinomial logit results

	Continuous corn			Continuous soybean			corn-soybean			corn-soybean-wheat			other crop rotation		
Variable	Coef	Std Err	Sig	Coef	Std Err	Sig	Coef	Std Err	Sig	Coef	Std Err	Sig	Coef	Std Err	Sig
intercept	8.735	5.740		5.006	3.716		10.043	2.077	***	15.680	3.381	***	0.224	2.155	
return	0.005	0.003	.	-0.007	0.002	***	-0.001	0.001		-0.027	0.002	***	-0.002	0.001	***
mean_prec	0.752	0.877		-1.224	0.588	*	2.418	0.329	***	-1.517	0.598	*	-0.202	0.287	
mean_tmax	-0.672	0.282	*	-0.242	0.178		-0.772	0.100	***	-0.032	0.169		0.394	0.105	***
mean_tmin	-0.036	0.175		0.636	0.104	***	0.071	0.065		0.184	0.103	.	-0.845	0.074	***
pasture_06_09	0.274	0.175		-0.834	0.118	***	-0.432	0.065	***	-0.669	0.108	***	1.873	0.054	***
forest_06_09	-2.770	0.180	***	-2.519	0.125	***	-2.178	0.080	***	-2.070	0.128	***	-1.985	0.063	***
dist100k	1.15E-05	4.57E-06	*	-6.49E-06	2.91E-06	*	3.85E-06	1.71E-06	*	-4.37E-06	2.74E-06		1.51E-05	1.33E-06	***
distelev	-1.95E-05	1.79E-05		7.34E-06	1.17E-05		-1.57E-05	6.63E-06	*	-1.79E-05	1.10E-05		-1.17E-05	5.68E-06	*
distetha	-1.54E-05	5.07E-06	**	-1.42E-06	3.28E-06		-6.30E-06	1.75E-06	***	-1.76E-05	3.19E-06	***	9.13E-06	1.52E-06	***
distriv2	-8.81E-06	2.89E-05		-2.75E-05	1.73E-05		-4.81E-06	1.03E-05		4.42E-05	1.71E-05	**	-2.48E-05	9.11E-06	**
parcelsize	0.037	0.006	***	0.036	0.004	***	0.028	0.002	***	0.022	0.004	***	0.019	0.002	***
parcelsize_sq	0.000	0.000	***	0.000	0.000	***	0.000	0.000	***	0.000	0.000	***	0.000	0.000	***
clay_total_rep	-0.018	0.008	*	0.021	0.005	***	-0.005	0.003	.	-0.003	0.004		-0.009	0.002	***
rock_total_rep	-0.080	0.040	*	-0.002	0.014		-0.035	0.011	**	-0.016	0.014		-0.019	0.009	*
sand_total_rep	0.011	0.005	*	0.001	0.004		0.007	0.002	***	-0.006	0.003		-0.001	0.001	
silt_total_rep	0.013	0.009		0.017	0.007	*	0.005	0.003		-0.005	0.006		0.001	0.003	
slope_rep	-0.364	0.168	*	-0.119	0.094		-0.107	0.044	*	-0.097	0.071		0.005	0.029	
draincl_rep	0.066	0.046		0.038	0.033		0.040	0.017	*	-0.012	0.030		-0.046	0.014	**
farmcl_rep	-0.126	0.068	.	-0.183	0.048	***	-0.182	0.025	***	-0.018	0.040		-0.061	0.019	**
flood100y2	-0.033	0.209		-0.084	0.127		-0.048	0.079		0.038	0.131		0.029	0.066	
hydro_rep	-0.171	0.121		0.026	0.071		0.107	0.042	*	0.235	0.068	***	0.055	0.034	
runoffcl_rep	-0.115	0.060	.	0.036	0.039		-0.002	0.022		0.071	0.039	.	0.043	0.018	*
sol_awc_rep	0.109	1.305		-1.072	0.964		-0.012	0.475		-1.232	0.827		0.520	0.376	
sollcc_rep	0.036	0.088		-0.127	0.074	.	-0.018	0.033		-0.202	0.063	**	0.050	0.025	*
usle_k_rep	-0.310	1.012		-1.450	0.713	*	-0.183	0.367		0.535	0.643		-0.274	0.308	

Table 2: Multinomial logit models of transitions into various crop rotation patterns for non-cropland parcels

Note: the base alternative is staying in non-cropland use like forest and pasture. The significance levels are denoted as "***' and '**' denote significant at 1% level, '*' at 5%, and '.' at 10% level. Adjusted R-squared is 0.1807, the number of observations is 23,796, and the log-likelihood is -19657

We break the crop rotation choices into two periods: the pre period from 2006 to 2009 and the post period from 2010 to 2012, and focus on the crop rotation choices in the post period for the land parcels that are dominated by forest or pasture use from 2006 to 2009. The multinomial logit model of crop rotation choices for these 23,694 non-cropland parcels are presented in table 2. The results clearly illustrate the significance of parcel-specific attributes and location characteristics. We discuss them in several categories. First, parcels further away from city center have a higher likelihood to switch into continuous corn rotation in 2006-2010, while proximity to ethanol plants would lead to higher likelihood of land use transitions into continuous-corn and corn-soybean-wheat rotations relative to the existing non-cropland use. Second, the parcel-specific spatial characteristics are important determinants of which crop rotation a parcel will transition into if they switch from non-cropland to agricultural land use. For example, higher clay soil content would lead to transitions into corn-soybean rotations, but would decrease the chance of continuous corn rotation. Land parcel with steeper slope and lower farmland class would decrease the chance of more corn-intensive rotation patterns. Third, past history matters in land use change: pasture parcels in 2006-2009 would be more likely to transition into other crop rotations that involve more hay. Fourthly, the weather conditions matter as well: a higher average daily temperature would reduce the chance of corn-intensive crop rotations such as continuous corn or corn-soybean rotation. Finally, we constructed a variable of economic return, however, we got counterintuitive negative coefficients, which suggest the higher the net return from this particular rotation, the lower the probability it is selected. We argue this might result from the heterogeneous responses that vary parcel to parcel, and thus we estimate a mixed logit model that allows the parameter for the “return” variable to vary individually. The results from Table 3 confirms our conjecture that the economic return would lead to higher adoption probability but the effect varies by parcel.

b) Mixed logit model results

	Continuous corn			corn-soybean			corn-soybean-wheat			corn-soybean-wheat-hay			other crop rotation		
Variable	Coef	Std Err	Sig	Coef	Std Err	Sig	Coef	Std Err	Sig	Coef	Std Err	Sig	Coef	Std Err	Sig
random parameters															
return	0.0025	0.0003	***												
sd.return	0.0024	0.0011	*												
fixed parameters															
intercept	11.646	2.954	***	-1.261	2.679		11.399	3.019	***	3.080	2.626		8.173	2.583	**
mean_prec	-3.710	1.008	***	0.976	0.917		-3.731	1.030	***	-0.354	0.902		-0.913	0.887	
parcelsize	0.001	0.007		-0.007	0.006		-0.007	0.007		-0.018	0.006	**	-0.034	0.006	***
parcelsize_sq	-2.36E-07	4.72E-05		3.21E-05	4.28E-05		2.77E-06	5.24E-05		7.07E-05	4.27E-05	.	1.33E-04	4.22E-05	**
dist100k	-9.61E-06	4.78E-06	*	2.56E-06	4.28E-06		4.58E-06	4.73E-06		4.47E-06	4.25E-06		-6.64E-06	4.22E-06	
distelev	5.06E-05	2.10E-05	*	7.46E-06	1.87E-05		1.05E-05	2.07E-05		4.28E-06	1.83E-05		4.61E-06	1.80E-05	
distetha	1.31E-05	6.09E-06	*	1.47E-05	5.57E-06	**	1.07E-05	6.04E-06	.	2.70E-05	5.53E-06	***	1.37E-05	5.48E-06	*
distriv2	-1.55E-06	3.30E-05		3.59E-07	3.03E-05		1.89E-05	3.26E-05		-5.69E-05	2.99E-05	.	-9.53E-06	2.94E-05	
draincl_rep	-0.031	0.054		-0.037	0.046		-0.082	0.053		-0.107	0.045	*	-0.086	0.044	.
farmcl_rep	-0.148	0.087	.	-0.033	0.075		0.120	0.081		0.119	0.073		0.158	0.072	*
hydro_rep	0.135	0.131		0.219	0.118	.	0.384	0.128	**	0.270	0.115	*	0.096	0.113	
rock_total_rep	0.096	0.048	*	0.040	0.047		0.073	0.047		0.061	0.046		0.080	0.046	.
runoffcl_rep	0.124	0.077		0.121	0.069	.	0.194	0.076	*	0.229	0.068	***	0.082	0.067	
clay_total_rep	0.040	0.009	***	0.008	0.008		0.016	0.009	.	0.012	0.008		0.005	0.008	
sand_total_rep	-0.019	0.006	**	-0.003	0.005		-0.018	0.006	**	-0.011	0.005	*	-0.016	0.005	***
silt_total_rep	0.008	0.011		-0.007	0.009		-0.019	0.010	.	-0.018	0.009	*	-0.014	0.009	
sol_awc_rep	-1.593	1.632		-0.085	1.407		0.024	1.563		1.492	1.379		-0.583	1.365	
sollcc_rep	-0.141	0.116		-0.033	0.091		-0.209	0.108	.	0.000	0.087		-0.029	0.087	
usle_k_rep	-1.581	1.286		0.186	1.115		0.735	1.229		0.436	1.093		0.902	1.078	

Table 3: Mixed logit models of transitions into various crop rotation patterns for non-cropland parcels

Note: the base alternative is staying in non-cropland use like forest and pasture. The significance levels are denoted as “***’ and ‘**’ denote significant at 1% level, ‘*’ at 5%, and ‘.’ at 10% level. Adjusted R-squared is 0.0610, the number of observations is 23,796, and the log-likelihood is -19435

The parameters of the variable “return” – economic return of choosing this particular crop rotation is assumed to be normally distributed with the 25th percentile, median and 75th percentile as 0.00086, 0.00246, and 0.00406. Note that these are coefficients, not the willingness to pay estimates.

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