TITLE:

Ethanol plant location and intensification vs. extensification of corn cropping in Kansas

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Abstract

Farmers' cropping decisions are a product of a complex mix of socio-economic, cultural, and natural environments in which factors operating at a number of different spatial scales affect how farmers ultimately decide to use their land in any given year or over a set of years. Some environmentalists are concerned that increased demand for corn driven by ethanol production is leading to conversion of non-cropland into corn production (which we label as "extensification"). Ethanol industry advocates counter that more than enough corn supply comes from crop switching to corn and increased yields (which we label as "intensification"). In this study, we determine whether either response to corn demand -- intensification or extensification -- is supported. This is determined through an analysis of land-use/land-cover (LULC) data that covers the state of Kansas and a measure of a corn demand shifter related to ethanol production -- distance to the closest ethanol plant -- between 2007 and 2009.

Key words: ethanol, crop choice, renewable fuels

(1) Introduction

Farmers' cropping and land-use decisions are a product of a complex mix of socio-economic, cultural, and natural environments in which factors operating at a number of different spatial and temporal scales affect how farmers ultimately decide to use their land in any given year or over a set of years. A major impact on U.S. farmers' land-use decisions is expected to be rising demand for biofuels, due to fossil fuel price increases, energy policies favoring ethanol production, and a belief that biofuel production helps ease national energy security concerns (Borras, McMichael, & Scoones, 2010; Brown, 2011; Coyle, 2007; Goldemberg, 2007; Verrastro & Ladislaw, 2007). Many scholars and policy analysts express concern about the possible socio-economic and ecological consequences of biofuel production. Among the concerns is that farmers are responding to the increased demand by bringing new land into production, what we term an "extensification response". The effects of this response are thought to include increasing carbon dioxide levels, due to land conversion, and loss of wildlife habitat and biodiversity as farmers potentially take land out of the Conservation Reserve Program (CRP) and other reserve programs. Increasing land ownership concentration, which has been a steady phenomenon for decades, represents a social concern relating to biofuel feedstock crop cultivation. Such concerns about the extensification response are typified by Lester Brown and Jonathan Lewis who write, "Here in the United States, farmers are pulling land out of the federal conservation program, threatening fragile habitats" (Brown & Lewis, 2008). Those entities representing interests linked with the expansion of the ethanol industry often claim the opposite – increases in the productivity of corn production, the main crop used for U.S. ethanol production, have allowed for greater ethanol production, while saving land from conversion into corn production. This claim is supported by data that show total corn production in the US doubled from 1980-2009, yet over the same period, corn acreage increased only three percent (Renewable Fuels Association, 2011). As important, ethanol production advocates claim that greater corn production stems from switching from other crops into corn. We identify this crop switching response as the "intensification response".

In recent years, research has begun to address this debate with a number of studies that use observations of land-use and land-cover change (LULCC). They differ, however, in terms of scope, study area, and methods, making comparisons and general conclusions difficult. These differences are highlighted here in a brief review of this growing literature. Iowa has attracted a lot of attention from researchers, given the importance of corn and ethanol production in the state. Secchi, Kurkalova, Gassman, and Hart (2011) produce a baseline model of crop rotations for the state based on the USDA National Agricultural Statistical Service (NASS) Cropland Data Layer (CDL) for a series of years and an understanding of optimal management practices under given corn price regimes. They predict changes in LULC, crop rotation, and tillage practice, including the environmental impact of these choices, across the state under different price scenarios. Through the use of the Environmental Policy Integrated Climate (EPIC) model, resulting environmental impacts were assessed on what the authors refer to as the extensive margin (CRP lands with no cropping) and the intensive margin (lands currently under row crop agriculture). The authors predict that land already in row crops would be converted to more intensive corn cropping (continuous corn from year to year) before any land in CRP would be converted to any corn production because of CRP land's marginal status. Stern et al. (2008, 2012) also focus on Iowa. In their 2008 paper, they assess "intensification" and "extensification" of corn cropping in Iowa from the year 2001 to 2007, using a combination of county level NASS data and the CDL. They conclude that no new areas are being put into production, with any total production increases coming from intensification. In an extension of this work, Stern, Doraiswamy, and Hunt (2012) affirm that intensification and extensification differ across regions, with extensification occurring mainly in southern counties where agriculture had room to expand.

Mueller and Copenahaver (2009) take a sub-state approach in their work in Illinois, focusing on the LULCC dynamics purely within a 45-mile radius of two ethanol plants in the state. They use the 2006-2008 CDLs to explore the impact of the plants on corn intensification vs. extensification. They determine that the two ethanol plants had no effect on corn extensification and that intensification (measured only in terms of yields) could have supplied all the added demand for corn possibly generated by the two plants going online. Wallander, Claassen, and Nickerson (2011), a USDA report, explores the continental US using farm-level data derived from the Agricultural Resources Management Survey (ARMS) surveys of corn and soybean farmers on the acreage and crops planted from 2006 to 2008. They also use aggregate data at the county level to map crop-type changes for the US. They conclude that a number of dynamics constitute the overall increase in total corn production during the study period: corn and soybean acreage came from a reduction in cotton, cropland replacing uncultivated hay, an increased use of double cropping, and an increase in use of inputs.

Finally, some recent, prominent studies address the intensification vs. extensification issue over greater spatial and temporal scales. Plourde, Pijanowski, and Pekin (2013) assess crop rotation patterns in the central US using the CDL from 2003 to 2010. They divide the study period into two sub-periods: 2003-2006 and 2007-2010. They find that the area under corn and soybean rotations decreased, while the area under corn-corn rotations increased. They also assess the change in crop footprint for the 8-year period, noting that the footprint of corn and soybeans remained relatively the same until 2007, thereafter the footprint of corn increased significantly, while soybeans decreased. Wright and Wimberly (2013) use the CDL to assess LULCC trajectories specifically from grassland to cropland between 2006 to 2011 in North Dakota, South Dakota, Nebraska, Minnesota, and Iowa. In this study, "grassland" is a general class that combines the following grassland-related classes in the CDL: native grassland, grass pasture, grass hay, fallow/idle cropland, and pasture/hay. They conclude grassland was converted to corn/soy between 1 % and 5 % annually, with the highest conversion in the Dakotas. In total, 530,000 hectares were converted, much of it from marginal lands with high erosion risk and vulnerability to drought. The authors suggest that corn production is expanding outside of the normal "corn belt" because farmers in more dry and western areas are willing to accept drought risk in exchange for higher prices of corn and soy.

Wright and Wimberly (2013) part strongly from all the other studies reviewed here by claiming that increased corn/soy production is coming from extensification, not intensification. This particular study generated a rebuttal from Geoff Cooper, a contributor to the land-use section of the website of the Renewable Fuels Association (Cooper, 2013). His main criticism of the study is that the loss of grasslands (from the CDL) does not match the picture drawn from USDA crop statistics showing that total cropland acreage for the five states is actually at the lowest level since 1995, implying that increased acres of soybean and corn stem from crop intensification, not extensification. (Rather than rely solely on Cooper's (2013) rebuttal, we independently confirmed his findings with our own examination of USDA data.) Moreover, Cooper criticizes the accuracy of the CDL, citing the USDA's own assessment that its grassland classifications, which include a number of different subclasses, show large inaccuracies. (For our analysis, the accuracy levels in the CDL for mapping crop types grown for grain such as corn, soybean, winter wheat and sorghum, are mapped relatively accurately in Kansas with errors of omission and commission below 15 %; see U.S. Department of Agriculture (2010b) for CDL-related reports.)

The present study contributes to this exploration of LULCC vis-à-vis the question of intensification vs. extensification of agriculture. In our empirical approach, we construct a primary independent variable relating to the top demand for corn at the county level – distance to the closest ethanol plants – and two separate dependent variables representing the intensification and extensification of corn cultivation between 2007 and 2009. We then explore the relationship between the independent and dependent variables. We also draw on data from 151 Kansas farmer interviews conducted during the summer of 2011 (Gray & Gibson, 2013) to deepen our understanding of the human-environmental processes that lead to the relationships we find in our statistical analysis.

Our study area is the state of Kansas. While not currently a biofuel "hotspot" like Iowa (Secchi, Kurkalova, et al., 2011), Kansas is part of the US Great Plains states, which as a whole produces the feedstocks for approximately 64 % of US ethanol production. Kansas produces approximately 5% of the total production of the Great Plains (calculated from Renewable Fuels Association (2012)). Like many other corn producing states, however, Kansas is also a major producer of beef, among the top four states producing beef cattle from feedlots, comprising another major demand for corn in Kansas (Clause, 2012).

(2) Methods

Farmers' decisions to plant a crop depend on myriad factors. In addition, the farmers' choices to intensify their crop rotations, or bring additional land into crop production, is affected by local markets (Hennessy, 2006; Pannell et al., 2006). With the further development of the ethanol market and increased capacity of ethanol production in Kansas over time, it is likely that Kansas farmers may have responded to the increased demand for corn locally, by intensifying corn production on existing cropland and/or bringing new land into crop production.

We posit a number of different explanatory factors—distance to an ethanol refinery, presence of livestock, crop yield, land characteristics and weather—that affect the decision to intensify or extensify land-use for corn production. We outline these factors in the following subsections below.

(2.1) Corn Extensification and Intensification

We created a unique value-added dataset of land-use/land-cover across the state of Kansas for all years representing field-level crop coverage, based on the USDA NASS

Cropland Data Layer (CDL) classifications for 2007 to 2009 (U.S. Department of Agriculture, 2010b). We generalized the CDL data, using a minimum mapping unit of six pixels or approximately five acres; this reduced single pixel speckling by smoothing the data to allow for more accurate detection of crop and land-use changes over the study period. From these data, we create two dependent variables representing sequences of LULCC that are consistent with the two cropping responses representing the subject of our study. The first response is extensification. To arrive at this variable, we calculate the total area in each county where the following LULCC trajectory took place from 2007 to 2009: non-cropland use in 2007, corn cultivation in 2008, and corn cultivation in 2009. This approach targets areas that were not initially cultivated in 2007 but then were planted to corn in 2008 and 2009. We then divide this area by the total rural area in the county to arrive at the percentage of land that underwent corn extensification. We repeat this procedure for all areas where the LULCC sequence is consistent with intensification: non-corn cropland in 2007, corn cultivation in 2008, and corn cultivation in 2009. This approach targets cropland that was cultivated, but not for corn in 2007, then converted to corn in 2008 and 2009. Again, we divide this total area by the total rural area in the county to arrive at the percentage of land that underwent corn intensification. To induce normality for the statistical analysis, we transform both dependent variables by taking natural logs.

(2.2) Explanatory Factors

We also construct variables to represent the primary locational demand shifters for corn at the county level: ethanol plants and feedlots. To measure the influence of ethanol plants, we obtained a map of plants from the Kansas Department of Agriculture (2010b) and calculated the Euclidean distance from the county centroid to the nearest ethanol refineries for each of the 105 counties in Kansas (see Figure 1). As of 2007, there were 10 ethanol refineries in operation. Two additional refineries (in Rice and Republic counties) came online in May 2008. These last two were included, assuming local demand for corn grain to produce ethanol would have been present as the plants were under construction. In addition, we examine an alternative version of this distance variable as the Euclidean distance from the mean center of cornfields in each county to the nearest ethanol plant; examination of this alternative version does not generate meaningfully different estimation results. Therefore, we do not show or interpret these results. We also explore ethanol plant locations in neighboring states. However, we find that their inclusion in the calculation of the distance to the closest ethanol plant remains the same for each county.

In order to isolate the effect of ethanol plants on land use choices, we incorporate control factors into our statistical analysis. To control for the likely significant demand for corn as a livestock feedstock, we include the total head of cattle for each county based on 2007 data (U.S. Department of Agriculture, 2012) as an additional covariate. To control for the possibility that intensification and extensification of corn acreage occurred primarily in counties that have historically produced corn in large volumes, we include a variable measuring the average yield of corn per acre by county over the years 2004 to 2007. The average corn yield serves as a proxy variable to capture the productivity of corn production in a given county. This explanatory variable helps to capture management and environmental characteristics that are not directly modeled and for which county-level data are not be available. We calculate the variable using corn yield data at the county level as reported by the U.S. Department of Agriculture (2012).

We also include these control factors: the standardized index of precipitation (SPI), the average slope of the land used for crop production, the percent of land in land capability classes 1 to 3, and a set of geographic dummy variables. The SPI is a drought index that is standardized so that the relative frequency of precipitation events has the same occurrence, allowing for spatial comparisons (McKee, Doesken, & Kleist, 1993). The index can be computed at multiple timescales depending upon the application. We apply a 12-month SPI calculated from the cumulative density of precipitation at the timescale of interest by fitting a gamma distribution to the observed precipitation values (Logan, Brunsell, Jones, & Feddema, 2010). We pull landscape characteristics, including land capability class and slope, from the Soil Survey Geographic (SSURGO) database to proxy for the productivity of arable land in the county (U.S. Department of Agriculture, 2010a). The land capability class (LCC) provides a classification for landscapes on their ability to produce common cultivated crops and pastureland. Our constructed variable represents the area of arable land planted to classes 1 to 3, which represent the most productive crop land in a county. The other land characteristic is the average slope of all arable land. Arable land within a county is defined as land under land capability classes 1 to 6. We construct county level averages for each landscape variable by calculating spatially weighted averages across soil polygons in the SSURGO database using the percent of area of arable land represented by each soil polygon as the weighting factor.

Finally, to capture any additional heterogeneity across the state, we include regional dummy variables in the statistical analysis. The dummy variables represent the nine agricultural reporting districts used by NASS. These reporting districts are defined groupings of counties in each state, by geography, climate, and cropping practices (U.S. Department of Agriculture, 2012).

Table 1 provides summary statistics for all of the variables used in the statistical analysis.

<insert Table 1 about here>

(2.3) Empirical Model

We empirically explore the trajectory of land use chosen by farmers operating in county *i*. For this exploration, we model the relationship between corn extensification or corn intensification, each denoted by y_i, and a set of explanatory factors, collectively denoted by x_i. We assume that a linear form captures this relationship:

$$y_i = \beta' x_i + \varepsilon_i, \qquad (1)$$

where β is a vector of estimated parameters and ε_i is a mean zero, normally distributed disturbance term, i.e., error term. We estimate a separate relationship for each of the two dependent variables.

We approach the estimation of equation (1) aware that spatial relations may affect the dependent variables, as well as the error term. Spatial autocorrelation in a regression framework typically manifests itself in different ways. Error terms can be correlated among themselves, which gives rise to so-called nuisance spatial autocorrelation and coefficients that are not efficient in the statistical sense (Luc Anselin & Rey, 1991). Alternatively, the dependent variable can be spatially autocorrelated, leading to substantive autocorrelation. When this form of the problem is present, OLS regression coefficients are biased. Spatial autocorrelation in our study likely arises due to spillover effects from local markets, agricultural policies (e.g. water limitations, conservation policies), and environmental factors (e.g., climate, weather) that span multiple counties. We test for this spatial autocorrelation using Moran's I and a Lagrange Multiplier Test for spatial dependence in the dependent variable and error process, ε_i, following Anselin (1988) and Pace and LeSage (2009). We describe the spatial weights matrix in more detail below. The results of the tests, as shown in Table 2, indicate the presence of both spatial dependence in the dependent variables and the error process of the model given by equation (1). The test results confirm that spatial autocorrelation presents estimation problems for the model given by equation (1) and that spatial autocorrelation comes through both the dependent variables and error process. Given these test results, we neither report nor interpret the OLS estimation results.

<insert Table 2 about here>

To address spatial autocorrelation, we adopt a general framework following Pace and LeSage (2009) that incorporates both spatial autocorrelation in the dependent variable and the error process. In this framework, we let W denote the spatial weights matrix capturing the spatial relationships between neighboring counties, which reflects the spatial dependence. Given this notation, the expanded model takes the following form:

$$y_i = \rho W y_i + \beta' x_i + \varepsilon_i \text{ , with } \varepsilon_i = \theta W \varepsilon_i + u_i \text{ ,} \tag{2}$$

where ρ and θ are spatial dependence parameters to be estimated and u_i is a mean zero, independent, normally distributed error term. We create the spatial weighs matrix as a first order contiguity matrix. That is, the spatial weights matrix, W, is a 105 by 105 matrix, where each row represents a particular county and each column represents a neighboring county. For each county bordering the county represented by a given row, we assign a value of 1 in the appropriate column; otherwise, we assign a value of 0. We then row standardize the spatial weights matrix so that the rows sum to 1, which facilitates estimation (Pace & LeSage, 2009).

We use MATLAB to estimate all models and conduct all the statistical tests. We estimate the models using the method of maximum likelihood (Pace & LeSage, 2009).

(3) Results

As Table 1 shows, from 2007 to 2009 farmers devoted much more land in Kansas to the intensification of corn production than to extensification. On average, 0.79 percent of counties' rural land fell into the category of intensive corn production as of 2009 while extensive corn production occurred on only 0.16 percent of rural land as of that year.

Table 3 presents regression estimation results for the spatial models following the specification given by equation (2). Each specification seems to provide an adequate explanation of the variation in corn extensification and intensification, with R^2 values around 0.60. Furthermore, the spatial autocorrelation parameters for the dependent variable and error process are significant for the extensification model. The spatial autocorrelation parameter for the dependent variable is significant for the intensification model. Thus, the processes underlying the models exhibit spatial dependence; thus, the more general framework given by equation (2) is appropriate, helping to avoid potential bias and inconsistency in parameter estimates.

<insert Table 3 about here>

We first interpret the effects of the control factors. Of these, certain slope coefficients prove statistically significant. At least one of the regional dummy variables is significant in each model, implying regional heterogeneity. In the corn extensification model, the coefficient on the precipitation index is significant at the 10 % level and negative in sign. This result indicates that as counties experience relative aridity, more non-corn land is brought into corn production. In both models, the coefficient on average corn yield is significantly positive. The percent of land in LCCs 1 to 3 is significant at the 5 % levels in the corn intensification model. With a focus on corn intensification, these two results jointly indicate that counties with more fertile ground suitable to crop production are likely to exhibit more intense corn production, as farmers can generate higher yields with fewer inputs. Interestingly enough, the amount of livestock does not play a significant role in corn intensification, perhaps due to the availability of distiller's dried grains (or DDGs) as a feed substitute for corn.

Lastly, we interpret the results relating to ethanol production. Regardless of the dependent variable, the coefficient on the distance of a county center from the nearest ethanol plant is significantly negative. Thus, as the distance between a county centroid and the closest ethanol refinery decreases, *both* corn extensification and corn intensification increases. In order to interpret the magnitude of these links from ethanol production to corn cultivation, we recall that the dependent variable is in natural log. Thus, an intuitive way to assess the marginal effect of a change in distance is to examine the elasticity, which is equal to the coefficient estimate (β) times the level of the explanatory variable. In this case, a one percent decrease in the distance to an ethanol plant when the county centroid is 25, 50, or 75 miles from the closest refinery, results in a 4 %, 8 %, and 11 % increase in the intensity of corn intensification, respectively. Similarly, a one percent decrease in the distance to an ethanol plant when the county centroid is 25, 50, or 75 miles from the closest refinery, results in a 5 %, 10 %, and 15 % increase in corn extensification, respectively.

(4) Discussion

This study shows that during the 2007-2009 period, while farmers planted more corn on already existing cropland (intensification) than on non-cropland (extensification), both processes are significantly correlated with distance to ethanol plants.

Interviews with Kansas farmers illuminate some of the reasons why both processes may be at work across the state (Gray & Gibson, 2013). It bears mentioning first, however, that farmers are generally dedicated to their crop rotations and rarely make wholesale changes. Their rotations are developed over many years, entail settled routines and practices, employ existing equipment and are adapted to local precipitation levels and soil conditions. In short, rotations offer farmers a good mix of reliability and income potential. Based on interviews, those farmers who recently added corn into their rotations talk about their decisions as "trying it out" or "experimenting" with it.

One major factor arose in interviews explaining that farmers would respond to increased demand for corn with intensification (Gray & Gibson, 2013). Conservationists may worry that rising corn prices drive farmers to convert fragile soils that are protected by enrollment in the CRP to crop production, but farmers explained why they are unlikely to make such a change. Farmers' commitments to the CRP program derive from their need to control for the uncertainty that comes with forces beyond their control—weather and prices—and from their identification as good stewards. The CRP program provides erosion control and improved water quality, and it protects habitat for wildlife. Participation in the CRP program also delivers regular and predictable CRP payments, a hedge against the volatility of global markets where prices fluctuate minute-to-minute. And CRP contracts use penalties to discourage early withdrawal from the program. Such are the benefits of maintaining CRP enrollment that farmers tell us they re-enroll their land if allowed to do so, and if denied re-enrollment, several farmers say that they would convert the land to pasture or hay ground instead of to grain crops. Some farmers even say that the land held in CRP should never have been farmed at all. Good farmers, they tell us, are good land stewards; they see participation in the CRP program as an expression of environmentally responsible behavior.

At the same time, interview data reveal that extensification of corn production has occurred in Kansas agriculture and some farmers have, in fact, converted their CRP acreage to cropland at the end of their contracts (Gray & Gibson, 2013). The rate of extensification might therefore increase as more contracts expire. However, this decision means that farmers must sacrifice valuable features and judge that the rewards will exceed short and long-term costs. Only a few farmers in our interview sample expressed an interest in converting CRP land to crops after the expiration of their contracts. Of these, some farmers gave the income potential of grains compared to the modest payments from CRP as a reason. Still farmers know that the fragility of CRP land means productive capacity is limited, a factor that militates against bringing CRP land under cultivation. Another reason farmers offered for extensification of corn onto CRP land is land scarcity. Rising land prices in recent years have made it more difficult for farmers to expand their holdings, yet expansion is highly desired by nearly all farmers in the interview sample. Many farmers told us that it is difficult even to rent additional acreage due to intensified competition for limited land, leading to higher rents. Where CRP land has been converted to corn production, Kansas farmers likely considered both factors: better income from grain and desires for expansion in a tight land market. Others have noted that farmers ultimately make narrow economic decisions on whether to enroll land in CRP. For example, Konyar and Osborn's (1990) study showed that expected net returns, with and without participation in CRP, affect the likelihood of CRP enrollment, and Isik and Yang (2004) also confirmed that more land is enrolled as production costs rise and/or crop revenues drop.

Finally, interviews reveal that ethanol plant location might not affect planting decisions at all (Gray & Gibson, 2013). The majority of farmers in our interviews sold their corn to the local grain elevator rather than directly to ethanol plants. Moreover, farmers state that they rarely know whether their corn goes to a feedlot, an ethanol plant, or another buyer. In other words, intensification or extensification of any crop is a decision made independently of its ultimate use. Instead, analysis of our interviews reveals that farmers' planting decisions are shaped by farmers' identification with good stewardship along with weather and price fluctuations. It also indicates that the kind of crop grown is less important than the minimization of the uncertainty introduced by a change in crop choices and rotations.

As part of our discussion, we identify important limitations of our study that should be addressed in future research. First, the kind of crop and rotation that is the target of the study is but one narrow way of defining intensification and extensification. Corn is the major crop, but not the exclusive crop, used for ethanol production in the state of Kansas. Sorghum, and even wheat, can be used interchangeably in ethanol production. Thus, future work should construct dependent variables that reflect the cultivation of these crops when considering intensification and extensification in response to demand for biofuel feedstock crops.

As a related point, future studies may also need to account for crops, such as switchgrass, grown as feedstocks for second-generation biofuels. As cellulosic ethanol production comes on line, it has been predicted that the first response of farmers will be to grow those crops on existing cropland rather than on non-cropland (e.g., (Swinton, Babcock, James, & Bandaru, 2011). Analysis of our interviews data supports this prediction. On the other hand, farmers could determine that perennial crops grown for the biofuel industry may be more suitable for production in fragile areas. Thus, consideration of second-generation biofuel feedstock crops is an area ripe for investigation.

Also, our study does not take into account the precise time an ethanol plant came online or ethanol plant capacity. Future studies should also explore the effects of using distance-to-ethanol-plant measures considering the road network, instead of simple Euclidean distance measures.

In addition, we consider only a limited number of years: 2007 to 2009. (We choose these years because CDL data for Kansas is only available beginning in 2006). While this limitation is typical of other studies in the literature, as more LULCC data become available, we hope to examine land change dynamics over the expanded timeframe of 2000 to 2014, which permits us to investigate much more variability in cropping decisions and how they relate to various shocks in the human realm (e.g., price shocks) and the physical realm (e.g., recent droughts). As we expand this work over longer periods of time, and explore alternative measures of distance to ethanol plants, fixed effects panel models could be employed to capture both spatial and temporal effects.

Moreover, we cannot explain the precise mechanisms behind the relationships linking ethanol production to land use choices. Specifically, our analysis is vulnerable to reverse causality. In other words, it may be that our primary estimates might be revealing that ethanol plants locate where the supply of corn is greater, or at least potentially greater, following construction of the ethanol plants. This concern is mitigated by the fact that our dependent variable reflects LULCC trajectories played out over a three-year period. Moreover, ethanol plant location is not simply determined by the location of input factors like cornfields and feed lots, the latter being a major market for DDG, an ethanol by-product; plant location is determined by a mix of numerous socio-economic and transportation variables (Haddad, Taylor, & Owusu, 2010).

As a related point, our analysis collapses two relationships into one. Clearly, farmers do not directly respond to the distance to the nearest ethanol plant. Instead, distance to the nearest ethanol plant may be viewed as influencing the profit margin associated with corn production, and thus it is the profit margin on corn that affects farmers' land use decisions. If we could directly measure the profit margin on corn, we could estimate both of these relationships in order to identify the underlying structure of the agricultural system and the role of ethanol production in this system. Since we cannot directly measure the profit margin on corn, when estimating farmers' land use choices, we simply replace this profit margin with the distance to the nearest ethanol plant so that we are still able to capture at least the indirect effect of ethanol production on cropping choices. This reduced form estimation still allows us to identify the influence of ethanol production. Future research should seek to gather direct measures of profit margins in order to estimate the underlying structure.

Additionally, our statistical analysis primarily explores the link from a time-invariant factor – distance to the nearest ethanol plant – to dependent variables constructed from changes over time in LULC. Thus, we must interpret more closely our primary explanatory factor. Over the sample period of 2007 to 2009, corn prices rose substantially. Most likely, this price increase influenced profit margins differently based on the proximity of agricultural land to ethanol plants. In particular, this price increase was more profitable for farmers located closer to ethanol plants. From this perspective, our primary explanatory variable represents an interaction or mediating factor between the price increase experience during the sample period and the proximity to ethanol production. Given this interpretation, both the dependent variables and the primary explanatory factor are derived from changes over time.

Lastly, studies based on observations and modeling of future scenarios point to the predominant response of farmers to intensify crop production over extensification. Thus, environmentalists might take comfort in the unlikely possibility of agricultural production pushing strongly into fragile areas. Nevertheless, a substantial environmental concern remains relevant since activities in the zone of intensification have their own deleterious effects on the environment, including eutrophication of water bodies and increased pesticide/herbicide use, among other effects (Donner & Kucharik, 2008; Donner, Kucharik, & Foley, 2004; Landis, Gardiner, van der Werf, & Swinton, 2008; Langpap & Wu, 2011; Secchi, Gassman, Jha, Kurkalova, & Kling, 2011). Thus, analysis should not focus exclusively on the environmental concerns relating to extensification.

(5) Conclusion

Our study is the first from Kansas to explore LULCC as it relates to ethanol plant location. It employs a county-level approach. For each county, we construct an independent variable representing the distance to the nearest ethanol plant, along with a control factor representing the presence of feed cattle, the primary consumers of corn in the state. For dependent variables, we exploit observational data representing farmers' land-use decisions (a value-added CDL) across the entire state and over a set of years (dependent variables) and we quantify the area of intensification vs. extensification response. Even though our sample period spans only three years, 2007 to 2009, we identify a significant effect for ethanol production on both the intensification and extensification of corn planting.

Public discourse on the issue of the impact of ethanol plants on LULCC currently pits supporters of the ethanol industry against environmental interests, the former arguing that farmers respond to increased demand with intensification, and the latter arguing that extensification is the response and should be a concern. Our results, which show that both responses are potentially in operation simultaneously, can help incrementally re-focus this debate on the effects of biofuel-induced land-use change on both the intensive and extensive margin. Clearly, continuous cropping and crop switching account for much of increase in total corn production, but our results also show the significance of corn production on the extensive margin. This result suggests that environmental awareness and action would be more effective if both sides focused attention on mitigating the deleterious effects of corn cultivation, especially continuous corn, regardless of whether it is occurring on the intensive or extensive margin. A collective effort across private and government organizations representing farmers, the ethanol industry, and communities should focus on understanding those impacts and working on various governance strategies to mitigate them.

(6) Tables

Table 1. Summary statistics of variables included in regression analysis, 101 Kansas counties, 2009.

	Mean	Standard Deviation
Dependent Variables:		
Corn Intensification (% land area)	0.79	0.80
Corn Extensification (% land area)	0.16	0.19
Independent Variables:		
Distance to Refinery (miles)	39.67	20.01
Heads of Cattle (tens of thousands)	4.78	8.24
Corn Yield (bu per acre)	141.47	34.94
Precipitation index	0.61	0.72
Percent of Land in LCC 1 to 3	71.09	14.30
Slope (%)	3.98	1.69

Table 2: Spatial Diagnostic Tests on OLS Regression Residuals

Test	Corn Intensification		Corn Extensification	
	Test Statistic	P-Value	Test Statistic	P-Value
Moran’s I	5.34	0.000	6.91	0.000
LM Test Spatial Error	9.47	0.002	19.26	0.000
LM Test Spatial Lag	118.32	0.000	63.84	0.000

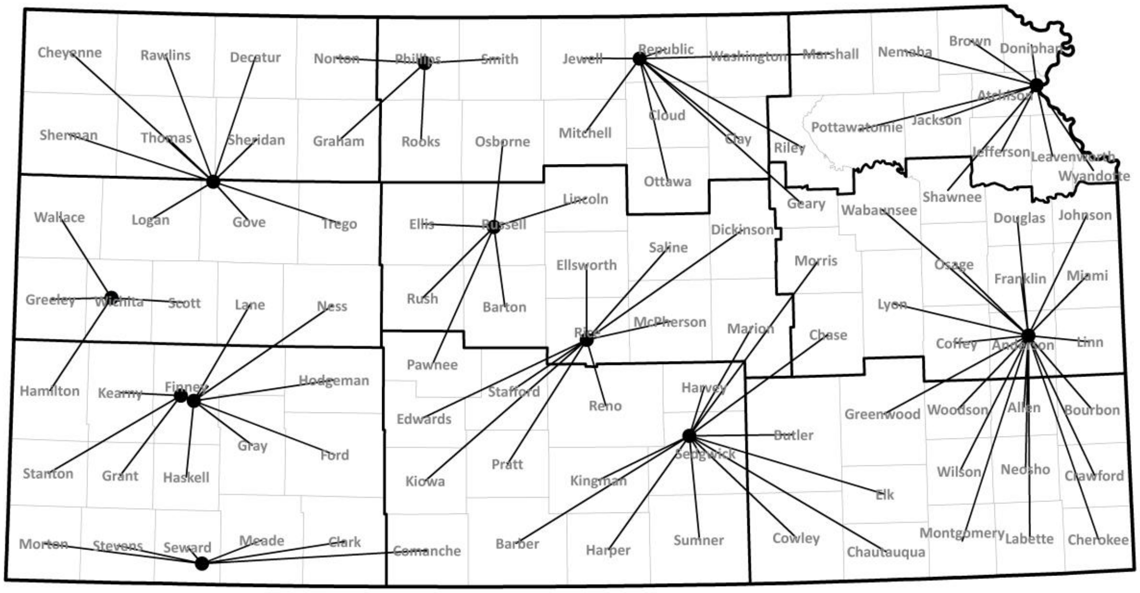
Table 3: Spatial Model Estimation Results for Corn Extensification and Intensification

Explanatory Variable	Corn Intensification Coefficient Estimate (Standard Error)	Corn Extensification Coefficient Estimate (Standard Error)
Intercept	-5.37***	-6.15***
	(1.51)	(1.56)
Distance to Refinery (miles)	-0.15**	-0.20***
	(0.066)	(0.067)
Heads of Cattle (tens of thousands)	0.025	0.012
	(0.016)	(0.016)
Precipitation Index	-0.49	-1.11*
	(0.56)	(0.58)
Corn Yield (bu per acre)	0.0077*	0.0082**
	(0.0041)	(0.0040)
Percent of Land in LCC 1 to 3	0.024**	0.014
	(0.010)	(0.010)
Slope (%)	-0.070	-0.040
	(0.11)	(0.10)
NASS Ag Reporting District 20	1.36**	2.19***
	(0.61)	(0.64)
NASS Ag Reporting District 30	-0.83	-0.66
	(0.52)	(0.57)
NASS Ag Reporting District 40	0.59	0.52
	(0.53)	(0.59)
NASS Ag Reporting District 50	-0.52	-0.21
	(0.51)	(0.55)
NASS Ag Reporting District 60	0.35	0.63
	(0.50)	(0.55)
NASS Ag Reporting District 70	0.67	0.93
	(0.58)	(0.64)
NASS Ag Reporting District 80	0.71	1.09*
	(0.56)	(0.61)
NASS Ag Reporting District 90	0.59	1.18*
	(0.61)	(0.65)
Spatial Lag (ρ)	0.45**	0.33**
	(0.16)	(0.14)
Spatial Error (θ)	0.24	0.48***
	(0.23)	(0.17)
	Fit Statistics	
Log-Likelihood	-42.90	-40.61
R^2	0.60	0.62
Number of Observations	105	105

Note: *,**, and *** denote statistical significance at the 10, 5 and 1 percent levels.

(7) Figures

Fig. 1. Map below illustrates a) ethanol plant locations (dots), b) the minimum distance from each county centroid to the nearest ethanol plant location (solid straight lines), and c) Kansas's 9 NASS reporting districts.



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