Spatial Interactions in Habitat Conservation: Evidence from Prairie Pothole Easements

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Introduction

The importance of the spatial arrangement of conservation activity—including both the size of protected habitat parcels and proximity to other protected habitat—is widely recognized in the ecology and conservation planning literature (Williams, Revelle, and Levin 2005). Consistent with this literature, protecting spatially contiguous habitat is one of the criteria used by public and private conservation agencies when allocating scarce conservation dollars.[1] There is a large literature on systematic conservation planning that explores the importance of incorporating ecological benefits, land costs, future risk of conversion, and the spatial arrangement of conserved parcels (Polasky and Segersen 2009). Recent research has also pointed out challenges associated with conservation planning in regions dominated by privately held land where conservation agencies cannot unilaterally dictate the location of conserved parcels (Polasky et al. 2012; Banerjee and Shogren 2012). This is particularly problematic in regions where many private landowners have little incentive to coordinate conservation activity (Parkhurst and Shogren 2011).

In this study, we investigate the extent to which agencies purchasing conservation easements in the prairie pothole region of western Canada are able to protect contiguous habitat. We are primarily interested in identifying the role of endogenous spatial interactions between protected habitat areas. Conservation easements may be placed on habitat adjacent to previously protected areas if conservation agencies attempt to capture ecological benefits arising from contiguous protected habitat. Interactions between neighboring landowners might also lead to spatial spillovers between conserved areas due to landowners learning about easements from their

[1] For example, Oregon's Conservation Reserve Enhancement Program (CREP) offers a one-time bonus if a sufficient quantity of neighboring land is enrolled in the program (Grout 2009; Hanley et al. 2012). The Nature Conservancy focuses conservation efforts within priority regions, has minimum acreage requirements, and targets new habitat based in part on the protected status of adjacent habitat (Kiesecker et al. 2007).

neighbors, possible reputation effects, and changing social norms within landowner social networks. If local conservation activity increases the likelihood that neighboring habitat is protected due to a change in neighbors' preferences or attitudes towards conservation, then agencies can leverage past conservation effort to enroll more contiguous habitat (Chen et al. 2012). Alternatively, easements may be repelled from previously protected areas if there are diminishing returns to additional protected habitat in a given region (Albers, Ando, and Batz 2008). This might arise, for example, if conservation agencies wish to diversify the spatial location of protected habitat.[2]

Recent empirical research examines interactions between government conservation activities and purchases of land by private land trusts.[3] Albers, Ando, and Chen (2008) examine spatial attraction and repulsion between government and privately protected land using a township-level cross-sectional dataset for the states of California, Illinois, and Massachusetts. They find that publicly-protected areas repel private reserves in Illinois and Massachusetts, whereas they attract private reserves in California. Parker and Thurman (2011) investigate the role of crowding in and crowding out of US federal land conservation programs on private land trust activity using a county-level dataset for the years 1990 and 2000. The authors find that federal land conservation programs affect private conservation investment; federal conservation has a small crowding out effect on private land trusts that focus on preserving open space and a crowding in effect on land held in trust by The Nature Conservancy, which selects sites on the basis of biodiversity benefits.

[2] Recent research has examined the role of diversification in conservation planning. This research proposes modern portfolio theory to deal with climatic changes in the US prairie pothole region (Ando and Hannah 2011; Ando and Mallory 2012).

[3] A couple of related papers (Lynch and Liu 2007; Lynch and Liu 2009) assess the role of spatial spillovers in agricultural land preservation programs in Maryland. An important consideration in these papers is the possible impact of the preservation programs on surrounding land values. The conservation easements in our study restrict agricultural uses on parcels and are purchased in a region dominated by intensive production agriculture with little potential for residential development. These easements affect the value of the parcel with the easement but should have little impact on surrounding agricultural land values (Lawley and Towe 2014).

The approach we take in this paper is substantially different from the research cited above. The prior research examining government crowding in and crowding out of private conservation investment makes use of spatially aggregated data. This enables the researchers to examine overall conservation investment within regions, but provides less information about the spatial configuration of protected habitat. In this study, we make use of quarter section-level panel data, which enables us to estimate the extent to which *immediately adjacent* protected quarter sections influence subsequent conservation easement activity via positive or negative spatial spillovers.[4] Further, in contrast to the previous literature that focuses on public versus private conservation investment, in this paper we examine purchases of conservation easements under a public/private joint venture involving two conservation agencies with a common mandate. This allows us to examine endogenous spatial interactions between protected areas over time as well as spatial interactions between the two conservation agencies.

A related line of research examines the role of incentives in encouraging landowners to conserve habitat. van Kooten and Schmitz (1992) present evidence that prairie pothole conservation programs in western Canada relied too heavily on moral suasion and too little on financial incentives for landowners. Several recent papers examine the impact of social norms and reputation effects on the conservation efforts of landowners in the presence of financial incentives (Banerjee and Shogren 2012; Sorice et al. 2011; Chen et al. 2009). Lewis and Plantigna (2007) and Lewis et al. (2009) examine the use of incentive payments to reduce habitat fragmentation. A series of theoretical papers investigate methods of providing incentives for conservation program participants to enroll spatially contiguous habitat. Sometimes referred to as "agglomeration bonuses," this literature focuses on designing formal market mechanisms,

[4] The Dominion Land Survey system divides most of Western Canada into one square mile sections. Sections are further divided into quarter sections, which are 160 acre square plots of land.

such as auctions, in settings with asymmetric information about opportunity costs and spatially-dependent benefits of ecosystem services (Polasky et al. 2012; Drechsler et al. 2010; Parkhurst and Shogren 2007; Parkhurst et al. 2002).

We build on this literature by examining an incentive-based conservation program operating in an environment with asymmetric information and with a goal of protecting contiguous habitat. From the beginning, the conservation agencies operating in the prairie pothole region of western Canada have relied on one-on-one interactions between field staff and landowners. Agency field staff reside in local communities and attempt to form long-term relationships with networks of landowners, with an objective to change local social norms and to gradually increase awareness of conservation issues within local communities. Similarly, investment in conservation easements is thought to shift social norms such that conservation becomes more socially acceptable in local communities (Carlyle 2013). An outcome conservation agencies hope to realize from this approach is an increase in protection of contiguous habitat.

We investigate the role of spatial interactions in habitat conservation using a quarter section-level dataset documenting all conservation easements held by Ducks Unlimited Canada (DUC) and the Manitoba Habitat Heritage Corporation (MHHC), as well as permanently protected government land in the prairie pothole region of Manitoba. Our data includes all conservation activity in Manitoba—both easements and government-protected land—updated annually from 2000 through to 2011. The habitat conservation easement data is merged with a large set of physical characteristics of quarter sections and neighboring land as well as time-varying data documenting changes in land ownership and measuring changes in local land values. We take advantage of the panel nature of our data to specify a recursive model, where variation in the timing of neighboring easements and government-protected areas is used to identify endogenous spatial interactions (Brock and Durlauf 2001).

We find that endogenous spatial interactions influence the location of conservation easements. Our results suggest that, on average, an additional neighboring easement within one mile increases the likelihood of an easement by 9.8 percent annually. This result implies that the addition of a neighboring easement roughly doubles the likelihood of an easement over the course of ten years—a substantial interaction effect that reflects a combination of positive social interactions among neighboring landowners and agency targeting. This result suggests that one impact of investment in conservation easements is to increase neighboring landowners' likelihood of enrolling habitat in an easement. Economic incentives therefore appear to be an indirect investment in moral suasion.

We also find that the strength of the spatial interaction effect due to neighboring easements declines with distance. This is consistent with weaker social interactions among landowners that are more distant neighbors. It is also consistent with conservation agency targeting criteria that place more weight on immediately adjacent habitat. Finally, government-protected land appears to have a small crowding out effect on conservation easements: on average, an additional quarter section with government-protected land within five miles of a quarter section reduces the likelihood of an easement by approximately 1 percent annually. This small crowding out effect appears to be strongest when a relatively large number of neighboring quarter sections are protected by the government.

The remainder of the paper proceeds as follows. We begin with a brief background of the institutional setting surrounding conservation easements in Manitoba, our study area. Section 3 describes the econometric model, followed by a presentation of the data in section 4. Section 5 presents results followed by concluding remarks in section 6.

Background

Conservation easements have emerged as an important conservation tool in North America (Parker and Thurman 2013). Passage of legislation enabling conservation agencies and landowners to enter into conservation easements was initiated in several Canadian provinces in the late 1990's (Brown et al. 2011). The *Manitoba Conservation Agreements Act* was introduced in 1997 and a number of conservation agencies including DUC, MHHC, and Nature Conservancy Canada (NCC) now actively purchase conservation easements in Manitoba. Conservation easements are agreements between landowners and conservation agencies where the landowner agrees to not drain or convert existing wetlands and upland habitat in exchange for a one-time payment. Conservation easements are perpetual agreements and follow the land title. The majority of easements purchased in the prairie pothole region of Manitoba are funded through the North American Waterfowl Management Plan (NAWMP). The NAWMP, initiated in 1986, focuses on restoring waterfowl populations with a goal of reaching 1970 levels (Williams, Koneff, and Smith 1999).

The NAWMP has employed regionally based "joint ventures" between public and private partners to address waterfowl population decline. In the Canadian prairies, the Prairie Habitat Joint Venture (PHJV) spans a region accounting for 20 percent of North America's total duck production and serves as an important breeding ground for the Pacific, Central, and Mississippi flyways (van Kooten and Schmitz 1992; van Kooten 1993).[5] NAWMP activities in the PHJV are funded by contributions from Canadian, US federal, and US non-federal sources, with

[5] The Prairie Pothole Joint Venture distributes NAWMP resources in the US portion of the prairie pothole region.

approximately two thirds coming from US sources. The PHJV partners secure habitat in permanent conservation easements, fee simple acquisitions, land donations, Crown land transfers and land designations, and long-term arrangements such as cooperative land use agreements (NAWMP Committee 2010). As of March 2007, the PHJV had enrolled 222,173 acres in perpetual conservation easements (PHJV 2008).

Two agencies—DUC and MHHC—are responsible for the majority of conservation easements in the prairie pothole region of Manitoba. MHHC is a provincial Crown Corporation formed in 1986 through the *Manitoba Habitat Heritage Act*. MHHC receives funding for habitat securement from several sources including the Manitoba provincial government, Canadian federal government, and US sources for conservation programs that are guided by PHJV implementation plans and partners. DUC is a private non-profit organization established in Canada in 1938. DUC secures funds from several sources, including private donations and Canadian and US government sources for their activities in the PHJV. Prior to passage of conservation easement legislation, both DUC and MHHC participated in projects that involved short-term leases of existing habitat as well as fee simple purchases of larger tracts of land. Passage of the *Manitoba Conservation Agreements Act* allowed these agencies to shift some resources to permanent conservation easements on existing habitat, which reduce the costs of habitat securement and maintenance and permit landowners to continue farming the surrounding acreage that is not under easement.[6]

DUC and MHHC field staff work with private landowners to secure conservation easements. In some cases DUC and MHHC personnel approach prospective landowners to solicit their interest in enrolling their habitat in an easement. In other cases, interested

[6] Parker (2004) provides a thorough discussion of the economic issues surrounding fee simple ownership versus conservation easements.

landowners initiate contact with DUC or MHHC. Potential habitat is ranked according to its ecological value and vulnerability to conversion. Importantly for this study, the agencies assign greater weight to habitat on quarter sections that are within one mile (or one to five miles) of previously protected habitat (Carlyle 2013). This indicates that DUC and MHHC explicitly target habitat close to previously protected habitat with the intent of increasing the connectivity of habitat secured by conservation easements. The agencies also rank habitat according to its capability to support waterfowl, the acreage of existing habitat within the quarter section (including wetlands and natural upland), the percentage of permanent cover within one mile, and wetland acreage within one mile.

The conversion vulnerability of habitat on the quarter section is assessed based on agricultural soils capability class and field staff assessment of the percentage of surrounding wetland acreage within one mile that has been drained (Carlyle 2013). Conservation easements are often placed on multiple quarter sections under the same agreement. Each quarter section being considered is scored according to the above criteria and if the minimum standard is met, the conservation agency and the landowner proceed to negotiate the compensation to be paid to the landowner.

During our study period, the one-time payment for eased habitat acreage was approximately 30 to 40 percent of the average assessed values of surrounding land, up to a maximum payment of approximately $100/acre.[7] Once the landowner and conservation agency agree on the terms of payment, the conservation agency conducts a baseline assessment of the proposed habitat for use in annual compliance monitoring. The baseline assessment documents the extent, type, and condition of existing habitat. In Manitoba, conservation agencies obtain the right to access the

[7] DUC ran reverse auctions in the early stages of development of their conservation easement program. These reverse auctions were used primarily as price discovery tools (Brown et al. 2011).

property as a part of compliance monitoring, which may include annual visits as well as aerial monitoring of the eased property.

Identifying Spatial Interactions between Protected Areas

We draw from the large literature on social interactions in economic decision making.[8] As outlined by Manski (2000), this literature is concerned with the factors that lead members of a group to have similar outcomes, which can be grouped into correlated effects, exogenous interactions, and endogenous interactions. Correlated effects result when members of a group have similar individual characteristics and preferences, or face similar institutional environments. In the context of conservation easements, landscape features tend to be positively correlated due to spatial clustering. Therefore, we might observe easements on neighboring quarter sections driven solely by the fact that they have similar habitat features. Correlated effects might also arise due to local factors such as municipal infrastructure, municipal tax rates, and local economic development, which expose neighboring quarter sections to similar economic environments.

Exogenous interactions arise when actions or choices are a function of exogenous characteristics of others.[9] In our setting, conservation agencies target habitat based on the quantity of neighboring existing habitat. For example, habitat on a quarter section is more likely to be targeted by conservation agencies if neighboring quarter sections have a large amount of wetland and grassland habitat, independent of whether or not that neighboring habitat is permanently protected by an easement.

[8] Irwin and Bockstael (2002; 2004) build on the social interactions literature in their work on spatial spillovers in residential development. Lewis, Barham, and Robinson (2011) examine the choice to convert to organic dairy production with a focus on the role of learning about organic production from neighbors.

[9] Exogenous interactions are also referred to as contextual interactions in the social interactions literature.

In this paper we are primarily interested in identifying the presence and magnitude of endogenous spatial interactions that might arise if the choices of landowners and conservation agencies are a function of neighboring conservation activity. Conservation agencies target habitat that is adjacent to previously protected habitat. If this targeting is sufficiently strong it will generate a positive spatial spillover such that previously protected habitat attracts neighboring easements—a form of spatial crowding in of conservation activity (Albers, Ando, and Chen 2008). It is also possible that spatial crowding out occurs. For example, the provincial and federal governments typically protect large tracts of land with parks and wildlife management areas and it may be the case that investment in conservation easements adjacent to government land provides lower incremental benefits to the conservation agencies relative to other locations. It is also possible that the benefit of protecting contiguous habitat is diminishing and at some point additional neighboring eased habitat reduces the likelihood of an easement. In these cases we will observe a negative spatial spillover between protected areas.

Perhaps more importantly, landowners may respond to endogenous spatial interactions through observational learning or changing social norms. Observing neighbors place easements on their land might increase awareness or alter landowners' perceptions of easements. Lynch and Lovell (2003) present survey evidence that landowners learn about agricultural land preservation programs from their neighbors and are subsequently more likely to participate in a preservation program. If a landowner has a good (bad) experience with the conservation agency, neighboring landowners may be more (less) likely to enroll habitat in an easement with that agency. Social norms within a landowner's reference group might influence perceptions of conservation easements. Since neighbors are part of a rural landowner's reference group, an increase in the number of neighboring quarter sections with easements is expected to shift the social norm such that enrollment of habitat in an easement becomes more acceptable.[10] Recent research suggests local social norms influence participation in a land set aside program in China's Wolong Nature Reserve (Chen et al. 2009). A sufficiently large shift in the social norm due to neighboring conservation easement activity will generate positive spatial spillovers.

Empirical model

We model the impact of neighboring protected quarter sections on the likelihood that a previously unprotected quarter section transitions into protected status via an easement. We are primarily interested in identifying the influence of endogenous spatial interactions on transitions, where spillovers might arise due to conservation agencies preference for spatially contiguous protected habitat and the impact of landowners' conservation choices on the conservation preferences of neighboring landowners. The identification challenge is in identifying endogenous spatial interactions, separate from the influence of exogenous interactions and spatially correlated effects. The econometric analysis that follows utilizes the panel nature of our dataset to separately identify the endogenous spatial interaction.

The probability that quarter section *i* is protected by an easement at time *t* given it has not yet been protected is written as:

$$\text{(1)} \qquad \Pr(e_{it} = 1 | e_{it-1} = 0\ ) = \Pr(d_{it}^* > 0 | d_{it-1}^* \leq 0)$$

where e_{it} is a dummy variable that takes a value of one if quarter section *i* is protected by an easement in period *t*, and d_{it}^* is a latent variable that is greater than zero if $e_{it} = 1$ and less than or equal to zero if $e_{it} = 0$. The latent variable d_{it}^* is written as:

[10] We identify an endogenous interaction based on spatial proximity. Of course, this does not capture the role of other networks or reference groups that might influence landowners' conservation choices. A detailed survey documenting network membership of individual landowners would shed more light on the importance of social interactions in habitat conservation.

(2) $$d_{it}^* = \alpha' x_i + \beta' y_{it} + \gamma' z_t + \delta' m_{n(i)t} + c_i + \varepsilon_{it}$$

where $\alpha, \beta, \gamma,$ and δ are vectors of unknown parameters to be estimated; x_i denotes observed time-invariant quarter section characteristics, characteristics of neighboring quarter sections thought to influence the likelihood of an easement, and spatial fixed effects; y_{it} denotes observed time-varying quarter section characteristics including changes in ownership and local land prices; z_t denotes a set of year fixed effects that capture time-varying factors common to all quarter sections such as interest rates, exchange rates, and crop and livestock prices; $m_{n(i)t}$ denotes the cumulative number of protected quarter sections in the neighborhood of quarter section i, denoted $n(i)$, as of the start of period t; c_i is a time-invariant random effect that accounts for quarter section-specific unobserved characteristics; and ε_{it} represents idiosyncratic shocks.

The parameters of equation (2) are estimated using a discrete-time transition model, where each duration is one year in length. This is consistent with the fact that conservation agencies are constrained by time-limited budgets and must often allocate funds to conservation easements by the end of each fiscal year. For each quarter section one of two possible outcomes occurs each year: (1) an easement may be secured on the quarter section or (2) the quarter section remains unprotected. When an easement is secured on a quarter section that quarter section is dropped from the data for all remaining periods, which implies we have an unbalanced panel dataset. We utilize a random effects complementary log-log model, which is the discrete-time version of the Cox proportional hazards model.[11] Nicoletti and Rondinelli (2010) demonstrate that

[11] In a linear model, fixed effects could be used to control for parcel-specific unobserved effects. Although not subject to the consistency concerns characteristic of fixed effect probit models, the fixed effect logit model drops observations with insufficient variation in the dependent variable. In our application, this implies all parcels that do not have an easement at some point in our study period are dropped from the dataset.

distributional assumptions about unobserved heterogeneity do not bias parameter estimates in discrete-time duration models.

As is the case with all random effects models, we are concerned about possible correlation between the random effect and the variables capturing endogenous spatial interaction effects. We handle this in a couple of ways. First, we have assembled a rich dataset that allows us to control for the dominant drivers of conservation easement enrollment. We describe this data in detail in the next section. Second, we make use of several alternative specifications to account for any possible remaining quarter section-specific unobservables that may bias our endogenous interaction estimates. The outcomes of these alternative specifications are presented as robustness checks in the results section.

Data

Our variable selection is based on the criteria conservation agencies use to enroll existing habitat and the factors influencing landowners' likelihood to enroll habitat in a conservation easement. We assemble a comprehensive quarter section-level dataset documenting the location and timing of all permanently protected prairie pothole habitat and other conservation lands in southwestern Manitoba from 2000 to 2011. Figure 1 outlines the study region. The conservation activity dataset is merged with geo-referenced data documenting soil productivity, land use, distance of quarter sections to cities and major grain elevators, elevation, and the suitability of the quarter section as waterfowl habitat. Table 1 presents summary statistics for the variables used in the analysis, which are described in detail below.

The unit of observation in this study is the quarter section. We are able to track all conservation easement activity annually at the quarter section-level. This includes all habitat conservation easements signed by MHHC and DUC. We also observe the location and date of protection of all other permanently protected areas in our study region. This includes fee simple purchases of land by MHHC and DUC, Federal and Provincial parks, Provincial wildlife management areas, and Provincial forests. Wildlife management areas are parcels of land set aside for wildlife management under the *Manitoba Wildlife Act*. In addition to providing wildlife habitat, wildlife management areas are utilized for recreational purposes, such as wildlife and bird watching, hunting, fishing, and trapping.

Endogenous spatial interactions

We expect that the likelihood a quarter section will be enrolled in an easement is a function of protected habitat in the area immediately surrounding the quarter section. The Dominion Land Survey imposes a square grid on the landscape, which we use to determine neighboring quarter sections. We document the protected area status, including both eased land and other protected areas, for a series of square buffers surrounding each quarter section. Examples of one mile and one to five mile buffers are shown in Figure 2. The one-mile buffer is comprised of all eight quarter sections that are immediately adjacent to the quarter section and all sixteen quarter sections immediately adjacent to the first eight neighboring quarter sections. Table 1 indicates that, on average, 0.29 quarter sections are eased within the first one-mile buffer. The one to five-mile buffer includes quarter section buffers three through ten, comprised of 416 quarter sections. On average, just over five quarter sections are eased within the one to five mile buffer. We also document the number of government-protected quarter sections within five miles. On average, there are fewer than eight government protected quarter sections within the five mile buffer.

Table 2 provides the frequencies of the number of neighboring protected quarter sections for the entire dataset. Just under 35,000 quarter sections have one neighboring easement within one mile and approximately 20,000 have two neighboring easements within one mile. Less than 1 percent of the sample quarter sections have five or more eased quarter sections within one mile. It is more common for a quarter section to neighbor eased quarter sections within one to five miles; approximately 20 percent of quarter sections have nine or more neighboring eased quarter sections within one to five miles. Approximately 20 percent of quarter sections have nine or more neighboring government-protected areas within five miles.

Quarter section Characteristics

We control for a rich set of observable characteristics at the quarter section-level that are expected to influence the likelihood a quarter section has an easement. Conservation agencies target potential habitat according to several physical landscape features. Perhaps most importantly, they document the extent of existing habitat acreage—including wetland, pasture, brush, and native hay—within a quarter section. To control for this we include the share of quarter section acreage that is in annual crops, forages, and other land uses, assessed using Agriculture and Agri-Food Canada (AAFC) land cover data based on Landsat 7 images from the year 2000. The share of the quarter section in habitat acreage is the omitted category. Consistent with conservation agency targeting, we expect quarter sections with more acreage in annual crops and forages (relative to permanent cover such as wetlands, grassland, pasture and hay) are less likely to have an easement. The agencies also assess the suitability of the potential habitat to support waterfowl. We control for this using the Canada Land Inventory (CLI) waterfowl suitability index and a dummy variable indicating whether or not the quarter section is located within a PHJV target region.

Conservation agencies also assess the vulnerability of existing habitat to conversion based on the agricultural capability of the soil. We use quarter section-level soil productivity indices generated by the Manitoba Agricultural Services Corporation (MASC).[12] The MASC soil productivity index is based on soil survey reports conducted in the 1930s combined with long-term average yields. The soil productivity index classifies quarter sections into categories A through J, where A is the highest rated soil and J the lowest productivity soil. The productivity index is a composite of multiple factors, including soil texture, organic matter, water-holding capacity, topsoil depth, salinity, soil erosion, topography, and stoniness. We classify A, B, and C as high productivity soil and D, E, and F as medium productivity soil Low productivity soil includes classes G through J and is the omitted category. We also include the average elevation of the quarter section; all else equal wetlands on higher elevation land are easier to drain.

We also include variables that are expected to influence the likelihood a landowner will enroll habitat in a conservation easement. On average, landowners presumably offer to enroll habitat with the lowest opportunity cost first. We include the MASC soil productivity index as a control for the opportunity cost of enrolling habitat in an easement. We also include the average distance of each quarter section to the nearest large elevator (defined as having an annual capacity in excess of 25,000 tons), as well as average distances to the cities of Brandon and Portage la Prairie, the two largest urban centers in the study area. Quarter sections closer to a major elevator should have lower grain transportation costs and are likely situated in areas with a higher density of annual crop production. We therefore expect the opportunity cost of an easement is greater for quarter sections closer to major grain elevators. Similarly, distance to the

[12] MASC is the Provincial crop insurance agency.

urban centers of Brandon and Portage la Prairie are included to control for urban development pressure and the value of access to urban amenities. Since habitat conservation easements impose restrictions on residential development we expect that landowners will be less likely to enroll land in close proximity to urban centers.

We construct three time-varying dummy variables that indicate the length of time since the most recent sale, constructed based on data documenting all agricultural land transactions since 1987. Each of these variables covers a four year span. The first dummy variable indicates whether or not the most recent sale occurred in the most recent four years, the second dummy variable indicates whether or not the sale occurred in the past 5 through 8 years, and the third dummy variable indicates if a sale occurred in the past 9 through 12 years. Sales occurring more that twelve years ago serve as the omitted category. Land use conversion often occurs when land changes ownership. Including this set of dummy variables controls for the possible effects of land ownership changes on the likelihood of entering into an easement.

Exogenous Interactions and Spatially Correlated Effects

Habitat characteristics of neighboring quarter sections within the one-mile buffer and within the one to five-mile buffer are used to control for exogenous interactions among quarter sections, where the interaction arises due to the physical characteristics of neighboring quarter sections as opposed to their protected status. Controlling for these habitat characteristics is important if they cluster spatially. These are also criteria conservation agencies use to assess the suitability of habitat for a conservation easement.

A common concern in spatial interaction models is the role of spatially correlated unobservable factors that may give rise to what appears to be an endogenous interaction (Irwin and Bockstael 2002). In our spatial interaction model, this might arise due to possible correlation between the protected status of neighboring quarter sections, $m_{n(i)t}$, and the random effects, c_i. We account for this as follows. First, as described above, we include a rich set of quarter section-specific variables that control for the primary drivers of conservation agency and landowner behavior. Including this rich set of controls reduces the set of factors that are contained in the random effect c_i and potentially correlated with $m_{n(i)t}$. Second, we include rural municipality fixed effects to control for spatially correlated factors under the control of municipalities, including municipal taxation rates and differential levels of investment in local infrastructure such as small roads, bridges, and agricultural drainage ditches.[13] MASC has divided southern Manitoba into regions with common agricultural production risks due to factors such as pest pressure, frost risk, and drought risk. These risk areas are used by MASC when setting crop insurance premiums. We include MASC risk area fixed effects as controls for spatially correlated agricultural production risk factors that may influence the likelihood a landowner enrolls habitat in a conservation easement. The crop insurance risk areas and municipal boundaries are outlined in Figure 1 and the sizes of these spatial fixed effects relative to the one and the one to five mile buffers are shown in Figure 2.

It is also possible that time-varying unobservables are spatially correlated with our time-varying measure of neighboring protected status, $m_{n(i)t}$. This might occur if localized shocks, such as local infrastructure improvements, the siting of a new processing facility or livestock operation, or changes in tax rates set by local municipal governments impact the costs and benefits of entering into conservation easement agreements. To account for these factors, we construct a local agricultural land price index to control for time-varying spatially correlated

[13] A rural municipality is the lowest of the three levels of government in rural Manitoba (below the Federal and Provincial levels) and excludes rural cities, towns, and villages.

factors that are substantial enough to be capitalized into land values. Using a land price index in this manner summarizes many potential local time-varying shocks into a single covariate.

The land price index is constructed at the rural municipality level for the years 2000 through 2011 following the propensity score matching approach proposed by McMillen (2012). The relatively low frequency of rural agricultural land transactions at the municipality level rules out construction of a repeat sales index. The McMillen propensity score matching approach, on the other hand, makes use of all land transactions in treated and control groups with common support, where assignment to treated or control groups is based on the year of sale. For example, all sales occurring in a base year or set of years serve as the control group, and sales occurring in subsequent years or sets of years are the treated sales. The land price index is comprised of a series of treatment effects computed for each period in the study relative to the base period. Propensity score matching is used to select the set of comparable land sales in each year, thereby producing a land price index that holds quality constant.

Our land price index is updated annually based on bare agricultural land sales occurring in the previous four years within a given rural municipality. The index therefore controls for price expectations formed on the basis of recent price movements. As an example, the land price index for the year 2000 is based on sales occurring in 1996 through 1999, relative to sales occurring in 1992 through 1995. The land price index for 2001 is based on sales occurring in 1997 through 2000, once again relative to sales in 1992 through 1995. Sales that have a conservation easement prior to the sale are excluded from our land price index sample, ensuring that our land price index is not directly influenced by easement activity.[14] Use of a four-year

[14] It is also possible that conservation decisions in a rural municipality affect land prices. Most of the land purchases and set asides by the conservation agencies and governments occurred well before our study period and should not influence more recent changes in land values. The more recent conservation easement activity may influence land values. We expect this effect, if present, to be small. The conservation easement program in Manitoba is just over

moving average land price index reduces the impact of short-run fluctuations in land prices and, given the low frequency of transactions in a given year, likely provides a better representation of land price expectations across the full distribution of land values.

Results

We begin with presentation of the results from our base model. We follow this baseline set of results with a series of robustness checks. Estimated hazard ratios from our baseline model are presented in Table 3. A hazard ratio greater (less) than one indicates that the likelihood of an easement increases (decreases) due to an increase in the covariate. We present results for two specifications where the neighboring protected quarter section variables are entered (1) linearly and (2) as a quadratic. Each of our specifications includes year fixed effects, MASC risk area fixed effects, and rural municipality fixed effects. In Table 4 we report average marginal effects (derived from the quadratic specification) that vary by the number of neighboring protected areas.

Endogenous spatial interactions

Our results suggest that, on average, an additional neighboring eased quarter section within one mile increases the likelihood of an easement by 9.8 percent annually, when the number of neighboring eased quarter sections within one mile is entered linearly. As presented in Table 4, when the number of neighboring eased quarter sections within one mile is entered as a quadratic, we find that the positive spatial interaction effect of neighboring easements falls as more

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ten years old at the end of our study period and the share of eased land in any one municipality is small. Further, the easements remove the right to convert existing habitat in the future and do not increase the current quantity of existing habitat in the landscape. Not all land buyers are aware of the extent of surrounding existing habitat that is protected in an easement and it is not clear that removing the right to convert neighboring habitat would be capitalized into land values within the time frame of this study.

neighboring quarter sections are protected. The first, third, and fifth easement within one mile increase the likelihood of an easement by 23 percent, 15 percent, and 8 percent, respectively. The effect of an additional neighboring easement drops to zero when the cumulative number of neighboring easements is six or more. As is indicated in Table 2, it is rare for a quarter section to have six or more neighboring eased quarter sections in our study region. Overall, our results provide strong evidence that neighboring easements attract, rather than repel, subsequent easements. It appears as though the agencies have captured opportunities to leverage past easement activity and enroll more contiguous habitat in permanent easements.

We also find evidence that the strength of the spatial interaction between easements decreases with distance. This is consistent with potentially weaker social interactions among landowners that are more distant neighbors. It is also consistent with agency targeting criteria that place greatest weight on immediately adjacent habitat. When the number of neighboring easements within one to five miles is entered linearly, we find no evidence of endogenous spatial interactions. When entered as a quadratic, the number of neighboring easements within one to five miles has a small statistically significant impact on the likelihood of subsequent easements at low levels of neighboring easement investment. This small positive effect diminishes quickly: if there are between 24 and 27 neighboring easements in the one to five mile buffer, an additional neighboring easement reduces the likelihood of an easement by 0.7 to 1 percent annually. As indicated in Table 2, approximately 5 percent of the quarter sections in our study region have more than 24 eased neighboring quarter sections within one to five miles.

We find that government-protected land within five miles has little impact on conservation easement activity. On average, an additional government-protected quarter section within five miles reduces the likelihood of an easement by less than 1 percent. If the number of neighboring government-protected quarter sections is small (less than 15), then additional government-protected land has no impact on conservation easement activity. If there is a large number of neighboring government-protected quarter sections (greater than 15), then additional government-protected land has a small crowding out effect on conservation easements. In this case, an additional government-protected quarter section within five miles reduces the likelihood of a conservation easement by approximately 0.8 percent.[15] This small crowding out effect might be due to increased development opportunities near government protected areas or diminishing returns to protecting habitat in regions where large tracts of land have been protected.

Quarter section characteristics

Several of the quarter section-level characteristics in our model have substantial impacts on the likelihood of an easement. Quarter sections with more acreage in annual crops and forages are less likely to have a conservation easement, consistent with the fact that agencies explicitly target existing habitat when signing easements. We find that a 1 percent increase in the share of acreage in annual crops reduces the likelihood of an easement by approximately 2 percent. Similarly, a 1 percent increase in the share of acreage in forages reduces the likelihood of an easement by 1.4 percent.

An increase in the share of high and medium productivity soil increases the likelihood of an easement. Conservation agencies use potential agricultural productivity as a proxy for the vulnerability of habitat to conversion, where higher productivity land is at higher risk of

[15] If government protected land is entered in one mile and one to five mile buffers we find that easements within the first mile have no effect and easements within the one to five mile buffer have a negative impact on the likelihood of an easement. These two coefficients are not statistically different from one another at conventional significance levels and we have no *a priori* rationale for entering them separately. We therefore report results for the five mile buffer for government-protected land.

conversion. Our result suggests that agencies are enrolling more vulnerable habitat. We find that higher elevation quarter sections, which are potentially easier to drain, are more likely to have an easement. We include a set of three variables that capture the location of quarter sections relative to cities and major grain elevators. We find that quarter sections closer to Portage la Prairie are less likely to have an easement, likely due to increased residential development pressure. Proximity to Brandon and major grain elevators do not have a systematic impact on the likelihood of an easement.

As expected, ecological characteristics of quarter sections influence the likelihood of an easement. Quarter sections in PHJV targeted regions are 1 percent more likely to have an easement. Similarly, quarter sections with high waterfowl suitability ratings are more likely to have an easement. Once again, these results are consistent with agency targeting objectives.

Quarter sections that have recently changed ownership are more likely to have an easement. If a sale occurred in the past four years, a quarter section is 25 percent more likely to have an easement placed on their habitat, while quarter sections with a sale sometime in the past five to eight years are 31 percent more likely to have an easement. It appears as though new landowners are more likely to enter into conservation easement agreements, perhaps due to a combination of conservation agency targeting, the conservation attitudes of new landowners, and potential use of conservation easement payments to offset the cost of land purchase.

Exogenous interactions and spatially correlated effects

Our controls for exogenous interactions and spatially correlated effects also have explanatory power. Conservation agencies target quarter sections with more permanent cover (including wetlands, grassland, and trees) within one mile, independent of its protected status.

We find that a 1 percent increase in the share of surrounding acreage in annual crops reduces the likelihood of an easement by 1.8 percent. Although agencies do not explicitly target quarter sections on the basis of land use beyond one mile, we include the percent of acreage in crops, forages, and other uses within one to five miles as a control for possible exogenous interactions or spatially correlated effects that may be present at this spatial scale. We find that a 1 percent increase in the share of acreage in annual crops within one to five miles increases the likelihood of an easement by 1.7 to 1.8 percent. This suggests that the agencies are more likely to place an easement on a quarter section if the broader landscape has more annual crops, perhaps consistent with targeting on the basis of vulnerability to conversion.

We control for spatially correlated unobservables with a combination of rural municipality fixed effects, risk area fixed effects, and the time-varying rural municipality land price index. We do not report coefficients on the large number of fixed effects due to space constraints. We find that quarter sections located in rural municipalities that are experiencing greater increases in the land price index are less likely to have an easement, holding all other factors equal. The impact is substantial: a 1 percent increase in the price index reduces the likelihood of an easement by 1.7 percent. This might be due to a couple of factors. First, landowners are likely reluctant to place restrictions on the use of agricultural land in regions with rapidly increasing land values. Second, conservation agencies may be unlikely to pursue habitat in regions with above average increases in land values since it would reduce the number of acres that can be protected on a fixed budget.

Interactions among conservation agencies

In this section we examine the conservation easement activity of the two conservation agencies— DUC and MHHC—separately. We estimate two equations, one examining MHHC easement activity and the other examining DUC easement activity. In each of these two models, we include neighboring easement activity of DUC and MHHC separately, allowing us to assess the impact of neighboring DUC and MHHC easements on the likelihood of a MHHC easement and a DUC easement, respectively. A positive spillover might arise if agencies attempt to capture increased ecological benefits due to contiguous habitat, irrespective of which agency holds neighboring easements. Alternatively, agencies might focus their efforts on certain locations in an attempt to reduce the costs of securing and maintaining easements.[16] This would produce a negative spillover between the agencies.

Table 5 presents marginal effects allowing for spatial interactions between the two agencies. Our results suggest that MHHC is more likely to place easements on quarter sections within one mile of both DUC and MHHC protected areas. We find no evidence that neighboring protected areas eventually crowd out MHHC easements at the one mile buffer. Our results do suggest that 15 or more MHHC easements within the one to five mile buffer may repel neighboring MHHC easements. Overall, our results are consistent with MHHC efforts to target contiguous protected habitat. Our results also suggest that government-protected land neither attracts nor repels MHHC easements.

We find that DUC is more likely to place an easement on a quarter section neighboring four or fewer DUC protected areas within one mile, or neighboring nine or fewer DUC protected quarter sections within one to five miles. Our results also suggest that DUC easements are less

[16] Concentrating on smaller geographic regions might reduce the cost of visiting potential and existing easement locations.

likely to be located adjacent to MHHC protected quarter sections. The magnitude of this effect diminishes as the number of neighboring MHHC protected areas increases. This may reflect DUC efforts to concentrate easement activity within certain regions in an attempt to reduce recruitment, maintenance, compliance monitoring, and enforcement costs. We find DUC easements are attracted to government-protected land when the number of neighboring quarter sections under government protection is small.

Robustness

In this section we present a series of robustness checks on our baseline results to assess the degree to which our estimates are influenced by correlation between the protected status of neighboring quarter sections, $m_{n(i)t}$, and the random effects, c_i.

Landowner clusters

One unobservable factor that might be correlated with $m_{n(i)t}$ is exogenous landowner conservation preferences and attitudes. This might arise, for example, if landowners sort spatially on the basis of the conservation attitudes of landowners of neighboring land. It is difficult to imagine that this type of sorting is prevalent among agricultural landowners in this region.[17]

On a more basic level a landowner might own multiple neighboring quarter sections. If the landowner places easements on different neighboring quarter sections at different points in time then what might appear to be an endogenous interaction among protected quarter sections would simply be due to unobserved characteristics of the landowner, including habitat conservation

[17] It is also possible that landowners sort on the basis on income and wealth. If this is true and income and wealth are correlated with conservation attitudes, then this sorting would lead to a spatially correlated unobserved preference for conservation. Since land use is correlated with land values, including surrounding land uses acts as an indirect control for localized spatial sorting on the basis of landowner income and wealth.

preferences. We suspect this is not an issue in our sample. We have excluded quarter sections with MHHC easements that have prior neighboring MHHC easements on quarter sections owned by a common landowner.[18] Since we lag neighboring protected quarter sections by one year we are not picking up the impact of MHHC easements placed on neighboring quarter sections in the previous period by the same landowner. This suggests that the endogenous spatial interaction between MHHC easements identified in the agency interaction model and reported in the MHHC easement model in Table 5 is not influenced by an unobserved landowner effect. Further, the interaction between MHHC easements reported in Table 5 is stronger than the spatial interaction effect averaged over MHHC and DUC as reported in Table 4. Since MHHC accounts for a large portion of the easements in our sample, these results suggest that an unobserved landowner effect is not causing a substantial positive bias of the endogenous spatial interaction we identify in the baseline results in Table 4.

We do not observe landowner names in the DUC easement data. Although we have no reason to suspect this is a major problem for the DUC easements, we conduct the following robustness check. We use all agricultural land transaction data in the study region between 1984 and 2011, including quarter sections with and without buildings, to group quarter sections together by landowner. Each property transaction recorded in the land transaction data is a sale comprised of one or more quarter sections. We can therefore determine which quarter sections are owned by the same landowner, both prior to and subsequent to a sale. Note that we cannot be sure we observe all of the quarter sections owned by any one landowner; instead, we observe

[18] Five quarter sections with an easement had neighboring quarter sections with prior easements owned by the same landowner within the one mile buffer. An additional 14 quarter sections with an easement had prior neighboring quarter sections with easements owned by the same landowners within the one to five mile buffer. We dropped these quarter sections from the dataset. Including these quarter sections in the data does not alter our baseline results. For example, the impact of an additional neighboring easement within one mile increases from 9.8% to 10% when these quarter sections are not dropped from the data.

one set of quarter sections owned by a single landowner. We use this landowner information to construct landowner clusters of quarter sections and merge it with our main dataset. We then drop all quarter sections from our main dataset that are not involved in a sale in the 1984 to 2011 period. When we do so, we are left with 314,147 observations from the full 2000 to 2011 panel dataset.

We run discrete-time transition models with quarter section random effects clustered by landowner. The results of this robustness check are presented in Table 6. As in the base model, we find that an increase in the number of neighboring easements within the one mile buffer increases the likelihood of an easement. In the linear specification an additional neighboring protected quarter section within one mile increases the likelihood of an easement by 7.8 percent annually. The parameter estimates in the quadratic specification are also similar in magnitude to those estimated in the quadratic specification of the base model. We find less evidence that protected quarter sections within one to five miles influence the likelihood of an easement and there is no evidence that government-protected land crowds out investment in conservation easements. The results for the remaining covariates in both the linear and quadratic specifications of the landowner clustered models are similar to those from the base model. These results suggest that unobserved landowner characteristics correlated across quarter sections are not driving our baseline results.[19]

[19] An alternative approach to handle unobserved landowner effects is to define the unit of observation on the basis of landownership boundaries. This is not ideal in the current application for a couple of reasons. First, the conservation agencies target habitat by quarter section. Parcels defined by landownership boundaries will often contain quarter sections with no eligible habitat acreage. Using average characteristics of parcels defined by landownership boundaries is therefore not appropriate. Second, we do not observe all landownership boundaries in our study region. Using landownership boundaries would therefore require us to discard a portion of our sample, many of which have easements. As a further robustness check, we ran models using landownership boundaries as the unit of observation. The results are robust to this alternative unit of observation: neighboring easements within the one mile buffer increase the likelihood of an easement by 10.1% annually, easements within the one to five mile buffer have no effect, and neighboring government protected land has a small negative impact on easements. These results are not reported due to space constraints but are available from the authors upon request.

Linear probability fixed effects model

As a second robustness check, we run a fixed effects linear probability model using quarter section fixed effects. Whereas there is concern that random effects at the quarter section level may be correlated with surrounding easement activity, correlation between quarter section fixed effects and surrounding easement activity is not a concern. We present the results of this robustness check in Table 7. As is the case in the baseline results, an additional easement within the first mile buffer increases the likelihood of an easement. In the linear probability model, the influence of an additional easement in the one to five mile buffer is also positive and is statistically significant. These results confirm that we have identified a positive and significant spatial interaction effect within the one and the one to five mile buffers. We find that neighboring government-protected areas have no influence on easement activity.

The time-varying municipal land price index has a negative and statistically significant impact on easement activity, whereas the variables capturing sales in the past 4 to 8 years and sales in the past 9 to 12 years have a positive impact on easement activity in the linear probability model. Overall, results from the fixed effects linear probability model are consistent with the results obtained from the baseline random effects discrete-time transitions model.

Concluding Remarks

We assess the extent to which conservation agencies operating in the prairie pothole region of western Canada are able to enroll spatially contiguous habitat in permanent conservation easements. We do so utilizing a quarter section-level panel dataset documenting more than ten years of conservation easement activity in Manitoba. To our knowledge, this is the first study of spatial interactions in habitat conservation to examine the role of endogenous spatial interactions that arise out of conservation agency targeting efforts and social interactions among neighboring landowners. We identify endogenous spatial interactions based off of variation in the timing of neighboring conservation easement activity, controlling for the important factors influencing enrollment in conservation easements. We account for spatially correlated unobservables through the use of spatial fixed effects and a local time-varying land price index.

We present evidence that endogenous spatial interactions do influence conservation easement activity. Our results suggest that, on average, an additional neighboring protected quarter section within one mile increases the likelihood of an easement by 9.8 percent annually. The interaction effect due to immediately adjacent protected quarter sections is large, but diminishes as more neighboring quarter sections are protected. This may be due to diminishing ecological benefits to protecting contiguous habitat. We also find that the strength of the spatial interaction decreases with distance: an additional protected quarter section within one to five miles increases the likelihood of an easement by less than 2 percent annually. This is consistent with agency targeting criteria and weaker social interactions among more distant neighbors.

We find that government-protected land has a small crowding out effect on conservation easements if a sufficiently large number of neighboring quarter sections are protected by the government. The conservation program we study is a public/private joint venture and it is therefore not surprising that we find little evidence of crowding out. Although we do not find strong evidence of crowding out in our study region it is not clear that these results will generalize to other regions where there is less cooperation between conservation agencies and governments. Further, in this study, we examine the extent to which government protected land attracts or repels conservation easements, but do not investigate the impact of government protected land on the overall level of investment by conservation agencies.

Our results suggest that the conservation agencies have successfully leveraged past conservation easement activity in order to increase enrollment of contiguous habitat. This is consistent with the targeting efforts of the conservation agencies to protect contiguous habitat. It is also consistent with landowners learning about conservation easements from their neighbors, possible reputation effects associated with easements, and changes in local social norms that make enrolling habitat in easements more socially acceptable. It therefore appears as though economic incentives to enroll habitat in easements are also an investment in moral suasion such that neighboring landowners become more likely to subsequently enroll their own habitat in an easement.

REFERENCES

Albers, Heidi J., Amy W. Ando, and Michael Batz. 2008. “Patterns of Multi-Agent Land Conservation: Crowding In/Out, Agglomeration, and Policy,” *Resource and Energy Economics*, 30(4): 492-508.

Albers, Heidi J., Amy W. Ando, and Xiaoxuan Chen. 2008. “Spatial-econometric Analysis of Attraction and Repulsion of Private Conservation by Public Reserves,” *Journal of Environmental Economics and Management*, 56(1): 33-49.

Ando, Amy W. and Lee Hannah. 2011. “Lessons from Finance for New Land-Conservation Strategies Given Climate-Change Uncertainty,” *Conservation Biology*, 25(2): 412-414.

Ando, Amy W. and Mindy L. Mallory. 2012. “Optimal Portfolio Design to Reduce Climate-Related Conservation Uncertainty in the Prairie Pothole Region,” *Proceedings of the National Academy of Sciences*, 109(17): 6484-6489.

Banerjee, Prasenjit and Jason F. Shogren. 2012. “Material Interests, Moral Reputation, and Crowding Out Species Protection on Private Land,” *Journal of Environmental Economics and Management*, 63: 137-149.

Brock, William and Steven Durlauf. 2001. “Interactions-based Models,” in *Handbook of Econometrics*, eds. J.J. Heckman and E. Leamer, 3297-3380. New York: Elsevier Science.

Brown, Laura K., Elizabeth Troutt, Cynthia Edwards, Brian Gray, and Wanjing Hu. 2011. “A Uniform Price Auction for Conservation Easements in the Canadian Prairies,” *Environmental and Resource Economics*, 50(1): 49-60.

Carlyle, Stephen. 2013. Personal communication, Program Development Manager, Manitoba Habitat Heritage Corporation.

Chen, Xiaodong, Frank Lupi, Guangming He, and Jianguo Liu. 2009. "Linking Social Norms to Efficient Conservation Investment in Payments for Ecosystem Services," *Proceedings of the National Academy of Sciences*, 106(28): 11812-11817.

Drechsler, Martin, Frank Watzold, Karin Johst, and Jason F. Shogren. 2010. "An Agglomeration Payment for Cost-effective Biodiversity Conservation in Spatially Structured Landscapes," *Resource and Energy Economics*, 32(2): 261-275.

Grout, Cyrus A. 2009. "Incentives for Spatially Coordinated Land Conservation: A Conditional Agglomeration Bonus," *Western Economic Forum*, 8(2): 21-29.

Hanley, Nick, Simanti Banerjee, Gareth D. Lennox, and Paul R. Armsworth. 2012. "How Should We Incentivize Private Landowners to 'Produce' More Biodiversity?" *Oxford Review of Economic Policy*, 28(1): 93-113.

Irwin, Elena G. and Nancy E. Bockstael. 2004. "Land Use Externalities, Open Space Preservation, and Urban Sprawl," *Regional Science and Urban Economics*, 34(6): 705-725.

Irwin, Elena G. and Nancy E. Bockstael. 2002. "Interacting Agents, Spatial Externalities, and the Evolution of Residential Land Use Patterns," *Journal of Economic Geography*, 2(1): 31-54.

Kiesecker, Joseph M., Tosha Comendant, Terra Grandmason, Elizabeth Gray, Christine Hall, Richard Hilsenbeck, Peter Kareiva, Lynn Lozier, Patrick Naehu, Adena Rissman, M. Rebecca Shaw and Mark Zankel. 2007. "Conservation Easements in Context: A Quantitative Analysis of Their Use by the Nature Conservancy," *Frontiers in Ecology and the Environment*, 5(3): 125-130.

Lawley, Chad and Charles Towe. 2014. "Capitalized Costs of Habitat Conservation Easements," *American Journal of Agricultural Economics*, 96(3): 657-672.

Lewis, David J. and Andrew J. Plantinga. 2007. "Policies for Habitat Fragmentation: Combining

Econometrics with GIS-Based Landscape Simulations," *Land Economics*, 83(2): 109-127.

Lewis, David J., Andrew J. Plantinga, and JunJie Wu. 2009. "Targeting Incentives for Habitat Fragmentation," *American Journal of Agricultural Economics*, 91(4): 1080-1096.

Lewis, David J., Bradford L. Barham, and Brian Robinson. 2011. "Are There Spatial Spillovers in the Adoption of Clean Technology? The Case of Organic Dairy Farming," *Land Economics*, 87(2): 250-267.

Lynch, Lori and Xiangping Liu. 2007. "Impact of Designated Preservation Areas on Rate of Preservation and Rate of Conversion: Preliminary Evidence," *American Journal of Agricultural Economics*, 89(5): 1205-1210.

Lynch, Lori and Xiangping Liu. 2009. "Does Targeting a Designated Area Crowd Out the Other Preservation Programs Efforts?" Selected Paper, Agricultural and Applied Economics Association Annual Meeting, Accessed online October 29, 2013 at http://ageconsearch.umn.edu/bitstream/49339/2/Liu%20and%20Lynch_crowding%20effect_april%202009_AAEA.pdf

Lynch, Lori and Sabrina Lovell. 2003. "Combining Spatial and Survey Data to Explain Participation in Agricultural Land Preservation Programs," *Land Economics*, 79(2): 259-276.

Manski, Charles F. 2000. "Economic Analysis of Social Interactions," *The Journal of Economic Perspectives*, 14(3): 115-136.

McMillen, Daniel P. 2012. "Repeat Sales as a Matching Estimator," *Real Estate Economics*, 40(4): 745-773.

Nicoletti, Cheti and Concetta Rondinelli. 2010. "The (Mis)Specification of Discrete Duration Models with Unobserved Heterogeneity: A Monte Carlo Study," *Journal of Econometrics*, 159: 1-13.

North American Waterfowl Management Plan (NAWMP). 2010. *Canadian Habitat Matters 2010 Annual Report*, Accessed November 21, 2013 at http://nawmp.wetlandnetwork.capdf/Canadian%20HMs%202010%20FINAL%20English.pdf

Parker, Dominic P. 2004. "Land Trusts and the Choice to Conserve Land with Full Ownership or Conservation Easements," *Natural Resources Journal*, 44:483-518.

Parker, Dominic P. and Walter N. Thurman. 2011. "Crowding Out Open Space: The Effects of Federal Land Programs on Private Land Trust Conservation," *Land Economics*, 87(2): 202-222.

Parker, Dominic P. and Walter N. Thurman. "Conservation Easements: Tools for Conserving and Enhancing Ecosystem Services." in Jay Shogren, ed. *Encyclopedia of Resource, Energy, and Environmental Economics*. London, UK: Elsevier, Inc., 2013, pp.133-143.

Parkhurst, Gregory M. and Jason F. Shogren. 2007. "Spatial Incentives to Coordinate Contiguous Habitat," *Ecological Economics*, 64: 344-355.

Parkhurst, Gregory M., Jason F. Shogren, Chris Bastian, Paul Kivi, Jennifer Donner, and Rodney B.W. Smith. 2002. "Agglomeration Bonus: An Incentive Mechanism to Reunite Fragmented Habitat for Biodiversity Conservation," *Ecological Economics*, 41: 305-328.

Polasky, Stephen, David J. Lewis, Andrew J. Plantigna, and Erik Nelson. 2012. "Optimal Conservation with Spatially-Dependent Benefits and Asymmetric Information," Working Paper http://www.ncsu.edu/cenrep/workshops/TREE/documents/Plantingaseminarpaper.pdf

Polasky, Stephen and Kathleen Segerson. 2009. "Integrating Ecology and Economics in the Study of Ecosystem Services: Some Lessons Learned," *Annual Review of Resource Economics*, 1:409-434.

Prairie Habitat Joint Venture (PHJV). 2008. "Prairie Habitat Joint Venture Implementation Plan 2007—2012," Report of the Prairie Habitat Joint Venture. Environment Canada, Edmonton,

Alberta 34 pp. (revised May 2009) Accessed online November 21, 2013 at
http://www.phjv.ca/pdf/PHJV%20Implementation%20Plan%20090506-lowres.pdf\

Shogren, Jason F. and Parkhurst, Gregory M. 2011. "Who Owns Endangered Species?" Property in Land and Other Resources, eds. Cole, Daniel H. and Elinor Ostrom. Cambridge, MA: Lincoln Institute of Land Policy

Sorice, Michael G., Wolfgang Haider, J. Richard Conner, and Robert B. Ditton. 2011. "Incentive Structure of and Private Landowner Participation in an Endangered Species Conservation Program," *Conservation Biology*, 25(3): 587-596.

van Kooten, Cornelis G. and Andrew Schmitz. 1992. "Preserving Waterfowl Habitat on the Canadian Prairies: Economic Incentives versus Moral Suasion," *American Journal of Agricultural Economics*, 74(1): 79-89.

van Kooten, Cornelis G. 1993. "Bioeconomic Evaluation of Government Agricultural Programs on Wetland Conservation," *Land Economics*, 69(1): 27-38.

Williams, B.K., M.D. Koneff, and D.A. Smith. 1999. "Evaluation of Waterfowl Conservation under the North American Waterfowl Management Plan," *Journal of Wildlife Management*, 63(2): 417-440.

Williams, Justin C., Charles S. Revelle, and Simon A. Levin. 2005. "Spatial Attributes and Reserve Design Models," *Environmental Modeling and Assessment*, 10: 163-181.

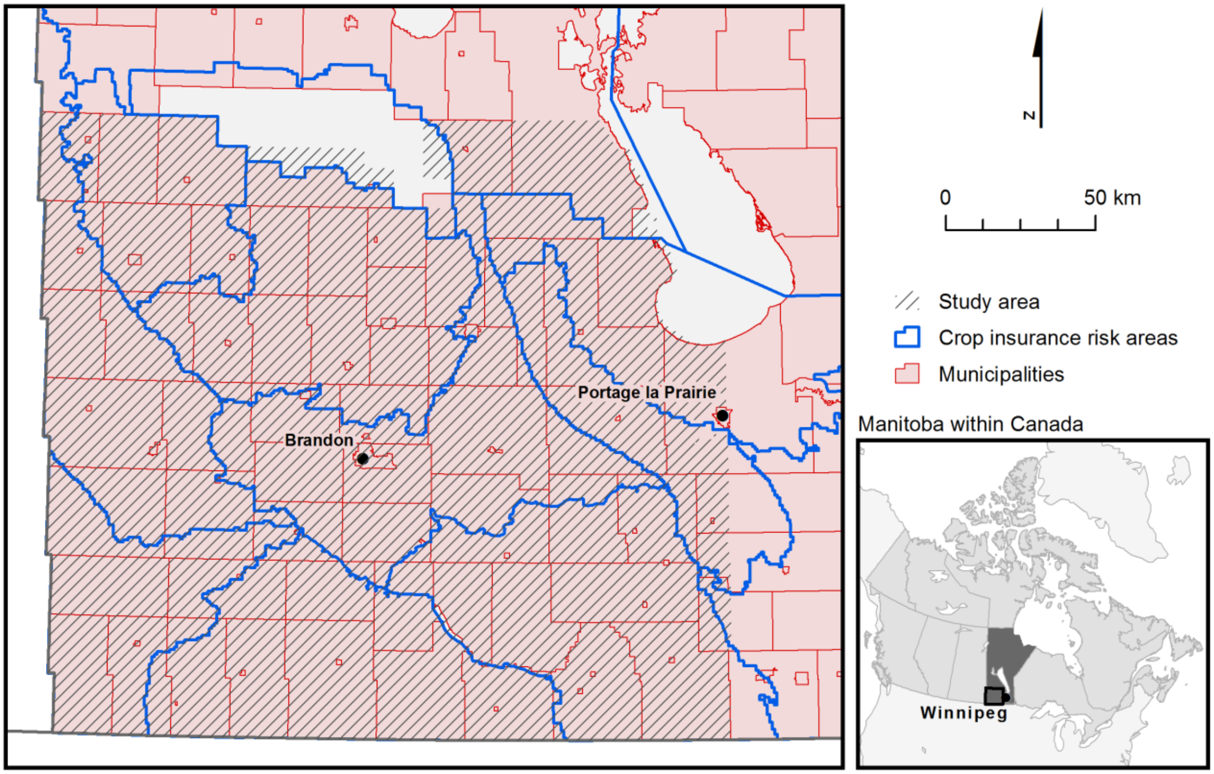

Figure 1: Study area, crop insurance risk areas, and rural municipalities

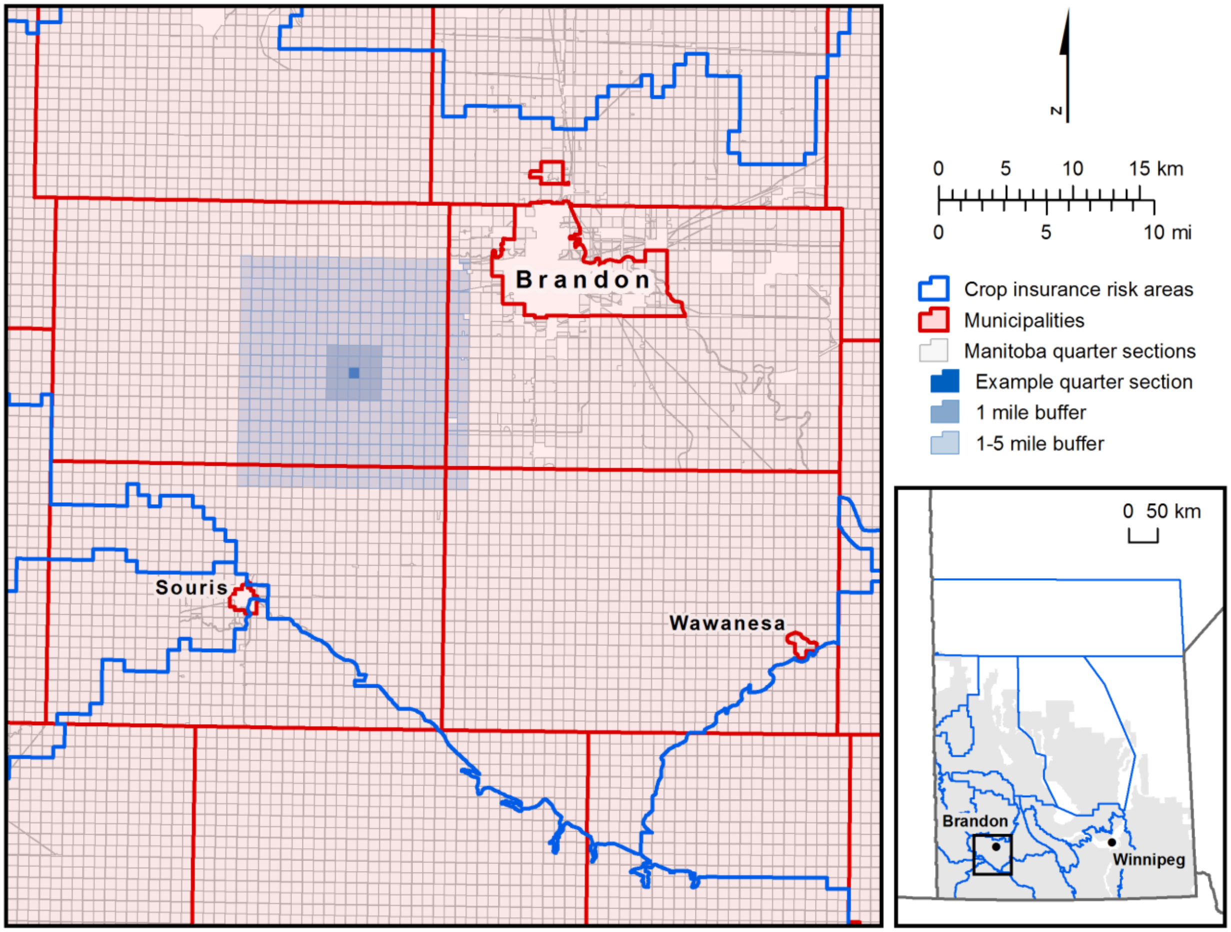

Figure 2: Neighboring buffers

Table 1: Summary Statistics				
	Mean	Std. Dev.	Min.	Max.
No. of eased quarter sections within 1 mile	0.30	1.00	0.00	15.00
DUC eased quarter sections	0.12	0.66	0.00	12.00
MHHC eased quarter sections	0.18	0.72	0.00	15.00
No. of eased quarter sections within 1 to 5 miles	5.63	8.60	0.00	69.00
DUC eased quarter sections	2.31	5.03	0.00	41.00
MHHC eased quarter sections	3.32	6.06	0.00	51.00
No. of gov't protected quarter sections within 5 miles	7.64	22.32	0.00	294.00
Crop acreage (%)	56.27	35.14	0.00	100.00
Forage acreage (%)	4.32	13.59	0.00	99.92
Other acreage (%)	1.58	3.01	0.00	92.16
Crop acreage within 1 mile (%)	56.00	23.90	0.00	98.72
Forage acreage within 1 mile (%)	4.28	4.63	0.00	37.17
Other acreage within 1 mile (%)	1.60	1.30	0.00	42.53
Crop acreage within 1 to 5 miles (%)	55.53	17.66	0.32	91.51
Forage acreage within 1 to 5 miles (%)	4.20	2.30	0.00	14.49
Other acreage within 1 to 5 miles (%)	1.60	0.49	0.28	5.85
Rural municipality price index	135.97	21.67	9.70	200.82
Sale in past 4 years (Yes=1)	0.11	0.31	0.00	1.00
Sale in past 5 to 8 years (Yes=1)	0.12	0.33	0.00	1.00
Sale in past 9 to 12 years (Yes=1)	0.14	0.35	0.00	1.00
Mean elevation (meters)	457.16	77.09	262.14	726.67
log(distance to Portage la Prairie)	11.73	0.47	9.89	12.40
log(distance to Brandon)	11.09	0.50	8.21	11.93
log(distance to elevator)	10.44	0.61	4.28	11.45
PHJV target region (%)	33.45	46.71	0.00	100.00
CLI high waterfowl suitability index (%)	33.30	44.96	0.00	100.00
High productivity soil (%)	23.76	42.56	0.00	100.00
Medium productivity soil (%)	42.94	49.50	0.00	100.00
No. of observations	577166			
No. of quarter sections	48811			

Table 2: Number of neighboring protected quarter sections		
	Frequency	Cumulative percent
Number of eased quarter sections within 1 mile:		
0	501,001	86.80
1	34,464	92.77
2	19,921	96.23
3	8,533	97.70
4	5,626	98.68
5	2,827	99.17
6	1,783	99.48
7	1,129	99.67
8	825	99.82
9	497	99.90
10	307	99.96
Number of eased quarter sections within 1 to 5 miles:		
0	207,889	36.02
3	32,171	59.96
6	19,472	71.85
9	12,283	79.47
12	8,326	85.06
15	6,058	88.63
18	4,449	91.36
21	3,660	93.37
24	2,856	94.96
27	2,156	96.24
30	1,819	97.25
Number of government-protected quarter sections within 5 miles		
0	204,218	35.38
3	31,759	59.02
6	19,837	70.75
9	12,450	78.47
12	8,570	84.21
15	6,259	87.89
18	4,395	90.67
21	3,689	92.72
24	2,889	94.31
27	2,229	95.66
30	1,943	96.76
Number of observations	577166	
Number of quarter sections	48811	

Table 3: Base random effects discrete-time transitions model						
	Linear specification			Quadratic specification		
	Hazard ratio		Std Err	Hazard ratio		Std Err
No. of eased quarter sections within 1 mile	1.098	***	0.018	1.255	***	0.050
(No. of eased quarter sections within 1 mile)^2				0.981	***	0.005
No. of eased quarter sections within 1 to 5 miles	0.996		0.004	1.016	*	0.009
(No. of eased quarter sections within 1 to 5 miles)^2				1.000	***	0.000
No. of gov't protected quarter sections within 5 miles	0.990	***	0.003	0.992		0.007
(No. of gov't protected quarter sections within 5 miles)^2				1.000		0.000
Crop acreage (%)	0.981	***	0.001	0.981	***	0.001
Forage acreage (%)	0.986	***	0.003	0.987	***	0.003
Other acreage (%)	0.937	***	0.016	0.937	***	0.016
Crop acreage within 1 mile (%)	0.982	***	0.003	0.982	***	0.003
Forage acreage within 1 mile (%)	0.988		0.009	0.989		0.009
Other acreage within 1 mile (%)	0.983		0.033	0.982		0.033
Crop acreage within 1 to 5 miles (%)	1.017	***	0.005	1.018	***	0.005
Forage acreage within 1 to 5 miles (%)	0.962		0.026	0.965		0.026
Other acreage within 1 to 5 miles (%)	0.681	***	0.071	0.681	***	0.072
Rural municipality price index	0.983	***	0.004	0.983	***	0.004
Sale in past 4 years (Yes=1)	1.247	**	0.109	1.245	**	0.109
Sale in past 5 to 8 years (Yes=1)	1.313	***	0.112	1.304	***	0.111
Sale in past 9 to 12 years (Yes=1)	1.026		0.089	1.022		0.089
Mean elevation (meters)	1.004	***	0.001	1.004	***	0.001
log(distance to Portage la Prairie)	0.230	**	0.153	0.212	**	0.141
log(distance to Brandon)	1.065		0.293	1.060		0.292
log(distance to elevator)	1.079		0.163	1.068		0.161
PHJV target region (%)	1.010	***	0.001	1.010	***	0.001
CLI high waterfowl suitability index (%)	1.003	***	0.001	1.003	***	0.001
High productivity soil (%)	1.003	*	0.002	1.003	*	0.002
Medium productivity soil (%)	1.002	**	0.001	1.002	**	0.001
Log likelihood	-7,629.74			-7,618.24		
Number of observations	577,166			577,166		
Number of failures	1,230			1,230		
Number of quarter sections	48,811			48,811		

Notes: Both specifications include year fixed effects, risk area fixed effects, and rural municipality fixed effects.
***,**,* denotes statistical significance at 1%, 5%, and 10% respectively

Table 4: Base model: Average marginal effects (AME)			
	AME		Std Err
No. of eased quarter sections within 1 mile:			
0	0.227	***	0.040
1	0.189	***	0.031
2	0.152	***	0.023
3	0.114	***	0.018
4	0.076	***	0.019
5	0.039		0.025
6	0.001		0.033
7	-0.037		0.043
8	-0.074		0.053
9	-0.112	*	0.063
10	-0.150	**	0.073
No. of eased quarter sections within 1 to 5 miles:			
0	0.016	*	0.009
3	0.013	*	0.008
6	0.010		0.007
9	0.007		0.006
12	0.005		0.005
15	0.002		0.004
18	-0.001		0.004
21	-0.004		0.004
24	-0.007	*	0.004
27	-0.010	**	0.004
30	-0.012	**	0.005
No. of gov't protected quarter sections within 5 miles			
0	-0.008		0.007
3	-0.008		0.006
6	-0.008		0.006
9	-0.008		0.006
12	-0.008		0.005
15	-0.008		0.005
18	-0.008	*	0.005
21	-0.008	*	0.005
24	-0.009	**	0.004
27	-0.009	**	0.004
30	-0.009	**	0.004
Number of observations	577,166		
Number of quarter sections	48,811		

Notes: Average marginal effects computed based on parameter estimates from quadratic specification presented in Table 3. Standard errors constructed by the Delta method.
***,**,* denotes statistical significance at 1%, 5%, and 10% respectively

Table 5: Agency interaction model: Average marginal effects (AME)						
	DUC easement model			MHHC easement model		
	AME		Std Err	AME		Std Err
No. of eased DUC quarter sections within 1 mile:						
0	0.51	***	0.11	0.16	*	0.09
1	0.37	***	0.07	0.12	*	0.06
2	0.24	***	0.05	0.09	**	0.04
3	0.10	*	0.05	0.05		0.04
4	-0.03		0.08	0.02		0.05
5	-0.17		0.11	-0.02		0.08
6	-0.31	**	0.15	-0.05		0.10
7	-0.44	**	0.19	-0.09		0.13
8	-0.58	***	0.22	-0.12		0.16
9	-0.71	***	0.26	-0.16		0.19
10	-0.85	***	0.30	-0.19		0.21
No. of eased MHHC quarter sections within 1 mile:						
0	-0.27	**	0.11	0.25	***	0.05
1	-0.22	***	0.08	0.22	***	0.04
2	-0.16	***	0.06	0.18	***	0.03
3	-0.11	**	0.05	0.14	***	0.02
4	-0.06		0.06	0.11	***	0.03
5	0.00		0.08	0.07	**	0.04
6	0.05		0.10	0.04		0.05
7	0.10		0.13	0.00		0.06
8	0.16		0.16	-0.03		0.07
9	0.21		0.19	-0.07		0.09
10	0.26		0.22	-0.10		0.10
No. of DUC quarter sections within 1 to 5 miles:						
0	0.17	***	0.03	0.04	*	0.02
3	0.13	***	0.02	0.03		0.02
6	0.08	***	0.02	0.01		0.01
9	0.03	***	0.01	0.00		0.01
12	-0.01		0.01	-0.02	*	0.01
15	-0.06	***	0.02	-0.03	**	0.01
18	-0.10	***	0.02	-0.05	**	0.02
21	-0.15	***	0.03	-0.06	***	0.02
24	-0.20	***	0.04	-0.08	***	0.03
27	-0.24	***	0.05	-0.09	***	0.03
30	-0.29	***	0.06	-0.10	***	0.04
No. of MHHC quarter sections within 1 to 5 miles:						
0	0.00		0.02	0.05	***	0.01
3	0.01		0.02	0.04	***	0.01
6	0.01		0.01	0.02	**	0.01
9	0.02		0.01	0.01		0.01
12	0.02	**	0.01	0.00		0.01

15	0.03	***	0.01	-0.02	***	0.01
18	0.04	***	0.01	-0.03	***	0.01
21	0.04	***	0.01	-0.04	***	0.01
24	0.05	***	0.01	-0.06	***	0.01
27	0.06	***	0.01	-0.07	***	0.01
30	0.06	***	0.01	-0.09	***	0.02
No. of gov't protected quarter sections within 5 miles						
0	0.06	**	0.03	-0.01		0.01
3	0.05	**	0.02	-0.01		0.01
6	0.04	**	0.02	-0.01		0.01
9	0.03	*	0.02	-0.01		0.01
12	0.01		0.01	-0.01		0.01
15	0.00		0.01	-0.01		0.01
18	-0.01		0.01	-0.01		0.01
21	-0.02	*	0.01	-0.01		0.00
24	-0.03	**	0.01	-0.01		0.00
27	-0.04	**	0.02	-0.01	*	0.00
30	-0.06	**	0.02	-0.01	*	0.00
Number of observations	577,166			577,166		
Number of quarter sections	48,811			48,811		

Notes: Average marginal effects computed based on parameter estimates from the quadratic specifications of the two agency interaction models (the full sets of results for each agency are available upon request). The log likelihood of the DUC model is -2,244.6; the log likelihood of the MHHC model is -5,817.11. Standard errors constructed by the Delta method.

***,**,* denotes statistical significance at 1%, 5%, and 10% respectively

Table 6: Landowner cluster model						
	Linear specification			Quadratic specification		
	Hazard ratio		Std Err	Hazard ratio		Std Err
No. of eased quarter sections within 1 mile	1.078	***	0.030	1.303	***	0.095
(No. of eased quarter sections within 1 mile)^2				0.973	***	0.010
No. of eased quarter sections within 1 to 5 miles	0.992		0.006	1.036	**	0.019
(No. of eased quarter sections within 1 to 5 miles)^2				0.999	**	0.000
No. of gov't protected quarter sections within 5 miles	0.998		0.006	0.997		0.011
(No. of gov't protected quarter sections within 5 miles)^2				1.000		0.000
Crop acreage (%)	0.984	***	0.002	0.984	***	0.002
Forage acreage (%)	0.988	***	0.004	0.988	***	0.004
Other acreage (%)	0.941	**	0.023	0.942	**	0.023
Crop acreage within 1 mile (%)	0.980	***	0.005	0.981	***	0.005
Forage acreage within 1 mile (%)	0.979		0.018	0.981		0.018
Other acreage within 1 mile (%)	0.983		0.055	0.981		0.056
Crop acreage within 1 to 5 miles (%)	1.017	**	0.008	1.018	**	0.009
Forage acreage within 1 to 5 miles (%)	0.921	*	0.041	0.924	*	0.041
Other acreage within 1 to 5 miles (%)	0.812		0.126	0.814		0.130
Rural municipality price index	0.975	***	0.006	0.975	***	0.006
Sale in past 4 years (Yes=1)	1.232		0.176	1.230		0.175
Sale in past 5 to 8 years (Yes=1)	1.283	*	0.173	1.271	*	0.171
Sale in past 9 to 12 years (Yes=1)	1.014		0.126	1.010		0.125
Mean elevation (meters)	1.002		0.002	1.002		0.002
log(distance to Portage la Prairie)	0.326	*	0.219	0.290	*	0.195
log(distance to Brandon)	0.640		0.292	0.639		0.295
log(distance to elevator)	1.181		0.256	1.172		0.257
PHJV target region (%)	1.013	***	0.002	1.012	***	0.002
CLI high waterfowl suitability index (%)	1.003	*	0.002	1.003	*	0.002
High productivity soil (%)	1.000		0.003	1.000		0.003
Medium productivity soil (%)	1.001		0.002	1.000		0.002
Log likelihood	-4,191			-4,173		
Number of observations	314,147			314,147		
Number of failures	691			691		
Number of landowner clusters	14,554			14,554		

Notes: Both specifications include year fixed effects, risk area fixed effects, and rural municipality fixed effects.
***,**,* denotes statistical significance at 1%, 5%, and 10% respectively

Table 7: Fixed effects linear probability model						
	Linear specification			Quadratic specification		
	Coefficient		Std Err	Coefficient		Std Err
No. of eased quarter sections within 1 mile	2.7e-3	***	1.1e-4	3.3e-3	***	2.2e-4
(No. of eased quarter sections within 1 mile)^2				-1.0e-4	***	3.0e-5
No. of eased quarter sections within 1 to 5 miles	2.4e-4	***	1.5e-5	4.2e-4	***	3.0e-5
(No. of eased quarter sections within 1 to 5 miles)^2				-4.5e-6	***	6.5e-7
No. of gov't protected quarter sections within 5 miles	-1.2e-5		2.1e-5	-1.1e-5		3.0e-5
(No. of gov't protected quarter sections within 5 miles)^2				3.6e-8		5.2e-7
Rural municipality price index	-5.8e-5	***	6.0e-6	-5.4e-5	***	6.0e-6
Sale in past 4 years (Yes=1)	5.7e-5		2.4e-4	5.6e-5		2.4e-4
Sale in past 5 to 8 years (Yes=1)	6.1e-4	**	2.4e-4	5.9e-4	**	2.4e-4
Sale in past 9 to 12 years (Yes=1)	4.3e-4	**	2.2e-4	4.2e-4	*	2.2e-4
R^2	0.0023			0.0024		
Number of observations	577,166			577,166		
Number of quarter sections	48,811			48,811		

Notes: Both specifications include year fixed effects
***,**,* denotes statistical significance at 1%, 5%, and 10% respectively