HEDONIC VALUATION OF ECOSYSTEM SERVICES USING AGRICULTURAL LAND PRICES

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ABSTRACT

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Agriculture, an ecosystem transformed by humans for the purpose of supplying food, fiber and biofuel, can provide people a host of benefits, or ecosystem services (ES). While markets exist for farm products, many of today's central agro-environmental policy concerns are related to ES that lack complete markets, such as regulating ES and recreational, aesthetic and cultural ES. Valuation of non-marketed ES linked to agriculture is needed to improve their utilization and efficient provision. Some ES that facilitate agricultural production or provide natural amenities can be perceived by people through various natural resources and landscapes on farmlands and surrounding areas. One indirect way to measure the value of ES is via what people pay for the lands that provide them. In this hedonic study, the agricultural land price is used to reveal marginal values of those resources and landscapes, and to infer the degree of ES capitalization into land prices in southwestern Michigan. Results suggest that recreational and aesthetic services are largely capitalized through lakes, rivers, wetlands, woodlands and conservation lands. Some production-supporting regulating services may have also been partially capitalized. Certain ES from the land parcel and its surroundings are unlikely to be capitalized due to unawareness or little realized value (e.g., beneficial insects and soil microbial communities), as well as missing incentive for large scale public goods (e.g., carbon sequestration and biodiversity). In comparing sales prices and appraisal values, we find that sales prices reflect amenity benefits better than appraisal values, which tend to emphasize agricultural production potential and built capital values.

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CARL	Conservation and Recreation Lands Database
C-CAP	Coastal Change Analysis Program
ES	Ecosystem Services
EPA	Environmental Protection Agency
GIS	Geographic Information System
KBS	Kellogg Biological Station
LTER	Long Term Ecological Research
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
MDOT	Michigan Department of Transportation
MEA	Millennium Ecosystem Assessment
MLE	Maximum Likelihood Estimation
NASS	National Agricultural Statistics Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRCS	Natural Resources Conservation Service
OLS	Ordinary Least Squares
PDR	Purchase of Development Rights
SEV	State Equalized Value
SSURGO	Soil Survey Geographic Database
TDR	Transfer of Development Rights
USDA	United States Department of Agriculture

USFS	United States Forest Service
USFW	United States Fish and Wildlife Service
VIF	Variance Inflation Factors

1. Introduction

1.1 Ecosystems and ecosystem services

An ecosystem is a dynamic complex formed by the interaction of living components, such as plant, animal, and microorganism communities, and their nonliving environment (Millennium Ecosystem Assessment, 2003). The benefits people obtain from the ecosystem are defined as ecosystem services (ES) (Millennium Ecosystem Assessment, 2003). The idea of ecosystem services has been refined in the past to include not only those services that humans get opportunistically from nature, but also services from ecological systems that humans manage directly (Antle, et al., 2001).

Agriculture, a unique composite ecosystem, is intensively managed by humans while interacting with other terrestrial and aquatic ecosystems. Ecosystem services that are supplied to or derived from agriculture are known as agricultural ecosystem services, which include four categories of services as shown in Figure 1. Basic services from agriculture are those that provide agricultural products such as food, fiber and biofuel (*Provisioning ES*). *Regulating ES* are generated by regulating ecosystem processes. Some are performed by agricultural ecosystems, such as wildlife habitat and carbon sequestration, while others supplied to agriculture boost its productivity via biological control of crop pests, waste treatment, disturbance prevention, etc (Zhang, et al., 2007). *Recreational, Aesthetic and Cultural ES* from agricultural ecosystems are experienced directly by humans. Finally, *Supporting ES* (e.g., soil formation, nutrient cycling and water supply) are fundamental for the existence and evolution of agriculture and all other ecosystems.

1.2 Valuation of ecosystem services

The value of ecosystem services depends on the role of ecological properties in attaining human goals in a given certain socio-economic context (Barbier, et al., 2009). Human incentives for utilizing and manipulating ecosystem services are driven by ES values in the form of market price, private nonmarket benefits and social institutions (Robertson and Swinton, 2005). In a highly managed ecosystem like agriculture, it is critical to understand how those incentives are created and how they influence human behaviors.

Some agricultural ES, such as provision of farm products, can be directly priced by commodity markets. Hence, there exists a price incentive for efficient level of production and management. Other ES can provide value to private resource owners despite not being sold through markets. Examples include natural amenities and production-enhancing services (e.g., flood mitigation and biological pest control by natural pest enemies) from own farmlands and surrounding open spaces. Those ES also influence human decisions since they act on conditions for producing marketable goods and quality of life. However, the value of other services accrues to the general public beyond resource owners. For example, conservation farming practices can mitigate global warming by reducing greenhouse gas emissions linked to nitrogen and by storing carbon in soil. Because global warming is a public good that benefits the global community, resource users have no incentive to pay for benefits, giving resource owners no incentive to provide benefits. Public policy plays an important role by reconciling the behaviors of users and owners and leading to the efficient provision of those ES. Therefore, in the absence of a real market, nonmarket valuation of agricultural ES is needed to recognize private benefit incentives and stimulate public policy incentives for their efficient provision. The explanation of nonmarket valuation methods for ecosystem services and preferred methods for different ES can be found in Barbier et al. (2009) and De Groot et al. (2002). More detailed applications of those methods can be found with National Research Council (2005) and Pagiola et al. (2004).

Agricultural land is primarily managed for the profitable production of farm products, the basic provisioning ecosystem service. The production role of land cannot be sustained without ecosystem services regulating soil, water, insects and climate. Meanwhile, agricultural land also performs consumption roles not only for rural residence but also for recreational and aesthetic services. Some of those ES are perceived and valued by people through various natural resources and landscapes on farmlands and surrounding areas. Thus, agricultural land can be used as a medium to reveal the value of land-linked agricultural ecosystem services that support both production and consumption roles. It has long been recognized that agricultural land is a differentiated good with a large number of characteristics that varies across parcels. Some characteristics are easily changed by land owners, e.g., tillage techniques, land irrigation and building structures. Others are relatively inherent, e.g., soil type, topographic features and local climate (Palmquist, 1989).

By studying land prices that vary along with those characteristics, we can separate the implicit value of each component, including those related to ecosystem services. This is a revealed preference nonmarket valuation method known as *hedonic analysis*. By treating land as a bundle of characteristics, the hedonic method uses statistical regression methods to examine how changes in specific land characteristics affect land prices. In this study, both sales price and tax assessors' estimates of land price, namely appraisal values, are used to elicit marginal values of natural resources and landscapes providing ecosystem services.

1.3 Research gap and objectives

Previous hedonic studies of agricultural land prices have focused on selected aspects of ecosystem services. Since provisioning ES of food, fiber and fuel is a basic role of farmland, almost every study addressed farm production with one or more measures, as simple as cropland acres (Elad, et al., 1994) and cultivated land percentage (Shonkwiler and Reynolds, 1986), or as complex as a productivity index from soil and land use conditions (Drescher and McNamara, 1999, Nivens, et al., 2002). Some studies extended the estimation of farmland production to regulating ES on water, soil and weather (Faux and Perry, 1999, Maddison, 2000, Palmquist and Danielson, 1989). For complete valuation of agricultural land, several other studies took into account land characteristics for consumption use. Bastian et al. (2002) especially highlighted the amenities from recreation activities and scenic views. However, that study and three other studies (Drescher, et al., 2001, Nivens, et al., 2002, Pyykkönen, 2005) that evaluated ES attributes supporting both production and consumption functions of farmland ignored the value of on-site buildings, which is an important determinant of farmland value. If the residential structures play a big role for land price in those regions, the results could suffer from omitted variable bias. While Petrie and Taylor (2007) and King and Sinden (1988) conducted studies related to ES with complete specifications, the variables measuring consumptive ES are not designed for both on-site and off-site effects, as their interests concentrate on water use permits and soil conservation respectively.

Based on the review of literature, although various studies have used hedonic methods to value certain impacts related to ecosystem services embodied in agricultural land, we are unaware of any hedonic study that measures the value of land-based ecosystem service in a holistic fashion that integrates both production and consumption attributes related to land assets and associated ES. To accomplish this integration, we propose a conceptual model of agricultural land price determination, and estimate it empirically with data from southwestern Michigan.

In order to understand the degree to which ES linked to agriculture have their value signaled through the agricultural land market in this area, the hedonic method is applied to infer farmers' willingness to pay for ecosystem services that either support the provisioning of agricultural products or offer natural amenities. The objectives of this study are:

1) To identify which natural resources or landscapes providing ES have values that can be discerned from land prices and evaluate their relative magnitudes;

2) To characterize which ES are likely to be highly capitalized, partially capitalized or not capitalized into land, based on specific ES characteristics with regard to land markets;

3) To explore the difference in capturing the value of ES using data on sales price as compared to appraisal value.

Our hypotheses are:

1) Natural resource and landscape traits that *directly* influence farmland owners' production (e.g., provisioning ES) and consumption (e.g., aesthetical and recreational ES) will be capitalized in land prices.

2) Natural resources and landscape traits that *indirectly* influence farmland owners' production or consumption via local public good effects (e.g., regulating ES at local scale) will be partially capitalized, and those that have larger scale public good effects (e.g., regulating ES at regional and global scales) will not be capitalized in land prices.

3) Sales prices will reflect more on land owners' valuation of ES than appraisal values, due to their different value generation mechanisms.

The next section explains the conceptual framework in detail. Section 3 describes the hedonic method, empirical model and data. Section 4 presents and interprets the analysis results. Section 5 summarizes the conclusions and discusses policy implications.

2. Conceptual Model

2.1 Ecosystem services embodied in agricultural land

Agricultural lands are mostly owned privately and managed for the profitability of production. Farming practices based on agricultural land take advantage of ES generated within and outside the parcel boundaries. Meanwhile, agricultural ecosystems also yield services to other agricultural or nonagricultural systems. According to the total economic value theory, the value of an ecosystem service can be categorized by the nature of its interaction with humans (Pearce, 1993). Some agricultural ecosystem services are valued directly for the actual use experienced by land owners; some have indirect use value for their support of the direct use, while others are simply valued for existence, bequest and potential for future use/nonuse.

Agricultural ecosystem services can also be distinguished by their ownership characteristics. Two criteria are widely used for defining four types of good/service (Olson, 1971). The first and most important one is excludability, i.e., whether it is costly or not to exclude beneficiaries from consuming a good or service. The second one is rivalness or subtraction, i.e., whether the consumption of units by one person subtracts form the availability of benefits to others. Those that are nonexcludable and nonrivalrous are known as public goods, whereas private goods are the opposite. Common-pool resources are rivalrous but nonexcludable since the existence of resources is limited. Club goods which are owned by a defined group of people are excludable but nonrivalrous. *Property right,* an enforceable authority to undertake particular actions in a specific domain (Commons, 1968), is not well defined for goods/services that are nonexcludable, namely, public goods and common-pool resources. As no beneficiary is willing to pay for utilization of those goods/services, they cannot be provided at the socially optimal level. High level use of a common-pool resource will also lead to its congestion, degradation and even destruction (Ostrom, 2003). Clearly specified property rights are potential remedies for solving those problems.

An integrative explanation of agricultural ecosystem services in terms of total economic values and property rights is represented in Figure 2. There are four forms of ES embodied in farmland:

- *On-site ES with direct use value* (provisioning ES, recreational ES and aesthetic ES) are a type of private good. Those services are invested and managed by land owners with benefits accrue only to them. Those ES are likely to be valued by land owner or farm product market, and can be expected to be fully capitalized in land market.
- *Off-site ES with direct use value* (recreational ES and aesthetic ES) partly benefit the owners of farmlands, hence could be partly capitalized into land price. While the recreational resources can be rivalrous as common-pool resources, aesthetic ES are mostly treated as public good.
- *On-site and off-site ES with indirect use value* (regulating ES such as natural soil fertility and habitat provision for natural pest enemies) are resources that partly support the direct use ES for farmland. Their values might be partly capitalized in the land market due to unawareness of land owners or little privately realized value. However, on-site resources may also generate negative effects on cropland as a "private bad", e.g., the impacts of flood and erosion from on-site rivers.
- *On-site ES with nonuse or option value* (regulating ES for climate and biodiversity, supporting ES and cultural ES) have the properties of public goods in the sense that they benefit the entire population. Thus, their value could not be capitalized by private land price. With little value gained from regulating ES, the on-site private provision of public good would normally lead to under-provision of those services.

2.2 Total economic land value

The conceptual model of agricultural land valuation is grounded in land rent theory, which captures the intertemporal essence of land value and the principal land determinants. In political economy, land is recognized as an inelastic factor of production. Land rent is the distribution paid to the land holder. Hartwick and Olewiler (1998) provided the definition of *land rent per unit* as "the surplus between the price of a good produced using a natural resource and the unit costs of turning that natural resource into the good". The unit costs include the value of the labor, capital, materials and energy inputs used. For homogenous land, the return to land as an input factor of production is defined as land rent, which is maximized when the marginal product equals the marginal cost of variable factors. For heterogeneous land, the concept of *differential rent* is applied. Ricardo, who first clearly exposited the source and magnitude of land rent, states differential rent as "the economic advantage obtained by using the site in its most productive use, relative to the advantage obtained by using marginal land for the same purpose, given the same inputs of labor and capital" (Ricardo, 1821). The conventional present value of land can be represented by Equation 1:

$$Y_t = \sum_{s=0}^{\infty} \frac{E[y_{t+s} | I_t]}{(1+r)^{s+1}} \tag{1}$$

where Y_t, is the real value per acre of farmland at the start of period t, y_t, is the real net rent per acre in period t (paid at the end of period t), and r is the real interest rate. Expression $E\ [y_{t+s} | I_t]$ denotes the market expectation of net rent formed at the start of time t based on the information set I_t at that time (Falk, 1991).

Klinefelter (1973) explained land prices by two distinct components---- expected net rents and expected capital gains. Alston (1986), Burt (1986) and Melichar (1979) supported that the land price variation can mostly be attributed to net rents under different assumptions. However, Featherstone and Baker (1987) suggested that speculative forces can purely determine farmland prices. Farmland development is an important driver of speculative gains as urban growth pressures often increase the demand for land in non-farm uses and the profitability of converting farmland over time. As indicated in Equation 2, the value of a farm parcel is a function of the discounted present value of farming returns (A_t) up to the optimal development time (u) and the discounted present value of returns from converting a farm to a non-farm use (R) at the optimal development time. A_t is the per acre annual net returns from farming, R is the one-time per acre returns from development, net of conversion costs, x is a vector of exogenous parcel characteristics (Nickerson and Lynch, 2001).

$$V = \int_{t=o}^{u} A_t\left(x\right)e^{-rt}dt + R\left(x,u\right)e^{-ru} \quad (2)$$

2.3 Agricultural land valuation model

The conventional total economic land value based on land rents from production and capital gains from development is incomplete, for it omits an important component of land value from consumption amenities. The integrated valuation of farmland should be built on a full understanding of its functions. Agricultural land as a carrier of managed ecosystems simultaneously performs many public and private functions. Farmers utilize land for agricultural production to earn their livelihood and store wealth. Land is also a home site for a farmstead and rural residents seeking open space to pursuit of a country lifestyle. Recreational activities, such as fishing and hunting, and aesthetic sceneries derived from agricultural land are enjoyed by farmers, rural residents and visitors. Besides the production and consumption functions, agricultural lands act as an asset that also provide opportunities for developers to invest and develop for non-farm uses. Therefore, the value of agricultural land should be estimated from its production, consumption and asset roles. Similar components of agricultural land value have been explicated by several studies. In the 1960s, Hartman and Anderson (1962) viewed land as a home for implicit rental income and a production unit for returns. Henneberry and Barrows (1990) then formulated land value from individual utility and state that "land as a factor of production will influence income, land as an asset will influence wealth, and lands as a consumption good will influence the quality of leisure". Xu et al. (1993) summarize land value from productive, consumptive and speculative aspects. This study extends the three-component land value model by distinguishing between attributes built and managed by landowners and those provided and regulated by ecosystems in the production and consumption components.

We develop a conceptual model for farmland valuation in a market with sellers and purchasers. From the standpoint of the **land purchaser**, the model is organized from the production, consumption and asset functions of land. In the **consumption** aspect (Equation 3), the land purchaser chooses the parcel of land M to maximize their utility embodying consumption built attributes B_c (e.g., on-site residence), consumption ES attributes E_c (e.g., recreational and aesthetic services) and other goods N (daily necessity). While $P(z)$ is the hedonic price of the parcel, there is a budget constraint indicating that the expense on other goods $P_N N$ and land purchase $P(z)M$ should be less than or equal to the sum of discounted present values of future profits from land production π^b, the option value for future development $\pi(T)$ and the present value of other nonfarm income, NFI. D denotes a vector of purchaser attributes.

$$MaxU(N, E_c, B_c, D) \text{ s.t. } P_N N + P(z)M \le \pi^b + \pi(T) + NFI \quad (3)$$

The value of on-site structures is an important determinant of land price and has been modeled in many hedonic farmland price studies. Measures of building size, age, quality and permits are frequently adopted (Drescher and McNamara, 1999, Ervin and Mill, 1985, Faux and Perry, 1999, Palmquist and Danielson, 1989). However, consumption values due to natural amenities are only addressed by limited research. Bastian et al. (2002) applied a hedonic study to Wyoming farmland in a state with wide-ranging agricultural areas and abundant natural amenities, in demonstrating that farmland values are also driven by rural residence demanders in addition to agricultural producers. Amenity variables measuring elk habitat, fish habitat, and scenic view composition were especially designed to capture recreational and aesthetic values. Results suggested that increases in view diversity and trout density enhance farmland prices, while the presence of elk habitat implied a negative effect, probably because the damage from elk outweighs potential hunting benefit. In Minnesota, a county-level natural amenity index constructed from climate, topography, and water conditions had a positive effect on the potential for retirement and recreational activity development (Drescher, et al., 2001). The impacts of recreational use on farmland were also valued as conditional variables in other studies via percentage of surrounding water body, distance to water body and recreational use dummy (King and Sinden, 1988, Nivens, et al., 2002, Petrie and Taylor, 2007, Pyykkönen, 2005). Some disamenity effects from animal feeding operations, nearby mining and quarries were also addressed in several studies (Chicoine, 1981, Huang, et al., 2003).

In the **production** aspect (Equation 4), the profit equals discounted farm products revenue P_yY minus input cost P_xX and fixed cost FC. The production of Y is facilitated by production ES attributes E_p (e.g., water regulation and soil fertility), production built attributes B_p (e.g., land improvements) and other input, X.

$$\pi^b = P_y Y - P_x X - FC \quad \text{s.}t. \quad Y = f(X, B_p, E_p) \tag{4}$$

The built production attributes such as percentage of tillable land are always included in the empirical models. Other attributes considered are land improvement (Bastian, et al., 2002, Gardner and Barrows, 1985, Huang, et al., 2003, Petrie and Taylor, 2007, Vendeveer, et al., 2000), farm rights to tobacco/mining/peanuts/milk quotas (Gardner and Barrows, 1985, Maddison, 2000, Nivens, et al., 2002, Palmquist and Danielson, 1989), and agricultural buildings (Xu, et al., 1993). Ecosystem services related to production are provisioning ES for farm products and regulating ES that support provision of products. The quality of provisioning ES, namely productivity, is measured in various ways. Drescher et al. (2001) examined the general determinants of farmland prices in Minnesota. The variables related to provisioning services are crop equivalent land capability rating (measuring land productivity), share of tillable acres, as well as county-level demand factors like crop and livestock values. Those variables were found to have a significant positive influence on land price. With county-level data, the general yield of farm products can also be easily calculated (Drescher and McNamara, 1999, Pyykkönen, 2005, Roka and Palmquist, 1997). Other productivity index attributes have been constructed from soil potential (Chicoine, 1981, Ervin and Mill, 1985, Vitaliano and Hill, 1994) or with the assistance of remote sensing (Nivens, et al., 2002) and Geographic Information System (GIS) (Bastian, et al., 2002).

The benefits for agriculture from regulating those systems were also emphasized by some hedonic studies. Faux and Perry (1999) applied hedonic farmland price analysis to reveal the implicit market price of water in irrigation using agricultural property sales in Oregon. According to the seven soil quality classes from the Natural Resources Conservation Service (NRCS) Soil Survey, the lack of rainfall causes the better quality soils (I-V) to be no more productive than low quality non-irrigated land (VI and VII). Value of irrigation water can be determined by subtracting the value of dryland (class VI) from each of the five irrigated land classes. The marginal value of water for irrigation was estimated to be $9 per acre-foot. The capitalization of water permits (Petrie and Taylor, 2007) and shares of irrigation company stock (Hartman and Anderson, 1962) were also examined.

Palmquist and Danielson (1989) studied the value of erosion control and drainage using data from North Carolina. Attributes indicating soil quality, soil wetness and erosion potential were included. The soil wetness coefficient suggested that draining wet soil increases land values by 34% on average. The variable representing erosion potential suggested one ton/acre/year reduction in potential soil loss worth $6.19 in land price. Several other hedonic studies also addressed soil erosion, drainage and conservation problems with similar attributes (Ervin and Mill, 1985, Gardner and Barrows, 1985, King and Sinden, 1988, Miranowski and Hammes, 1984).

The impact of climate regulation on agricultural land needs to be tracked for a long period, and hence related characteristics are rarely present in the hedonic studies. Maddison (2000) did such a county-level analysis on farmland values in England and Wales with long-term indicators of the weather conditions. Results showed that frost days in winter, summertime temperatures and relative humidity during the summer had a significant impact on price. The average elevation indicating the diurnal variation in temperatures was also significant with a negative effect.

Besides production and consumption roles, farmland is also valued from its **asset** function for non-farm development. The option value $\pi (T)$ is gained from the potential for future development of the land asset included in *T*. Development potential is widely measured in hedonic farmland studies using proxy variables such as distance to major cities or towns and county-level socio-economic measures (Shonkwiler and Reynolds, 1986). Some studies highlight the price effects from farm preservation programs. Nickerson and Lynch (2001) estimated the effect of voluntary development restrictions (Purchase of Development Rights (PDR)/Transfer of Development Rights (TDR)) in Maryland. Results showed little evidence that voluntary permanent preservation programs significantly decrease the market price because the restriction was not expected to be permanently binding and the preserved farms might be purchased as hobby farms for residential and lifestyle value. Henneberry and Barrows (1990) estimated the effect of compulsory development restrictions (exclusive agricultural zoning). The results suggested that net capitalization of zoning is likely to be positive for parcels with high agricultural potential because other effects would outweigh the development constraint effect while capitalization is negative for parcels with high development potential. Vitaliano and Hill (1994) studied the Agricultural District program in New York State, and found no capitalization of the preservation program since voluntary participants' most valuable use is likely to be agriculture in the foreseeable future.

From the **land seller** perspective (Equation 5), we simplified the model as profit maximization with similar consideration of benefit and cost from the land (M). S denotes a vector of seller attributes.

$$Max\pi^{s} = P(Z)M - C(M,Z,T,S) \tag{5}$$

The agricultural land attributes Z are made up of consumption ES characteristics (E_c), production ES characteristics (E_p), consumption built characteristics (B_c) and production built characteristics (B_p) (Equation 6). The farmland sale transaction is carried out by the interaction of purchasers and sellers, and both face sale transaction costs (also included in T).

$$Z = (B_c, B_p, E_c, E_p, T) \tag{6}$$

Based on the conceptual framework and literature review, four studies (Bastian, et al., 2002, Drescher, et al., 2001, Nivens, et al., 2002, Pyykkönen, 2005) evaluated ES attributes supporting both production and consumption functions of farmland, but ignored the value of on-site buildings, an important conditioning determinant of farmland price. This missing variable not only overlooks on important consumption attribute of farmland, but would also cause inconsistent estimates if it is correlated with some other variables. While Petrie and Taylor (2007) and King and Sinden (1988) did conduct studies related to ES with complete specifications, the variables measuring consumptive ES are not designed for both on-site and off-site effects since their interests concentrate on water use permits and soil conservation respectively. We are unaware of any hedonic study measuring the value of land-based ecosystem service in a holistic fashion that integrates both production and consumption attributes related to land assets and associated ES. This study will apply the hedonic method to the conceptual framework above, using data from southwestern Michigan to estimate the values of ecosystem services provided by natural resources and landscapes that are embodied in agricultural land prices and appraised values. It will interpret values associated with other related ecosystem services that are likely to be partially capitalized or not capitalized.

3. Method and empirical model

3.1 Hedonic method

Hedonic analysis is a powerful revealed preference method for non-market valuation of the environment and natural resources. The discussion of agricultural land prices dates back to 1826 when von Thünen established the location theory of agricultural production and land price in Germany. While Hass' (1922) use of agricultural land price as a function of city size and distance to the city center is regarded as an early example of hedonic analysis (Colwell and Dilmore, 1999), Ridker's (1967) work on the economic cost of air pollution, is often credited as the first hedonic price estimate (Mathis, et al., 2003). Based on a branch of microeconomic theory in which utility is generated by characteristics of the goods (Lancaster, 1966), Rosen provided a classic theoretical foundation for the hedo nic model by exhibiting individual choices in market equilibrium (Rosen, 1974). Let $Z = (z_1, z_2, ... z_n)$ denote n attributes of a differentiated market good. In a perfectly competitive market with sufficient number of goods, the equilibrium price p can be determined by the interaction of utility-maximizing consumers and profit-maximizing producers. Practically, the fundamental hedonic equation is $p = h(Z)$, where $h(\cdot)$ representing the relationship between good price and the attributes can take diverse functional forms. Regressing observed prices p on all attributes of the good, ignoring differences in supplier or consumer characteristics, we can obtain an estimated marginal price $\hat{p}_i$ of each attribute as depicted in equation $\hat{p}_i = \partial \hat{h}(Z) / \partial z_i$.

The estimation of a hedonic function can be performed in two stages. The first and most common stage is the estimation of the hedonic price equation to obtain marginal prices that people would pay for a small change in each attribute. The second stage attempts to recover structural supply and demand parameters for individual characteristics. In that stage, the implicit prices obtained from the first stage are combined with the information on socio-economic characteristics of the consumers or producers to estimate the behavioral equations (Taylor, 2003). Given that most analysis are on the demand side, the resulting equations may be demand or inverse demand equations or the utility function, depending on the application (Palmquist, 1999). Identification of the demand function and endogeneity of prices and income are often associated with the second stage estimation (Malpezzi, 2003). Given the limitation of information and complexity of empirical model, the second estimation stage is rarely conducted. Elad et al. (1994) applied two-step hedonic analysis to the Georgia farmland market. County-level socio-economic data were incorporated in the second stage to estimate the marginal implicit value of each variables at a given income and utility level. King and Sinden (1988) also used the two-step estimation to study the influence of soil conservation in Australia. In the second stage, unlike most studies, they estimated the marginal implicit value of each variable at a given input and technology from the land seller's perspective. The current study focuses on the first stage estimation.

3.2 Study area and data

This study seeks to estimate the capitalization of ecosystem services embodied in farm land prices in southwestern Michigan (Figure 3). For consistency with the agricultural ES research in the Kellogg Biological Station - Long Term Ecological Research (KBS-LTER) project, it focuses on four counties (Allegan, Barry, Eaton and Kalamazoo) surrounding the KBS (Figure 4). Lake Michigan is located to the west of Allegan County. Major cities such as Grand Rapids, Lansing and Kalamazoo are located in or close to the four counties.

This area of Michigan not only is suited for cropland and pasture for agricultural production, but it also is endowed with abundant natural recreational and aesthetic amenities. Michigan has relatively high-quality soils and a range of microclimates created by glacial landforms and the surrounding Great Lakes. These attributes enable varied agricultural production and make Michigan the second most agriculturally diverse state in the nation. However, in the twentieth century and earth twenty first century, there were significant changes in the use of farmland in Michigan. From 1950 to 2007, farmland acres decreased from 17.3 million acres to 10.0 million acres, while cropland fell from 11.0 to 7.8 million. The number of farms has decreased from 155.5 thousand in 1950 to 56 thousand in 2007. The Michigan Land Resource Project projected that more than 10 percent of Michigan's farmland, or approximately one million acres, will be lost between 2000 and 2040. Although the rate of loss of farmland is projected to decrease between 2000 and 2040, the fragmentation of farmland during this time period will still significantly impact the sustainability of agriculture in the state (Michigan Department of Agriculture, 2003). In the four counties studied, 0.44 million acres of farmland was lost between 1950 and 2007, of which 54% of the loss occurred in cropland. The average percentage of farmland in the four counties has been decreased from 79% in 1950 to 50% in 2007 (United States Department of Agriculture (USDA), 1950-2007).

Two major factors have contributed to the use of agricultural land for nonfarm development. First, population statistics indicate that the number of households in the area is increasing, while at the same time, the average size of a household is decreasing. The conversion of agricultural land from production to residential use has occurred as former urban dwellers move out to the suburbs and rural areas. Second, the advantageous soil and water resources that result in the agricultural bounty also make this area a desirable place to live and to recreate. The construction of secondary residences for recreation and retirement has increased, and they directly compete with land for farming.

Lands in the study area are used for a mix of agricultural production, residence and recreation. Development pressure for commercial and industrial use of farmland near major cities also exists. Thus, this area is a good representation of the three functions of agricultural land and hence can be used to study the implicit value of ecosystem services embodied in land. According to the 2007 Michigan Land Value Survey, the major agricultural factors that influence land prices in southwestern Michigan are grain price and farm expansion, while the non-agricultural factors include home sites, hunting access, water access and interest rates (Wittenberg and Harsh, 2007).

Data for this study includes sale transaction information, such as land price, appraisal value, sales time, contract type and land class, which came from the County Equalization Office in each of the four counties. The associated GIS parcel maps were obtained from county GIS offices. Other variables describing the social and natural status of farmlands were constructed with ArcGIS software using several GIS databases, including the United States Department of Agriculture (USDA) Soil Survey Geographic Database (SSURGO), the Conservation and Recreation Lands (CARL) dataset, the National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) land cover database, and other Michigan GIS data on rivers, lakes, wetlands, cities and major roads. Information covering 337 parcel transactions was collected for the years 2003-2007. Of these 220 observations are used for sales price regression model and 283 for the appraisal value regression model. According to Michigan agricultural statistics, average per-acre farm real estate value increased annually from 2003 to 2008, but a 3.8% decline to $3,370 per acre occurred in 2009. The annual Michigan Land Value survey also showed that 2009 survey reported land values declined around 0.8% statewide compared with 2008 (Wittenberg and Harsh, 2009). Thus, the land prices here are unlikely to have been influenced by the U.S. economic crisis during our study period (2003-2007).

3.3 Empirical model

3.3.1 Variables

The appropriate dependent variable in a hedonic farmland value study is the transaction price or appraisal value of the parcel that represents the discounted present value of all future rents from the property. Most studies use the per-acre land price to diminish the dominant influence of parcel area on price. In this study, both per-acre sales price and appraisal value are used as dependent variables (P) in two separate models. The sales prices for all available arms-length transactions[1] were reported by County Equalization Office in the four counties. However, it is sometimes difficult to obtain sales prices since limited transactions take place in a certain study area and period. As an alternative, tax assessors' estimates of land value, known as appraisal value that are well maintained public information for most parcels in continuous years. Several studies have examined whether appraisal value is a good substitute for sales price in urban real estate markets (Clapp and Giaccotto, 1992, Dornbusch and Barrager, 1973, Kashian, et al., 2006, Rush and Bruggink, 2000, Schuler, 1990), a rural residential land market (Kim and Goldsmith, 2005) and an agricultural land market (Grimes and Aitken, 2008). To test the difference between sales price and appraisal value, we also use appraisal value as the dependent variable in an equivalent model for parcels sold in those years, and compare its results with the sales price models. The appraisal value used in this study is known as State Equalized Value (SEV), which is especially used in Michigan for property tax purposes. According to the 1994 constitutional amendment (known as Proposal "A"), the Assessed Value (AV) of each real property is determined by local assessors based on the condition of the property on December 31 of the previous year, which is normally at 50% of the estimated market value (referred to as True Cash Value). The State Equalized Value (SEV) is adjusted from the Assessed Value following county and state equalization procedures. SEV is approximately equal to 50% of the sales price if there

[1] Includes *warranty deed* and *land contract deed*, but exclude *quitclaim deed*. In a warranty deed, the grantor is promising that the grantor has good title to the land, can transfer title to the land, and can deliver possession of the land to the grantee. In the transaction with land contract, the price is paid in periodic installments by the purchaser, who is in possession of the property. The vendor and vendee each have an interest in the property until final payment is made. A quitclaim deed conveys all of the right, title and interest that the grantor had in the land at the time of the transfer, without warranting or professing the validity of the grantor's claim. It is often used for transfers between family members, gifts, placing personal property into a business entity, to eliminate clouds on title, or in other special or unusual circumstances.

was a transfer of ownership in the previous year; otherwise it is mainly determined by local assessors following a mass appraisal technique. The SEV data was only available in year 2007 or 2008. Both sales price and SEV were deflated to 2007 constant prices using the Prices Paid by Farmer Index (NASS, 2008).

The independent variables are those characteristics that affect the land value and vary across most observations. This study uses vectors of human built attributes (B_p, B_c), ecosystem services related attributes (E_p, E_c) and asset and transaction attributes (T) to estimate the value of ES embodied in farmland.

Variables representing the level of ecosystem services were constructed from measures of natural resources and landscapes. As each ecosystem service may relate to several resources and landscapes, and each natural resource may provide various ecosystem services, we can only infer the joint value of ecosystem services from those variables. The provisioning ES for crops and livestock can be directly indicated by the tillable area in parcel, specifically the PERCENTAGE OF CULTIVATED LAND for crops and PERCENTAGE OF PASTURE for livestock. To measure the influence from nearby tillable lands, we also include a variable of CULTIVATED LAND PERCENTAGE IN THE SURROUNDING AREA calculated from a 1.5 kilometers radius from the parcel centroid. Natural habitats within a radius of 1.5 kilometers could provide a biological pest control service (Gardiner, et al., 2008, Thies, et al., 2003) and a pollination service (Kremen, et al., 2004, Steffan-Dewenter, et al., 2002) that promoting agricultural production. This is also within the travel distance of other game animals that may both provide recreational opportunities and cause crop destruction. Thus, the radius is chosen for all surrounding landscapes. An illustration of natural resources and landscapes data in GIS format can be found in Figure 5.

Land productivity is represented by dummy variables of FARMLAND CLASSIFICATION from the SSURGO database, which identifies the location and extent of the soils that are best suited to food, feed, fiber, forage, and oilseed crops. Class one used as baseline is "all areas prime farmland", whereas class two is "Prime farmland if drained", three is "farmland local importance" and four is "not prime farmland".

The regulating services of soil are also constructed from GIS data in SSURGO. Soil erosion condition is calculated as the weighted average of SOIL LOSS TOLERANCE FACTOR, which is the maximum average annual rate of soil erosion by wind and/or water. The natural drainage of soil is categorized by two dummy variables from the weighted average value of a drainage index (1-99). WELL DRAINED dummy has an index value between 34 and 65, while POORLY DRAINED dummy has an index value above 65. The base category with index value below 34 indicates over drained farmland. On-site water provision and regulating services are indicated by RIVER LENGTH and LAKE PERCENTAGE in parcel. Variables measuring recreational effects and off-site irrigation opportunity[2], DISTANCE TO RIVER and DISTANCE TO LAKE, are the straight line distance from parcel centroid to the edge of the nearest river or lake. WETLAND PERCENTAGE IN SURROUNDING AREA measures the ability both to regulate water resource in parcel and to host beneficial insects. PERCENTAGE OF GRASSLAND and PERCENTAGE OF FOREST IN PARCEL indicate recreational services as well as regulating services from beneficial insects. Similarly, SURROUNDING CONSERVATION

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[2] According to a 2009 Michigan Department of Agriculture report on irrigation water use, irrigation is needed for some high value crops in Michigan during July and August, when rain-fed crops often suffer from a moisture deficit. The primary source of water for agriculture irrigation in Michigan is groundwater (75 %), with the remainder withdrawn from surface water sources. http://www.michigan.gov/mda/0,1607,7-125-1567_1599_1605-69180--,00.html

LAND PERCENTAGE[3] as a mix of grassland, forest and other natural landscapes indicates the service from the neighborhood of farmland. On-site and off-site water resources could provide recreational opportunities like fishing and boating, as well as aesthetic views. Forest and conservation land could also be associated with recreational activities like hunting and hiking. The influence of managed recreational land[4] is measured by its distance from the parcel centroid along roads, labeled as RECREATION LAND DISTANCE.

The built attributes for production include basic land properties like TOTAL ACRES and DEGREES of SLOPE, which is the weighted average of representative land slope from SSURGO. The dummy variables of CLASS define land use types, where the baseline 101 is for crop production, 102 is for livestock production and 401 is mainly used for residential purpose or hobby farm. Building attributes are constructed from farmland aerial photographs combined with information from county equalization offices. BUILDING PERCENTAGE is the proportion of parcel area covered by buildings and accessories. The NUMBER OF AGRICULTURAL BUILDINGS represents the land improvement for production purposes and NUMBER OF RESIDENTIAL BUILDINGS represents structures for consumption purposes.

Variables related to land asset value and transactions are also necessary in the model as conditioning attributes for a complete specification. To capture the option value of nonfarm development, measures of surrounding urban area and distance have been included. As the urban development pressure disperses from major cities rather than counties[5], binary dummy variables indicate if the closest major city of each parcel is GRAND RAPIDS,

3 Conservation lands include lands owned by federal agencies (USFS, USFW, NPS, and NRCS), state agencies (MDNR, MDEQ, and MDOT), NGO, local government (County, Township, and Municipal) and private land with conservation easements, long-term contracts and similar efforts.

4 Recreational lands are open spaces used for recreation with all ownership (federal, state, local and private), such as parks, beaches and camping sites.

5 County dummies were also eliminated due to their correlation with several other variables.

LANSING, KALAMAZOO, HOLLAND or Battle Creek (omitted baseline), each of which has a population greater than 35000. To better capture the urban access effect, we use a DISTANCE TO MAJOR CITY variable measuring the straight line distance to the closest major city and a DISTANCE TO MAJOR ROAD variable measuring the straight line distance from parcel centroid to the edge of the nearest interstate, freeway or highway (Framework Classification Code A11, A12 and A21)[6]. The variable URBAN PERCENTAGE IN NEIGHBORHOOD is used to capture the nearby urbanization effect from high/medium/low intensity developed land cover in the 1500 meters radius. In addition, the dummies for sales year, month and transaction instrument type (Warrant Deed or LAND CONTRACT) are included. The variable indicating land owners' enrollment in farmland preservation programs is not included in the study, since those voluntary easements are rarely capitalized in land prices. The Michigan Farmland and Open Space Preservation Program (PA116) is such a program in the study area that provides tax credits for participants to restrict development from farmland. Although the original agreement is contracted for a minimum of 10 years, land owners still have the option to release at any time if farming is restricted by surrounding land usage or economically inviable. As a result, voluntary land preservation programs do not place a permanent easement on the property, and thus have little impact on land values. This argument is also supported by other hedonic studies, which have found no evidence of decreasing land prices if the program is completely voluntary (Nickerson and Lynch, 2001, Vitaliano and Hill, 1994).

See Appendix 1 for variable details and Appendix 2 for summary statistics.

[6] A11 – Limited access Interstate; A12 – Limited access non-Interstate; Divided unlimited access US Highways & State Highways.

3.3.2 Functional form

The relationship between dependent and independent variables is indicated by the functional form of the hedonic price function. There is little theoretical basis for choosing the functional form of a hedonic regression. The Box-Cox transformation, a general and flexible class of functions, is widely applied in empirical hedonic analysis. It was developed by Box and Cox in 1964 in order to make the residuals more closely normal and less heteroskedastic. The general transformation is in Equation 7,

$$y^{(\lambda)} = \frac{y^{\lambda} - 1}{\lambda} \tag{7}$$

where $y^{(\lambda)}$ takes the linear form *y-1* if λ=1. It takes the logarithmic transform *ln(y)* if λ=0 and it takes the reciprocal transform if λ=-1.

Some hedonic studies used an unrestricted functional form based on the test using Box-Cox transformation, and estimated the model by Maximum Likelihood Estimation (Elad, et al., 1994, Nivens, et al., 2002, Roka and Palmquist, 1997). Point estimates of mean marginal implicit prices were used to compare the effects. Some other studies used different functional forms, e.g., linear, semi-log, log-linear and log-log, to examine the consistency of estimates with respect to different forms (Bastian, et al., 2002, Gardner and Barrows, 1985, Palmquist and Danielson, 1989). In most cases, a preferred functional form based on the Box-Cox test is adopted, among which semi-log is a common one.

For both sales price model and appraisal value model, the Box-Cox tests are conducted to decide the functional form. The test results of dependent variable transformations clearly reject the linear form and reciprocal form with p values close to zero, but cannot reject the log transform at the 0.01 level. As there are many independent variables for both models, some of which are even binary variables, the flexible transformation cannot be conducted. Although the transformation of land acres variable is possible, for simplicity of interpretation we do not use it, allowing linear effects from all independent variable. See Appendix 4 for detailed test results.

Based on the functional form test, this study therefore uses a semi-log model with log farmland value per acre (P) regressed on the vectors of untransformed independent variables (B_p, B_c, E_p, E_c, T). Two models are estimated following Equation 8 with real sales price and appraisal value as the dependent variables.

$$LnP = \alpha_0 + B_p\beta_1 + B_c\beta_2 + E_p\beta_3 + E_c\beta_4 + T\beta_5 \tag{8}$$

Empirically, built production attributes B_p include abiotic physical properties and historic crop production potential. Built consumption attributes B_c mainly represent on-site residential structures. ES production attributes E_p include the existence of soil, water resources, forest and grassland inside and surrounding the parcel that could provide regulating ES to benefit agricultural production. ES consumption attributes E_c measure amenities from natural resources within and surrounding the parcel. Finally, the asset and transaction characteristics T cover the location, timing and contract type of the land sale.

3.3.3 Spatial autocorrelation

As the hedonic method is dealing with spatially ordered data, the spatial dependence among observations cannot be ignored. It can be simply explained by the *first law of geography* that “everything is related to everything else, but near things are more related than distant things”(Tobler, 1970). Cliff and Ord (1973) defined this effect as “spatial autocorrelation”. Paelinck and Klaassen (1979) first modeled the spatial effect with econometrics method, the rapid growth and wide acceptance of spatial econometrics occurred since Anselin’s classic work (1988) that explicitly defined and explained spatial effects in the econometric analysis of regional science models. According to Anselin, spatial dependence is "the existence of a functional relationship between what happens at one point in place and what happens elsewhere". Unlike the dependence in time series, the spatial autocorrelation is multidirectional, asymmetric and may be defined exogenously. A spatial weighting matrix is used to display and model the complex spatial relationship. Each element of weighting matrix w_{ij} can be determined by distance, contiguity and common borders of polygons, and can be weighted by exogenous factors with various functional forms. The most common spatial weight is constructed by the inverse distance between each two points. Let d_{ij} denote the distance between parcel i and parcel j, the elements of weighting matrix $w_{ij} = 1/d_{ij}$ if $d_{ij}<c$, and $w_{ij} = 0$ if i=j or if $d_{ij}>c$, where c is the cutoff point for spatial autocorrelation. This weighting approach implies that those observations closest to the farm observation are more highly correlated than those observations further away. As the distance between parcels increases, the correlation weights get smaller. When the distance is over the cutoff point, no correlation is assumed (Lynch and Lovell, 2002).

The common spatial autocorrelation tests are Moran's *I*, Geary's *c* and Getis and Ord's *G*; whereas Moran's *I* is most often used. It is defined in Equation 9,

$$I = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}\left(Y_i - \bar{Y}\right)\left(Y_j - \bar{Y}\right)}{\sum_i \sum_j w_{ij} \sum_i \left(Y_i - \bar{Y}\right)^2 / N} \tag{9}$$

where Y_i denotes the value taken on by the variable *Y* of interest at location *i*; $\bar{Y}$ denotes the mean of variable *Y*. Under the null hypothesis of no global spatial autocorrelation, the expected value of *I* is given by $E(I) = -1/(N-1)$. If *I* is larger than its expected value, then the overall distribution of variable *Y* can be seen as characterized by positive spatial autocorrelation, meaning that the value taken on by *Y* at each location *i* tends to be similar to the values taken on by *Y* at spatially nearby locations. On the other hand, if *I* is smaller than its expected value, then the overall distribution of variable Y can be seen as characterized by negative spatial autocorrelation, meaning that the value taken on by *Y* at each location i tends to be different from the values taken on by Y at spatially nearby locations, and *vice versa*. Inference is based on z-values, computed by subtracting *E(I)* from I and dividing the result by the standard deviation of *I*. Under the total randomization assumption, z follows a normal distribution (Anselin and Hudak, 1992).

To explain the pattern for spatial autocorrelation, we need to look at the structure of the spatial dependence model. Take the Ordinary Least Squares (OLS) model for example, two kinds of spatial dependence will be considered. The first one, the spatial error model, takes the form of a spatial autoregressive process in the error term and corresponds to the following spatial regression model (Equation 10):

$$Y = X\beta + \varepsilon \quad \varepsilon = \lambda W\varepsilon + \mu \tag{10}$$

where λ denotes the spatial autoregressive parameter, μ denotes a vector of homoskedastic and uncorrelated errors, and all the other terms are defined as above. The second kind of spatial dependence is known as spatial lag model, which takes the form of a mixed regressive spatial autoregressive process and corresponds to the following spatial regression model (Equation 11):

$$Y = \rho WY + X\beta + \mu \tag{11}$$

where ρ denotes the spatial autoregressive parameter, *WY* denotes the spatially lagged dependent variable, and all the other terms are defined as above. Based on the diagnosis, both Maximum Likelihood and Generalized Spatial Two-Stage Least Squares can be used to estimate the spatial model (Anselin, 1988, Kelejian and Prucha, 1998).

To model the spatial effect, we generated an inverse distance weighting matrix with a cutoff point of 600 meters from the centroid of the parcel. This distance band is chosen based on the Moran's I spatial correlogram, which suggests that the observations in distance band 200-400 and 600-800 meters have significant spatial correlation. Similar cutoff points have been used in other hedonic studies. Lynch and Lovell (2002) studied the easement payment on farmland in Maryland and set the cutoff at 490 meters from parcel centroid. Bastian et al. (2002) studied the production and consumption effect on agricultural land in Wyoming with GIS tools and set the cutoff at 400 miles (643.6 meters) from parcel centroid. Thus, the range of 600 meters would be appropriate for considering spatial influence among land parcel observations. The global spatial autocorrelation by Moran’s I test indicates significant spatial autocorrelation for 37 out of 50 variables in the sales price model and 29 out of 35 variables in the appraisal value model (see Appendix 5 for Moran plots for sales price model and appraisal value models). The local spatial autocorrelation test suggests 12 observations (sales price model) and 20 observations (appraisal value model) have highly significant correlations while others still correlated at some extent. The diagnosis for the structure of spatial autocorrelation suggests the spatial dependence is only attributed to correlation in the error terms of the two models, implying spatial error structure. Since the eigenvalue matrix cannot be computed because more than a half number of parcels have no neighbors within 600 meters, the spatial error model by MLE cannot be implemented. In this study, we estimate the model by OLS using a Stata code by Conley to correct for spatial error[7]. Our discussion of results will be developed from the results that are robust to spatial autocorrelation.

[7] This Stata code (V 6.0) was designed by Professor Timothy G. Conley from the Graduate School of Business in the University of Chicago. http://faculty.chicagobooth.edu/timothy.conley/research/gmmcode/statacode.html. June 19, 2009.

3.3.4 Regression diagnostics

Regression diagnostics led to some adjustments in the data and econometric model. By examining the pair-wise correlation and Variance Inflation Factors (VIF), evidence of multicollinearity led to led to several variables being dropped, such as forest and grassland in parcel neighborhood, county dummies and some soil productivity measurements. However, we still keep the variable of FOREST PERCENTAGE IN PARCEL and WETLAND PERCENTAGE IN PARCEL for complete specification, though they are negatively correlated with two other variables at 0.5 level, and they raise the VIF. The joint F test for dropped variables is insignificant at 0.05 level indicating that the coefficients on all dropped variables are jointly equal to zero. To maintain the comparability of the sales price and appraisal value models, the same set of independent variables are used for both.

The Breusch-Pagan heteroskedasticity test is insignificant for sales price model, which suggests the null hypothesis of constant variance cannot be rejected. However, this test for appraisal value model is insignificant at 0.05 level but significant at 0.01 level, which suggests the null hypothesis can be marginally rejected. To allow for spatial error adjustment, standard errors that are not robust to heteroskedasticity are used.

We also did the influential observation tests by examining the standardized residual and leverage measures (Belsley, et al., 2004). Taking a close look at the influential observations, some sales parcels have unusually large non-crop areas that may determine the marginal value of those variables. However, there is no evidence that these observations were mistaken, so they were retained. The only cases that looked potentially erroneous are three pairs of parcels. Each pair is probably purchased by one buyer at the same time, but both parcels in the pair sold at the same price even though each parcel in the pair differs in total acres. However, as the coefficients and significance level of results did not change after dropping those six observations, we kept them in the dataset (see Appendix 3 for influential observations in a scatter plot).

4. Results

4.1 Sales price model

Our results suggest that per-acre land sales prices depend upon all five categories of variables (Table 1). ES attributes, represented by natural resources and landscapes in the parcel and a surrounding radius of 1.5 km, show various effects.

On-site natural resources and land uses that are likely to provide direct private amenities, or sometimes disamenities, are widely capitalized in land price. A *lake* present within the land parcel increases price by 6% per 1% of the lake surface. This large effect may reflects aesthetic ES of scenic views and recreational ES of swimming, fishing and boating. The land price is also raised by 1% per 1% increase in the percentage of *forest land* area in parcel. The value a land purchaser realizes from on-site forest is most likely attributed to its support of outdoor activities such as picnicking, wildlife watching, and hunting. In southern Michigan, a small proportion of landowners who have their land hunting rights purchased, gifted or reserved by the State, can even be paid by those programs or by hunters who visit their lands[8]. Forest could also perform regulation functions on water and soil by stabilizing water flow between wet and dry seasons and reduce sediment load in rivers (Guo, et al., 2000), though those services are rarely valued by land owners. There are also negative effects from on-site resources. For example, *on-site rivers* reduce land values by 0.9% per 1000m of river in the parcel. Although water resources provide ecosystem services to landowner, their negative effect may outweigh the benefits when present in the parcel. This so-called

8 Michigan Department of Natural Resources and Environment: http://www.michigan.gov/dnr/0,1607,7-153-10363_14518-197513--,00.html.

disservice could be largely due to field erosion along waterways and flood risk[9] threatening crop production.

Some resources and landscapes in the parcel surrounding areas are also capitalized as land owners could partly benefit from their surroundings. Results suggest that *nearby rivers* increase land values by 6% per 1000m closer to a river. Recreational activities like fishing could be carried out at nearby rivers. The off-site effect of rivers is also likely attributable in part to crop irrigation opportunities. Michigan is a water-rich state, but rain-fed crops such as corn, soybeans, potatoes and vegetables often suffer from a moisture deficit during a part of the growing season. Although groundwater is abundant in most of the state and contributes to 75% of irrigation water use, on-site and off-site surface water could provide alternative irrigation sources and facilitate aquifer recharge. Pyykkönen (2005) found similar results with a dummy variable for water bodies on the boundary. He explained that the irrigation possibility (or some recreational values) increases the land price by nearly 10% at the mean level.

Wetlands within a 1.5 km radius increase land value by 3% per 1% increase in wetland share of surrounding areas. This price effect is likely attributed to its well-realized recreational and cultural values. According to the Environmental Protection Agency (EPA)[10], more than half of all U.S. adults (98 million) hunt, fish, watch birds or photograph wildlife in wetlands. Known as the kidney of the earth, wetlands also provide several regulating services that facilitate agricultural production. For example, they mitigate flood by damping extreme flood events and channeling flood waters from upland areas into receiving waters, and they

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[9] Although not a major problem, flooding due to heavy rain is sometimes reported during spring and summer in some regions of Michigan (NASS Michigan Agricultural Statistics Bulletin 2001-2008).
[10] http://www.epa.gov/wetlands/vital/people.html#recreation

control erosion by stabilizing soil at the water's edge with interlocking root systems (Carter, 1996).

Off-site conservation land, a combination of different natural landscapes, boosts land price by 2% per 1% increase in its proportion of the surrounding area. Although abundant ecosystem services can be provided from conservation land, its capitalization in land price is mainly ascribed to recreational opportunities like hiking and hunting.

Besides recreational and regulating ES, variables indicating provisioning ES are also significant. One percent increases in the area of *cultivated land and pasture* in the parcel increase land price by 2% and 1% respectively. Those tillable areas are direct sources that farmers rely on for farm income, and cropland yields relatively higher returns. A large proportion of tillable area is also likely to reduce the marginal cost of farming due to economies of scale. *Surrounding cultivated lands* raise land prices by 2% per 1% increase in their proportion, presumably indicating suitability for agricultural production. As pointed out by Chicoine (1981), the surrounding farmland could also lead to a positive effect from reducing negative externalities of conflicting non-agricultural land use and insuring the compatibility of future land-use patterns.

Built production and consumption attributes also contribute to the land sales price. Consistent with other hedonic farmland value studies, the per-acre price decreases with total parcel area (see graph in Appendix 3), reflecting the scale effect and lower transaction costs for both the buyer and the seller. Land price also falls by 4% for each one degree increase in *representative land slope* because inclined land is unfavorable for farming. A 1% increase in agricultural and residential *building* area raises parcel price by 8%, which may contribute to either production or consumption roles of land. The development effect is well captured by city dummies. The development pressure from Grand Rapids has the largest effect - 50%

price increase - while Lansing and Kalamazoo also significantly raise farmland price. Attributes associated with the land sale process also appear to be capitalized. Transactions carried out by *land contract*, in which the price is paid in periodic installments, increase land price by 25%[11]. This higher price is likely caused by the land deal negotiation, where the buyer is in a relatively weak position due to the small down payment offered, whereas the seller is taking more risk in providing the high proportion of credit and hence would request a higher price (Murray, et al., 1983).

However, as we discussed in the conceptual model, some on-site and off-site ES that cannot be directly used by landowners tend to be less capitalized or even not capitalized at all. Some regulating services that provide indirect use value regarding water, soil and local climate may have been partially capitalized by water bodies, forest lands and conservation lands as discussed above. The values of other services are not likely to be captured in land price for three reasons. First, private landowners have no incentive to provide ES that are large scale public goods from farmland, such as carbon sequestration and non-game wildlife habitat. Public policy, such as incentive payment, can be applied to stimulate their provision. Second, even though landowners can indirectly benefit from some regulating ES, they may not be aware of those values and they have no incentive to pay for them through land prices. Ecological studies suggested that the population of pest predators and pollinators is more abundant near conservation lands and wetlands (Bianchi, et al., 2006, Naylor and Ehrlich, 1997, Vaughan, et al., 2004), which could promote agricultural production. However, most farmers are unaware of those effects. Third, even if landowners are able to identify some ES with indirect use values, the value may be too small to make a real change in land prices.

[11] Interest rate is typically not included in the sales price. However, the land seller may raise land price and lower interest rate in order to pay less tax, since the capital gain of land sales is taxed at a lower rate than the money received as interest (Murray et al., 1983).

Consider the natural pest enemies and pollinators example. Some farmers may be knowledgeable about beneficial insects, but in order to get them, they are unlikely to purchase land at a higher price, since they can apply pesticides at a low cost or their crops simply do not depend on pollinators. Similarly, ecological research has identified major differences in soil quality and productive potential due to microbial activities associated with crop management. However, the variables measuring natural soil quality and erosion are not significant or have an unexpected effect in the model. It is likely that the wide application of artificial improvements (e.g., fertilizer and intensive tillage) makes natural soil properties less important.

4.2 Appraisal value model and comparison with the sales price model

Although the appraisal values are positively correlated with the sale prices with a correlation coefficient of 0.3, and the two hedonic models share a core set of determinants, the models are found to be different in both overall determination power (R square) and significant explanatory variables.

The appraisal value model uses SEV per acre as the dependent variable. These results suggest that the per-acre SEV also depends upon all five categories of variables (Table 2). However, compared with other four categories of variables, the consumption ES attributes (E_c) have relatively less influence on SEV in this model. The explanation of the results is followed by comparison with the sales price model. In our dataset, some land sales do not have valid transaction prices but have appraisal values, while appraisal values are missing for some others with sales prices. The following discussion is based on the sales price model and appraisal value model with exactly the same land parcels (Table 3). The comparison of models with their most available data (220 for sales price model and 283 for appraisal value model) are also shown in Table 4.

Comparison of the two models first reveals that the appraisal value model gives a higher R^2 (0.7) than the sale price model (0.3). This result is consistent with previous studies. Kim and Goldsmith (2005) found R^2 for appraisal value models were 5-21% higher than those for sales price models in different settings, and attributed the difference to significantly larger sample used in the appraisal value models. Schuler (1990) used the same data set for residential properties in both assessed value and sales price models, and still found the assessed value as the dependent variable achieved higher explanatory power (0.88) than the model using sale price (0.80). As we are using same dataset for two models, the higher coefficient of determination from the appraisal value model suggests less variability among appraisers' value estimates than in the land market. The first variability is due to the far fewer individuals involved in land appraisal (33 township appraisers) compared with land sales (buyers and sellers for 203 parcels). Fixed effects regression of these recent, inflation-adjusted appraisal values on sale prices also found township dummy variables to be significant. The second source of variability is different determinants of value. Appraisal is based on some major factors, such as on-site buildings, soil property, and land use class, whereas more factors are taken into consideration by land buyers and sellers. This can be seen from the different significant variables discussed below.

The comparison of explanatory variables in the two models is also displayed in Table 3. The second column indicates whether the variable is significant in the sales price model (S), appraisal model (A) or both (S/A). "+/-" denotes that the significant variables have opposite signs in the two models.

Some variables are significant with the same signs in both models. Larger total parcel acreage decreases both land price and appraisal value by 3% with 10 more acres. The proportions of conservation land and pasture in the parcel neighborhood have positive effects in both models. However, the impacts from those natural landscapes in the appraisal value model are less than in the sales price model. The relative magnitudes of major city influence from Lansing, Kalamazoo and Grand Rapids are the same in both models, but the absolute effects are larger in the sales price model. Land with well drained or poorly drained soil has higher value than land with over drained soil in both models.

The variables related to water regulating services and recreational services, such as on-site river length, lake percentage and forest percentage are only significant in the sales price regression. However, an on-site wetland, which may provide recreational amenities but unfavorable conditions for crop production, shows a generally negative effect in the appraisal value model but neutral effect in sales price model. In contrast, the soil-related variables have stronger effects in the appraisal model. The farmland quality classification dummies have unexpectedly positive effects in the sales price regression where "local important farmland" and "not prime farmland" both have higher value than the "all prime farmland". Those variables are not significant in appraisal model. Moreover, the soil erosion tolerance factor, which is not significant in the sales price model, raises per-acre SEV by 9% as maximum average annual tolerance rate of soil erosion by wind and/or water increase by one ton per year in Table 4 (and raises SEV by 4% with p-value 0.28 in Table 3).

Land uses related to production and residence also vary between the two models. One percent increases in area of cultivated lands within the parcel and its neighborhood boost land sales price by 2% and 1% respectively, while no significant effect is found on the appraisal value. The area and number of buildings play more important roles in the land value appraisal model, whereas estimated values are negligible for on-site forest lands, croplands and pastures. This can be easily seen from the 22% value increase with an additional residential building, which is not significant in the sales price model. The dominant effects from buildings also lead to the insignificance of land residential class in the appraisal model. The land class indicating livestock production is only significant in the appraisal value regression, reducing average land value by 14%.

Based on the comparison, it seems that SEV mainly depends on physical productive and residential features of farmland like total acres, buildings and soil. By contrast, the sales price also captures on-site and off-site resources and landscapes that reflect amenity values, such as water bodies and forests. This distinction is derived from the data generation process of sales price and appraisal value. In this study, the appraisal value (SEV) is tax assessment appraised from existing market data by the county equalization office. Two features distinguish tax assessment from other types of farm appraisal. First, little time is spent on each parcel because all parcels in a county usually have to be completed by one date and because costs for detailed examination of each parcel would be prohibitive. Second, successful farm tax appraisal depends more on uniformity—the relative value of one parcel compared to another—rather than on their absolute value (Murray, et al., 1983). Thus, SEV is normally appraised on certain principal factors following a mass appraisal technique. A typical process includes: 1) soil ratings, determined from soil surveys, is multiplied by base values, which is generated from benchmark appraisals using the sales comparison approach; 2) building value is estimated by the cost of each attribute; 3) further adjustments are taken into account, such as natural resources, topography, erosion, drainage, location, roads, market, water supply, physical features, and nuisances. By consulting with a Michigan farm appraiser[12], we also learned that land tax assessment is normally conducted based on current land use, and therefore tends to concentrate on production-related attributes. In contrast, sales prices reflect individual market participants' perceptions and future expectations, and hence can better capture subtle effects, such as amenity values. A survey of land buyers and sellers also supports this conjecture by finding that land with perceived amenity values and development potential tends to have a higher sales price (Deaton, et al., 2007).

From comparison of the two models, we can conclude that the appraisal value from tax assessment is not a good substitute for sales price if we want to study the detailed behavior and perceptions of land buyers and sellers. In particular, it is not predictive of amenity value. However, the appraisal value is still useful in estimating the basic attributes of land based on its production and residential uses.

5. Conclusion

This study contributes to the existing literature in three ways. First, we propose a conceptual framework that categorizes the ecosystem services embodied in agricultural land. In this framework, four categories of ES (i.e., provisioning ES, regulating ES, recreational, aesthetic and cultural ES, and supporting ES) are linked to land property rights and total economic values (i.e., direct use value, indirect use value and nonuse value). Stemming from this framework, we construct a three-component agricultural land valuation model, for revealing the value of ES embodied in agricultural land from land prices based on production, consumption and asset roles of land.

[12] Email contact with Douglas K. Hodge, an appraiser/realtor in the Michigan office of the Capstone Realty Resources real estate brokerage, during August, 2009.

Second, we apply the hedonic method to estimate the value of natural resources and landscapes from agricultural lands and their surroundings, and we deduce which ES are likely to be capitalized, partially capitalized or not capitalized at all. Results suggest that recreational and aesthetic services are largely capitalized into land prices through lakes, rivers, wetlands, woodlands and conservation lands in southwestern Michigan. Some regulating services that provide indirect use value regarding water, soil and local climate may have been partially capitalized by water bodies, forests and conservation lands as well. Certain ES from the land parcel and its surroundings are unlikely to be capitalized into land prices because 1) buyers and sellers are either unaware of them or unwilling to pay for them (e.g., insects that provide biological pest control and pollination, soil microbial communities that contribute to soil quality), and 2) no value is expected to be found from large scale public goods provided by farmland (e.g, carbon sequestration and biodiversity), due to market failure.

Third, this study compares hedonic value estimates from real estate sales prices and tax assessors' appraisal values. While appraisal value has the advantage of being well maintained and publicly accessible for continuous years, it appears to concentrate on different land attributes compared with sales price, because of the distinct value generation mechanisms. We find that tax assessment appraisal value (SEV in Michigan) mainly depends on farmland total acres and soil properties, as well as buildings. These traits are most accurate for estimating values related to production and residence. The sales price model captures these values as well, but it also captures more amenity values from on-site and off-site water resources and landscapes.

Like other hedonic studies, this hedonic agricultural land price model can only capture the ES values that are perceivable by land owners. For the agricultural ecosystem services that are not realized in commodity markets and land markets due to market failure, public policies are needed to induce appropriate incentives for their provision. Economic incentive tools that stimulate voluntary participation for land retirement or desired land use by an incentive payment or cost share, may play an important role. Some existing policies that preserve farmland from development could also help to secure long-term ecological benefits.

Figures and tables

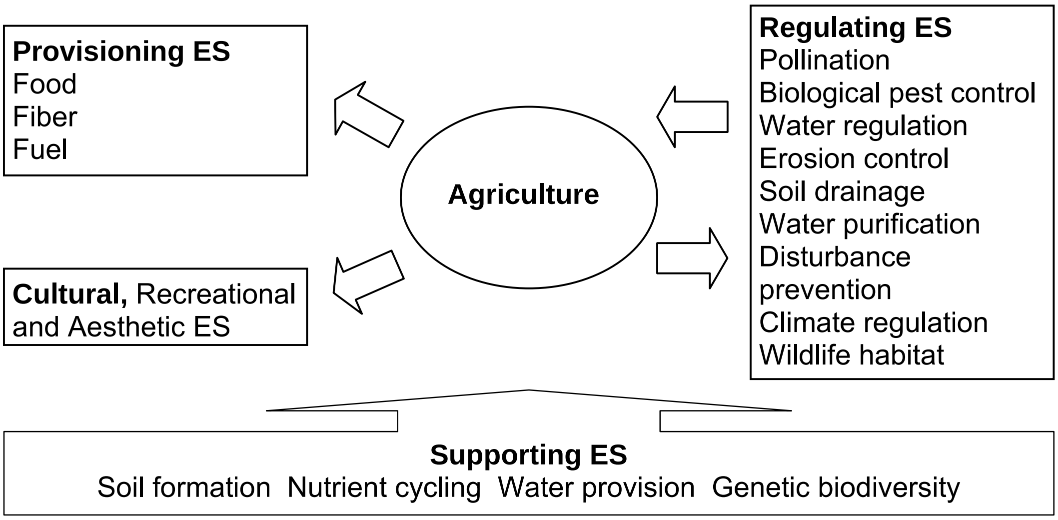

Figure 1 Agricultural Ecosystem Services

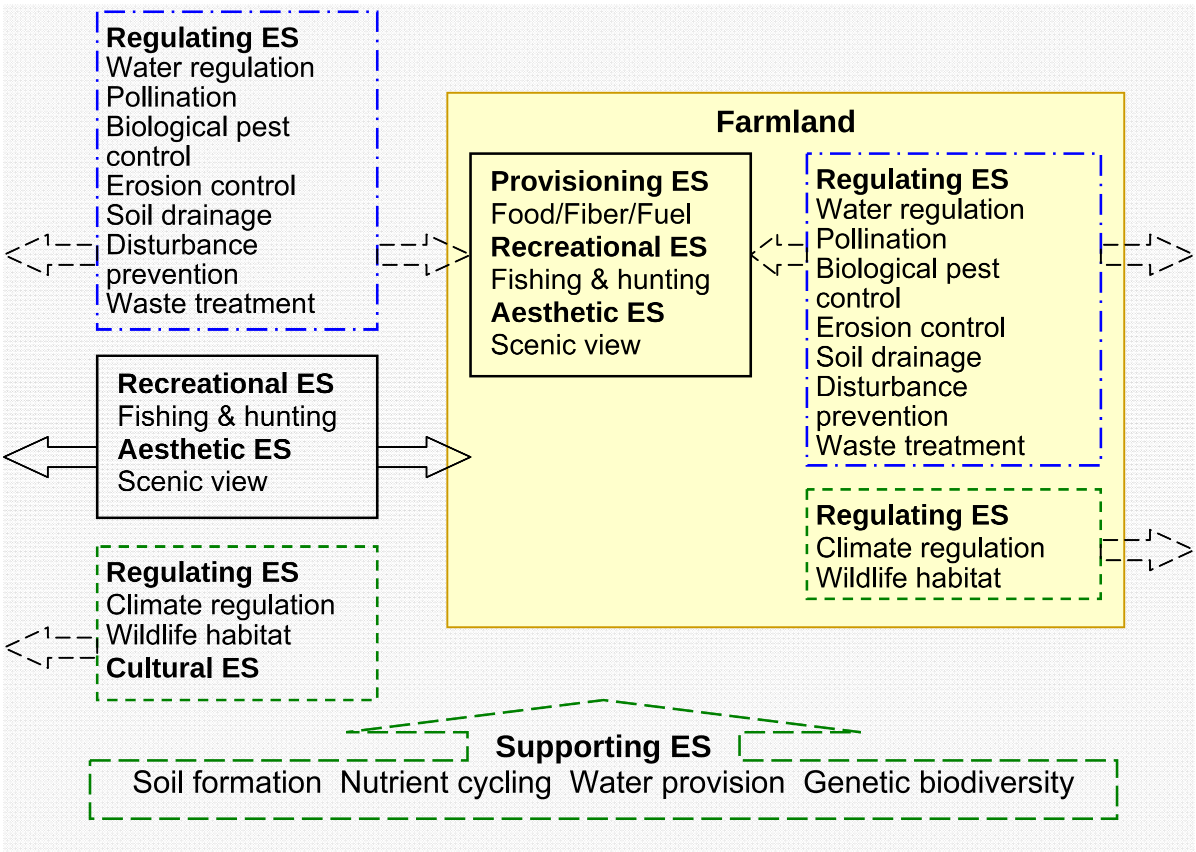

Figure 2 Agricultural ecosystem services related to farmland

Figure 3 Study area in the State of Michigan

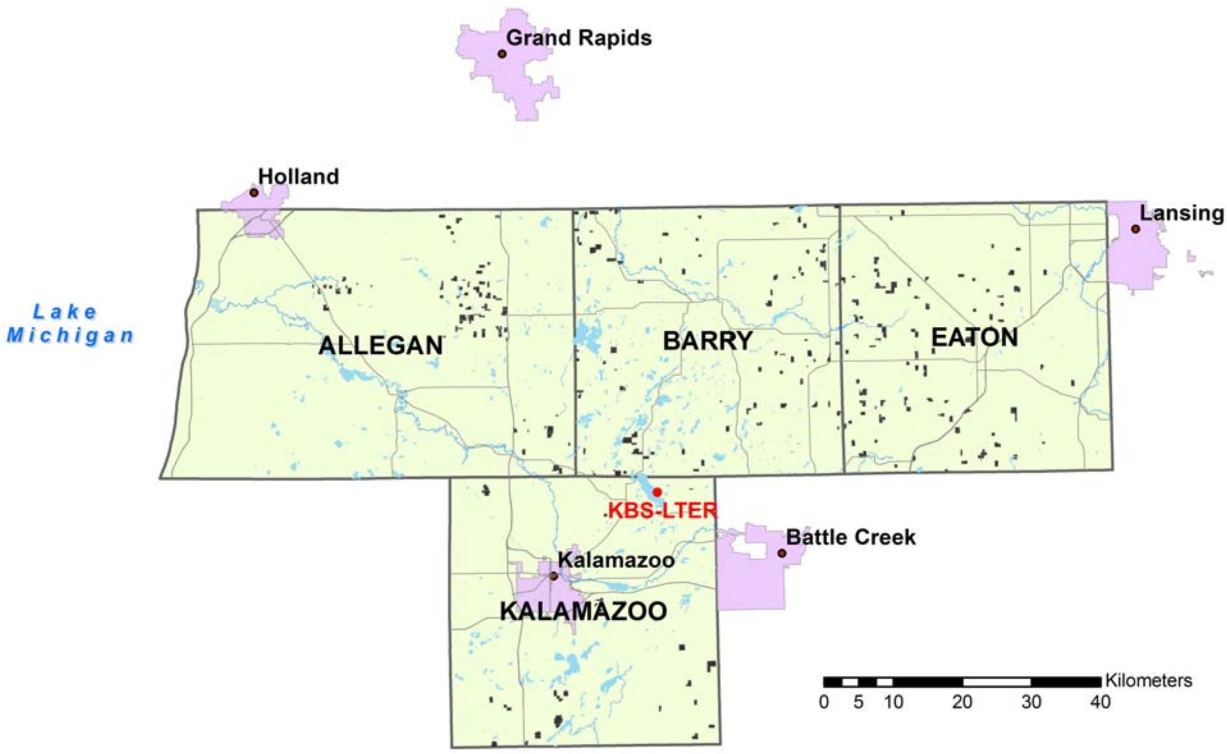

Figure 4 Detailed location of parcels in the four study counties

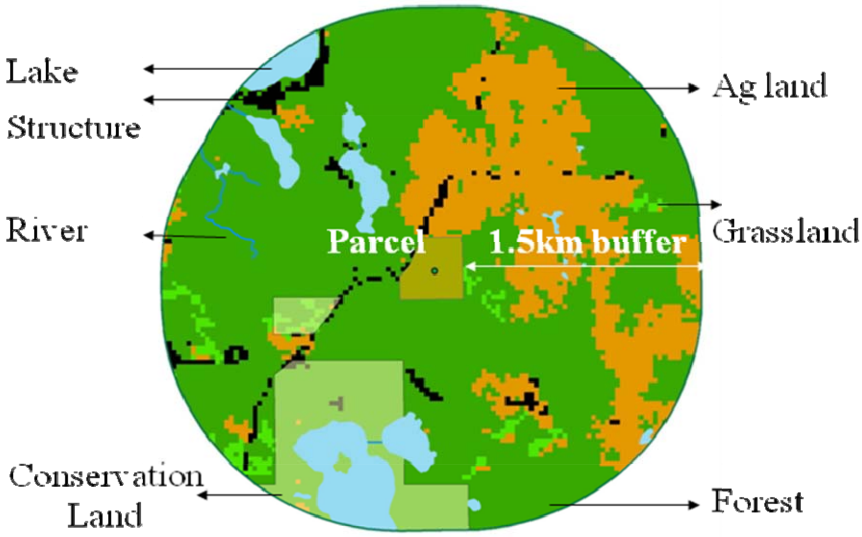

Figure 5 An example of natural resources and landscapes data in GIS

Table 1 Proportional marginal effect of agricultural land attributes on land sales price (OLS regression with correction for spatial autocorrelation), southwestern Michigan, 2003-2007

Details	Coefficients	s.e.	z	p-value
Production and Consumption Ecosystem Services Variables				
river length in parcel	-0.001**	0.00	-2.44	0.015
lake percent in parcel	0.056***	0.02	3.29	0.001
distance to river	-0.058**	0.03	-2.00	0.045
distance to lake	-0.028	0.06	-0.49	0.623
wetland % in parcel	0.005	0.00	1.21	0.227
wetland % in buffer	0.031***	0.01	3.05	0.002
conservation land % in buffer	0.017**	0.01	2.36	0.019
distance to recreational land	-0.003	0.02	-0.17	0.865
forest % in parcel	0.011**	0.00	2.25	0.025
cultivated land % in parcel	0.015***	0.01	2.83	0.005
pasture % in parcel	0.010**	0.01	2.03	0.043
grassland % in parcel	0.010	0.01	1.07	0.283
cultivated land % in buffer	0.016***	0.00	3.14	0.002
pasture % in buffer	0.014**	0.01	2.05	0.040
well drained dummy	0.462**	0.23	1.98	0.048
poorly drained dummy	0.431*	0.22	1.94	0.052
prime farmland if drained	-0.074	0.11	-0.66	0.509
local important farmland	0.234**	0.10	2.33	0.020
not prime farmland	0.496***	0.17	2.98	0.003
soil loss tolerance factor	-0.135	0.09	-1.45	0.147
Production and Consumption Built Variables				
total acres	-0.002**	0.00	-2.31	0.021
land class: livestock	0.083	0.11	0.75	0.455
land class: residential	0.452***	0.17	2.70	0.007
representative slope	-0.041***	0.02	-2.72	0.007
building area percent	0.079***	0.02	5.04	0.000
No. of residential building	0.135	0.13	1.04	0.299
No. of ag building	0.011	0.04	0.26	0.796
Development and Transaction variables				
distance to city	0.008*	0.00	1.77	0.077
Lansing	0.308**	0.12	2.56	0.010
Kalamazoo	0.400**	0.17	2.41	0.016
Grand Rapids	0.474***	0.13	3.63	0.000
Holland	0.137	0.17	0.82	0.414
distance to road	-0.030	0.02	-1.49	0.175
developed land % in buffer	0.026	0.02	1.43	0.153
land contract	0.247*	0.15	1.70	0.090
constant	5.908***	0.84	6.99	0.000
Number of obs.= 220				
Prob > F = 0.0000				
R-square = 0.48	Adjusted R-square = 0.33			

***significant at 1% level, **significant at 5% level, *significant at 10% level
s.e. is standard error, z is z-statistics

Table 2 Proportional marginal effect of agricultural land attributes on land appraisal value (OLS regression with correction for spatial autocorrelation), southwestern Michigan, 2003-2007

Details	Coefficients	s.e.	z	p-value
Production and Consumption Ecosystem Services Variables				
river length in parcel	0.000	0.00	1.00	0.324
lake percent in parcel	0.017	0.02	0.93	0.360
distance to river	0.000	0.00	0.64	0.530
distance to lake	0.000	0.00	1.18	0.247
wetland % in parcel	-0.005***	0.00	-2.99	0.005
wetland % in buffer	0.013*	0.01	2.00	0.053
conservation land % in buffer	0.010**	0.00	2.50	0.017
distance to recreational land	0.000	0.00	0.82	0.416
forest % in parcel	-0.016***	0.00	-4.62	0.000
cultivated land % in parcel	-0.012***	0.00	-3.99	0.000
pasture % in parcel	-0.013***	0.00	-4.25	0.000
grassland % in parcel	-0.003	0.01	-0.24	0.809
cultivated land % in buffer	0.003	0.00	1.14	0.261
pasture % in buffer	0.012***	0.00	3.04	0.005
well drained dummy	0.401*	0.23	1.77	0.085
poorly drained dummy	0.435*	0.23	1.86	0.072
prime farmland if drained	0.013	0.06	0.23	0.822
local important farmland	-0.049	0.06	-0.78	0.442
not prime farmland	0.010	0.10	0.10	0.919
soil loss tolerance factor	0.089*	0.05	1.80	0.081
Production and Consumption Built Variables				
total acres	-0.004***	0.00	-6.06	0.000
land class: livestock	-0.150**	0.06	-2.56	0.015
land class: residential	0.175	0.12	1.48	0.147
representative slope	0.008	0.01	0.86	0.395
building area percent	0.015***	0.00	8.09	0.000
No. of residential building	0.298***	0.05	5.83	0.000
No. of ag building	0.047***	0.01	5.15	0.000
Development and Transaction variables				
distance to city	0.002	0.00	0.64	0.528
Lansing	0.236***	0.06	4.21	0.000
Kalamazoo	0.309***	0.08	3.82	0.001
Grand Rapids	0.466***	0.08	5.83	0.000
Holland	0.458***	0.07	6.36	0.000
distance to road	0.000	0.00	-1.17	0.250
developed land % in buffer	0.002	0.01	0.26	0.796
constant	7.256***	0.54	13.56	0.000
Number of obs.= 283				
Prob >F = 0.0000				
R-square = 0.72	Adjusted R-square = 0.68			

***significant at 1% level, **significant at 5% level, *significant at 10% level
s.e. is standard error, z is z-statistics

Table 3 Comparison of results between sales price model and appraisal model (same observation number), southwestern Michigan, 2003-2007

		Sales Price (S)		Appraisal Value (A)	
Details	**Sig. model**	**coefficients**	**p-value**	**coefficients**	**p-value**
Production and Consumption Ecosystem Services Variables					
River length in parcel	S	-0.001**	0.031	0.000	0.472
Lake % in parcel	S	0.042**	0.021	0.020	0.302
Distance to river		0.000	0.166	0.000	0.671
Distance to lake		0.000	0.226	0.000	0.114
Wetland % in parcel	A	0.006	0.181	-0.004***	0.001
Wetland % in buffer	S	0.032***	0.004	0.008	0.214
Conservation land % in buffer	S/A	0.016**	0.017	0.010**	0.019
Distance to recreational land		0.000	0.587	0.000	0.406
Forest % in parcel	S	0.011**	0.023	-0.002	0.411
Cultivated land % in parcel	S	0.015***	0.008	-0.001	0.530
Pasture % in parcel		0.011	0.314	-0.002	0.253
Grassland % in parcel	S/A	0.010*	0.065	0.014**	0.015
Cultivated land % in buffer	S	0.014**	0.010	0.001	0.676
Pasture % in buffer	S/A	0.014*	0.055	0.008**	0.049
Well drained dummy	S/A	0.494**	0.039	0.577***	0.002
Poorly drained dummy	S/A	0.420*	0.057	0.631***	0.001
Prime farmland if drained		-0.045	0.700	0.007	0.866
Local important farmland	S	0.310***	0.007	0.010	0.860
Not prime farmland	S	0.528***	0.008	-0.029	0.743
Soil loss tolerance factor		-0.089	0.300	0.046	0.283
Production and Consumption Built Variables					
Total acres	S/A	-0.003**	0.020	-0.003***	0.000
Land class: livestock	A	0.154	0.203	-0.142***	0.005
Land class: residential	S	0.311**	0.016	0.191	0.185
Representative slope	S	-0.047***	0.002	0.004	0.734
Building area percent	S/A	0.079***	0.000	0.060***	0.000
No. of residential building	A	0.196	0.155	0.224***	0.000
No. of ag building		0.019	0.657	0.008	0.568
Development and Transaction variables					
Distance to city	S/A	0.009*	0.067	0.005*	0.081
Lansing	S/A	0.374***	0.003	0.231***	0.000
Kalamazoo	S/A	0.501***	0.006	0.256***	0.002
Grand rapids	S/A	0.511***	0.000	0.480***	0.000
Holland	A	0.070	0.675	0.446***	0.000
Distance to road		0.000	0.352	0.000	0.830
Developed land % in buffer		0.022	0.225	0.012	0.342
Land contract		0.224	0.113		
Constant	S/A	5.662***	0.000	6.211***	0.000
N		203		203	
Adjusted R-square		0.30		0.74	

***significant at 1% level, **significant at 5% level, *significant at 10% level
s.e. is standard error, z is z-statistics

Table 4 Comparison of results between sales price model and appraisal model (different observation number), southwestern Michigan, 2003-2007

Details	Significance	Sales Price (S)		Appraisal Value (A)	
		coefficients	**p-value**	**coefficients**	**p-value**
Production and Consumption Ecosystem Services Variables					
River length in parcel	S	-0.001**	0.015	0.000	0.324
Lake percent in parcel	S	0.056***	0.001	0.017	0.360
Distance to river	S	-0.058**	0.045	0.000	0.530
Distance to lake		-0.028	0.623	0.000	0.247
Wetland % in parcel	A	0.005	0.227	-0.005***	0.005
Wetland % in buffer	S/A	0.031***	0.002	0.013*	0.053
Conservation land % in buffer	S/A	0.017**	0.019	0.010**	0.017
Distance to recreational land		-0.003	0.865	0.000	0.416
Forest % in parcel	S/A +/-	0.011**	0.025	-0.016***	0.000
Cultivated land % in parcel	S/A +/-	0.015***	0.005	-0.012***	0.000
Pasture % in parcel	S/A +/-	0.010**	0.043	-0.013***	0.000
Grassland % in parcel		0.010	0.283	-0.003	0.809
Cultivated land % in buffer	S	0.016***	0.002	0.003	0.261
Pasture % in buffer	S/A	0.014**	0.040	0.012***	0.005
Well drained dummy	S/A	0.462**	0.048	0.401*	0.085
Poorly drained dummy	S/A	0.431*	0.052	0.435*	0.072
Prime farmland if drained		-0.074	0.509	0.013	0.822
Local important farmland	S	0.234**	0.020	-0.049	0.442
Not prime farmland	S	0.496***	0.003	0.010	0.919
Soil loss tolerance factor	A	-0.135	0.147	0.089*	0.081
Production and Consumption Built Variables					
Total acres	S/A	-0.002**	0.021	-0.004***	0.000
Land class: livestock	A	0.083	0.455	-0.150**	0.015
Land class: residential	S	0.452***	0.007	0.175	0.147
Representative slope	S	-0.041***	0.007	0.008	0.395
Building area percent	S/A	0.079***	0.000	0.015***	0.000
No. of residential building	A	0.135	0.299	0.298***	0.000
No. of ag building	A	0.011	0.796	0.047***	0.000
Development and Transaction variables					
Distance to city	S	0.008*	0.077	0.002	0.528
Lansing	S/A	0.308**	0.010	0.236***	0.000
Kalamazoo	S/A	0.400**	0.016	0.309***	0.001
Grand rapids	S/A	0.474***	0.000	0.466***	0.000
Holland	A	0.137	0.414	0.458***	0.000
Distance to road		-0.030	0.175	0.000	0.250
Developed land % in buffer		0.026	0.153	0.002	0.796
Land contract	S	0.247*	0.090		
Constant	S/A	5.908***	0.000	7.256***	0.000
N		220		283	
Adjusted R-square		0.33		0.68	

***significant at 1% level, **significant at 5% level, *significant at 10% level
s.e. is standard error, z is z-statistics

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APPENDIX 1: Variable details

	Category	Subcategory	Variable name	Variable details	Unit
T	Development	City	Citydummy	Major cities (1-Battle Creek, 2-Lansing, 3-Kalamazoo, 4-Grand Rapids, 5-Holland)	binary; 1-5
		Distance	MjCitySLDis	Straight line distance from parcel centroid to the center of the Commmercial Business District in the closest major city	kilometers
			MjRdSLDis	Straight Line Distance from parcel centroid to the nearest major road (FCC Class = A11, A12, & A21))	meters
		Urban	PBUrbanPct	Percentage of urban land cover in parcel and its 1500 meters radius neighborhood	%
	Transaction	Transaction Type	Instrument	Transaction Instrument type (1-WD, 2-LC)	binary; 1,2
		Time	Month	Sale month (Jan-Dec)	binary; 1-12
			year	Sale year (2003-2007)	binary, 2003 -2007
Bp	Basic Properties	Size and slope	TotalAcre	Total parcel acres	acres
			RepSlope	Weighted average for representative slope	degrees
	Operation	Rights	Class	Land use code of parcel, 101-cash grain, 102-Livestock, 401-residential	binary, 101,102,401
		Improvement	AgBuilding	No. of agricultural use buildings	number
Bc	Residential structures	Building	BuildingPct	Building area percentage in parcel	%
			ResBuilding	No. of residential buildings	number

	Category	Theoretical Variables	Variable name	Variable details	Unit
Ep	Ag Production Area	Cultivated land	PCultivatePct	Percentage of cropland in parcel	%
			PBCultivatePct	Percentage of cropland in parcel and its 1500 meters radius neighborhood	%
		Pasture	PPasturePct	Percentage of pasture in parcel	%
	Soil	Farmland Classification	FrmlndCls	Farmland Classification (identifies the location and extent of the soils that are best suited to food, feed, fiber, forage, and oilseed crops), 1-All areas prime farmland, 2-Prime farmland if drained, 3-farmland local importance, 4-Not prime farmland	binary; 1-4
		Erosion	Tfactor	Weighted average for Soil Loss Tolerance Factor (maximum average annual rate of soil erosion by wind and/or water)	tons per acre per year
		Drainage	DrainIndex	Drainage level from Weighted Average of Drainage Index (1-99,the long-term wetness of a soil), <34- over drained, 34-65-well drained, >65 poorly drained	binary, 1-3
	Water	Water resources in parcel	PRiverLgth	Length of river in parcel	meters
			PWetlandPct	Percentage of wetland in parcel	%
			PLakePct	Percentage of lake in parcel	%
		Water resources in surrounding area	RiverSLDis	Straight line distance from parcel centroid to the edge of the nearest river	meters
			LakeDis	Straight line distance from parcel centroid to the edge of the nearest lake	meters
			PBWetlandPct	Percentage of wetlands area in parcel and its 1500 meters radius neighborhood	%
	Habitat for pollinators and natural enemies	Grass and forest	PForestPct	Percentage of forest in parcel	%
			PGrassPct	Percentage of forest in parcel	%
			PBConsPct	Percentage of conservation land in parcel and its 1500 meters radius neighborhood	%
Ec	Recreation	Recreation use	PBRecNetDist	Network distance from the parcel centroid to the edge of the nearest recreation area	meters
		Fishing, Hunting, Hiking	Water, Forest, Conservation land	See Ep section	
	Aesthetic	Scenic view	Lake	See Ep section	
	Habitat Conservation	Conservation use	Conservation land	See Ep section	

APPENDIX 2: Summary statistics for all variables

2.1 Summary statistics for sales price model variables.

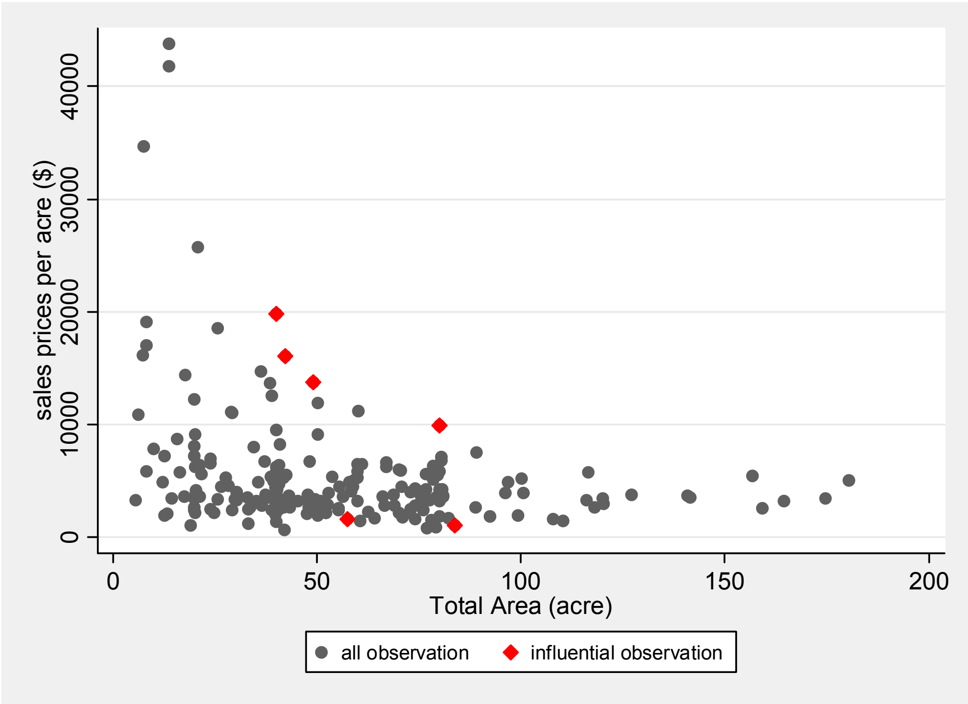
	Unit	Obs.	Mean	Std. Dev.	Min	Max
Dependent variables						
Sales price	Dollars	220	242519	175548	18415	910000
Sales price per acre	Dollars	220	5400	5499	638	43748
Production and Consumption Ecosystem Services Variables						
River length in parcel	Binary	220	49.9	146.9	0	944.8
Lake % in parcel	%	220	0.1	0.9	0	12.8
Distance to river	Meters	220	1299.7	1182.6	8.5	6030.9
Distance to lake	Meters	220	1280.3	748.2	64.8	4050.1
Wetland % in parcel	%	220	13.1	21.1	0	103.9
Wetland % in buffer	%	220	11.3	6.0	1	36.0
Conservation land % in buffer	%	220	1.3	5.7	0	48.4
Distance to recreational land	%	220	5723.6	2519.0	659.3	12216.3
Forest % in parcel	Meters	220	60.4	31.9	0	115.9
Cultivated land % in parcel	%	220	15.8	22.0	0	91.2
Pasture % in parcel	%	220	0.4	2.4	0	33.0
Grassland % in parcel	%	220	15.9	18.9	0	95.3
Cultivated land % in buffer	%	220	50.8	14.2	8.6	90.6
Pasture % in buffer	%	220	20.1	8.3	1.2	39.5
Well drained dummy	Binary	220	0.7	0.5	0	1
Poorly drained dummy	Binary	220	0.3	0.4	0	1
Prime farmland if drained	Binary	220	0.3	0.5	0	1
Local important farmland	Binary	220	0.3	0.5	0	1
Not prime farmland	Binary	220	0.1	0.3	0	1
Soil loss tolerance factor	Tons	220	4.5	0.6	2.1	5
Production and Consumption Built Variables						
Total acres	Acres	220	54.3	32.3	5.6	180.4
Land class: livestock	Binary	220	0.5	0.5	0	1
Land class: residential	Binary	220	0.0	0.2	0	1
Representative slope	Degrees	220	4.0	2.6	0	15
Building area percent	%	220	0.8	2.3	0	20.7
No. of residential buildings	Number	220	0.2	0.4	0	2
No. of agricultural buildings	Number	220	0.6	1.5	0	12
Development and Transaction variables						
Distance to city	Meters	220	34.0	8.0	12.7	53.5
Lansing	Binary	220	0.2	0.4	0	1
Kalamazoo	Binary	220	0.1	0.3	0	1
Grand Rapids	Binary	220	0.1	0.3	0	1
Holland	Binary	220	0.1	0.3	0	1
Distance to road	Meters	220	3473.8	2195.8	128.0	10915.0
Developed land % in buffer	%	220	2.7	2.6	0.3	22.3

Land contract	Binary	220	0.1	0.3	0	1
February	Binary	220	0.1	0.3	0	1
March	Binary	220	0.0	0.2	0	1
April	Binary	220	0.1	0.3	0	1
May	Binary	220	0.1	0.2	0	1
June	Binary	220	0.1	0.3	0	1
July	Binary	220	0.1	0.3	0	1
August	Binary	220	0.0	0.2	0	1
September	Binary	220	0.1	0.3	0	1
October	Binary	220	0.1	0.3	0	1
November	Binary	220	0.1	0.3	0	1
December	Binary	220	0.1	0.3	0	1
Year 2004	Binary	220	0.2	0.4	0	1
Year 2005	Binary	220	0.2	0.4	0	1
Year 2006	Binary	220	0.2	0.4	0	1
Year 2007	Binary	220	0.2	0.4	0	1

2. 2 Summary statistics for appraisal value model variables.

	Unit	Obs.	Mean	Std. Dev.	Min	Max
Dependent variables						
Appraisal value	Dollars	291	112055	78515	5400	460389
Appraisal value per acre	Dollars	291	2500	2492	385	23021
Production and Consumption Ecosystem Services Variables						
River length in parcel	Binary	291	53.5	159.6	0	1122.3
Lake % in parcel	%	291	0.1	0.8	0	12.2
Distance to river	Meters	291	1311.1	1253.8	8.5	7058.5
Distance to lake	Meters	291	1227.9	756.5	5.8	4050.1
Wetland % in parcel	%	291	11.8	19.4	0	100.0
Wetland % in buffer	%	291	11.1	5.8	1.0	36.0
Conservation land % in buffer	%	291	1.5	5.9	0	48.4
Distance to recreational land	%	291	5427.4	2494.4	574.5	12552.3
Forest % in parcel	Meters	291	16.1	20.1	0	92.6
Cultivated land % in parcel	%	291	58.7	32.7	0	100.0
Pasture % in parcel	%	291	16.2	22.6	0	91.2
Grassland % in parcel	%	291	0.5	2.7	0	33.0
Cultivated land % in buffer	%	291	49.2	14.6	8.6	90.6
Pasture % in buffer	%	291	19.3	8.6	1.1	39.5
Well drained dummy	Binary	291	0.7	0.5	0	1
Poorly drained dummy	Binary	291	0.3	0.4	0	1
Prime farmland if drained	Binary	291	0.3	0.5	0	1
Local important farmland	Binary	291	0.3	0.5	0	1
Not prime farmland	Binary	291	0.2	0.4	0	1
Soil loss tolerance factor	Tons	291	4.5	0.6	2.1	5
Production and Consumption Built Variables						
Total acres	Acres	291	54.7	35.2	2.3	180.4
Land class: livestock	Binary	291	0.4	0.5	0	1
Land class: residential	Binary	291	0.1	0.3	0	1
Representative slope	Degrees	291	4.2	2.9	0	15.5
Building area percent	%	291	1.7	10.0	0	160.9
No. of residential buildings	Number	291	0.3	0.5	0	2
No. of agricultural buildings	Number	291	0.9	2.1	0	23
Development and Transaction variables						
Distance to city	Meters	291	32.9	8.8	8.1	53.4
Lansing	Binary	291	0.1	0.3	0	1
Kalamazoo	Binary	291	0.2	0.4	0	1
Grand Rapids	Binary	291	0.1	0.4	0	1
Holland	Binary	291	0.1	0.3	0	1
Distance to road	Meters	291	3381.5	2285.8	45.2	10915.5
Developed land % in buffer	%	291	3.2	3.9	0.3	32.8

APPENDIX 3: Influential observations for sales price regression



*__Note__: three pairs of parcels are potentially erroneous (influential observations). Each pair is probably purchased by one buyer at the same time, but both parcels in the pair sold at the same price even though each parcel in the pair differs in total acres. As the coefficients and significance level of results did not change after dropping those six observations, we kept them in the dataset.

APPENDIX 4: Box-Cox functional form test for dependent variables

The Box-Cox transformation was developed by Box and Cox in 1964 in order to make the residuals more closely normal and less heteroskedastic. The general transformation of dependent variable is $y^{(\lambda)} = \frac{y^{\lambda} - 1}{\lambda}$, where $y^{(\lambda)}$ takes the linear form *y-1* if λ = 1. It takes the logarithmic transform *ln(y)* if λ = 0 and it takes the reciprocal transform if λ= -1. The following tests are used to determine the value of λ. Since λ= -1 and 1 are rejected with p-value equals zero for both sales price model and appraisal value model, the logarithmic transformation (λ = 0) is adopted.

Sales price model

Test H0:	Restricted log likelihood	LR statistic X~chi2	P-Value Pr > chi2
lambda = -1	-2075.8852	132.13	0
lambda = 0	-2012.6024	5.57	0.018
lambda = 1	-2164.9884	310.34	0

Appraisal value model

Test H0:	Restricted log likelihood	LR statistic X~chi2	P-Value Pr > chi2
lambda = -1	-2366.3267	161.48	0
lambda = 0	-2289.8209	8.46	0.004
lambda = 1	-2460.6369	350.1	0

APPENDIX 5: Spatial autocorrelation tests

1. Spatial correlogram for cutoff distance

Moran's I is a common spatial autocorrelation test defined as

$$I = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}\left(Y_i - \overline{Y}\right)\left(Y_j - \overline{Y}\right)}{\sum_i \sum_j w_{ij} \sum_i \left(Y_i - \overline{Y}\right)^2 / N}$$

where Y_i denotes the value taken on by the variable Y of interest at location i; $\overline{Y}$ denotes the mean of variable Y. Under the null hypothesis of no global spatial autocorrelation, the expected value of I is given by $E(I) = -1/(N-1)$. If I is significantly different from its expected value, then the overall distribution of variable Y can be characterized by spatial autocorrelation (Anselin and Hudak, 1992).

Spatial correlogram computes Moran's I statistics and related quantities of interest based on 5 consecutive distance bands (Cliff and Ord 1981). For each distance band, a row-standardized binary weighting matrix is first generated, and it is then used to compute the requested statistic. From the following results, we can conclude that spatial autocorrelation exists at cutoff distance 600 meters in both models.

Sales price

Distance Bands	I	E(I)	sd(I)	Z	p-value
(0-200]	0.051	-0.005	0.573	0.098	0.922
(200-400]	0.741	-0.005	0.217	3.439	0.001
(400-600]	0.272	-0.005	0.214	1.291	0.197
(600-800]	0.459	-0.005	0.205	2.260	0.024
(800-1000]	-0.262	-0.005	0.288	-0.896	0.370

Appraisal value

Distance bands	I	E(I)	sd(I)	z	p-value
(0-200]	-0.290	-0.003	0.701	-0.408	0.683
(200-400]	0.204	-0.003	0.185	1.122	0.262
(400-600]	0.628	-0.003	0.166	3.809	0.000
(600-800]	0.417	-0.003	0.160	2.622	0.009
(800-1000]	0.459	-0.003	0.178	2.596	0.009

2. Spatial diagnostics

Spatial diagnostics is used to explain the pattern for spatial autocorrelation. Two kinds of spatial dependence are considered:

1) Spatial error model: a spatial autoregressive process in the error term

$$Y = X\beta + \varepsilon \quad \varepsilon = \lambda W\varepsilon + \mu$$

where λ denotes the spatial autoregressive parameter, μ denotes a vector of homoskedastic and uncorrelated errors, and all the other terms are defined as above.

2) Spatial lag model: a mixed regressive spatial autoregressive process

$$Y = \rho WY + X\beta + \mu$$

where ρ denotes the spatial autoregressive parameter, WY denotes the spatially lagged dependent variable.

The following diagnostic results suggest that spatial dependence can only be attributed to error term in both models.

Sales price

Test	Statistic	Df	p-value
Spatial error:			
Moran's I	4.417	1	0.000
Lagrange multiplier	1.356	1	0.244
Robust Lagrange multiplier	1.028	1	0.311
Spatial lag:			
Lagrange multiplier	1.984	1	0.159
Robust Lagrange multiplier	1.656	1	0.198

Appraisal value

Test	Statistic	Df	p-value
Spatial error:			
Moran's I	2.043	1	0.041
Lagrange multiplier	0.248	1	0.619
Robust Lagrange multiplier	0.270	1	0.603
Spatial lag:			
Lagrange multiplier	0.148	1	0.701
Robust Lagrange multiplier	0.170	1	0.680