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Analysis

Valuation of ecosystem services from rural landscapes using agricultural land prices ☆

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ABSTRACT

Agricultural lands, primarily managed for crops and livestock production, provide various ecosystem services (ES) to people. In theory, the economic value of the service flows that can be captured privately is capitalized into land prices. This study proposes an integrative framework to characterize the ecosystem services associated with agricultural lands. Using that framework, we demonstrate how hedonic analysis of agricultural land prices can be used to estimate the private values of land-based ES. The model is estimated with data from southwestern Michigan, USA. Results suggest that ES values are associated with lakes, rivers, wetlands, forests and conservation lands in rural landscapes. Ecosystem services that support direct use values, such as recreational and aesthetic services, are likely to be perceived by land owners and capitalized in land prices. Some regulating services that provide indirect use values may be partially capitalized in a land parcel's relationship to natural resources and landscapes. Other ES from the land parcel and its surroundings are unlikely to be capitalized due to lack of private incentives, unawareness, or small perceived value. The private ES values measured in this study highlight opportunities to design cost-effective public policies that factor in the value of private benefits from agricultural lands.

1. Introduction

1.1. Ecosystem Services from Agricultural Lands and Surroundings

Agricultural land is primarily managed for production of crops and livestock, while it also provides residential properties and natural amenities to people at the same time. Agricultural land is an important resource in the global ecosystem, for it covers 38% of the world's land area and 45% of the United States (World Bank, 2007).

As the interaction between agricultural ecosystems and other terrestrial/aquatic ecosystems is largely linked to agricultural lands, a wide variety of ecosystem services (ES) can be supplied from agricultural lands and their surroundings, in other words, rural landscapes. ES are defined as the benefits people obtain from ecosystems (Millennium Ecosystem Assessment, 2003). The four categories of ecosystem services related to rural landscapes are shown in Fig. 1. Basic services from agricultural ecosystems are the provision of agricultural products such as food, fiber and biofuel (*Provisioning ES*). *Regulating ES* are generated by ecosystem processes that regulate water quality and quantity, climate, disturbance incidence, biological pest populations, and levels of other ecosystem outcomes. Some are performed by agricultural ecosystems, while others supplied to agriculture boost its productivity (Zhang et al., 2007). *Recreational, Aesthetic and Cultural ES* are also derived from natural resources and landscapes in agricultural ecosystems. These three major categories of ES that are directly experienced by humans are underpinned by one that is not, *Supporting ES* (e.g., soil formation, nutrient cycling and genetic biodiversity), that enable the existence and evolution of other ecosystems (including agricultural ones).

1.2. Valuation of Ecosystem Services via the Agricultural Land Market

The value of ecosystem services depends on how they contribute to attaining human goals (Barbier et al., 2009). In rural landscapes, ES contribute to both production and consumption goals. As a medium for agricultural production, land generates income streams for land owners and tenants. The provisioning services of land are sustained by soil, water, insects and climate regulation (Zhang et al., 2007). While these ES flows may be hard to measure, their broad levels can be signaled by the conditions of croplands, wetlands, forests and grasslands. On the consumption side, rural land also provides home sites and open space for natural amenities. These recreational and aesthetic ES rely on various natural amenities from lakes, wetlands, forests and other scenic landscapes (Knoche and Lupi, 2007).

The appropriate way to measure the economic value of ES from rural landscapes depends on how well markets function to connect

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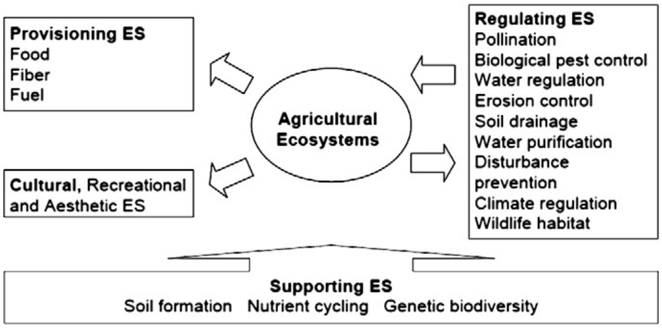

Fig. 1. Ecosystem services related to agricultural land.
Adapted from Zhang et al. (2007) and MEA (2003).

the supply of ES with demand from the beneficiaries. The provision of farm products can be directly valued by market prices. On the other hand, ES that are public goods lack markets and thus need for values to be estimated through surveys unless a public policy creates special property rights that imbue value (e.g., greenhouse gas mitigation). Some ES lie in between these two extremes so that although direct markets are missing, their value can be captured indirectly via related markets. Examples include natural amenities (e.g., recreational and aesthetic opportunities from lakes) and production-enhancing services (e.g., flood mitigation by wetlands). They satisfy human needs by improving quality of life and conditions for producing marketable goods. One way to measure their value indirectly is via the prices that people pay for the lands that provide access to these ES.

Agricultural land is a differentiated good whose characteristics vary across parcels with land uses, building structures, soil and local climate (Palmquist, 1989). Land prices differ along with these characteristics. Hedonic analysis, a revealed preference valuation method, uses multiple regression to infer the economic value of changes in specific land characteristics from their effects on prices, in this case the price of agricultural land.

1.3. Research Gaps and Objectives

Previous hedonic studies have examined the value of land attributes that support the production and consumption roles of farmland. Agricultural land cover areas designated as cropland, pasture, forest and wetland were used in hedonic analyses of the value of soil conservation (Gardner and Barrows, 1985), land preservation programs (Palm, 1994) and water use permits (Petrie and Taylor, 2007). Other studies constructed variables from landscapes and natural resources to measure the amenity value from farmland. Bastian et al. (2002) estimated the value of Wyoming elk habitat and scenic view composition in the USA. Drescher et al. (2001) created a county-level natural amenity index using climate, topography, and water conditions to capture recreational and aesthetic values in Minnesota, USA.

Among recent hedonic studies of agricultural land, few have incorporated the influence from surrounding natural resources and landscapes. Surroundings have been widely explored in residential property value studies (Geoghegan et al., 1997; Irwin, 2002; Johnston et al., 2001; Lake and Easter, 2002; Ready and Abdalla, 2005; Secchi, 2007). For agricultural lands, Spahr and Sunderman (1999) compared the impact of adjacent water bodies and scenic views on the sale prices of resort properties and other rural lands in Wyoming, USA. Nivens et al. (2002) employed remote sensing data to examine the effects of water bodies, cropland and pasture within a 1600 meter radius on farmland prices in Kansas, USA.

Based on the review of literature, although selected ES from rural landscapes have been valued, existing studies fall short of offering a comprehensive picture of the ecosystem services derived from landscapes and resources both on agricultural lands and surrounding areas. Among hedonic analyses of agricultural land prices, the ES from surrounding land covers and resources have been touched only twice (Spahr and Sunderman, 1999; Nivens et al., 2002, both using limited indicators of landscape-level ES. Thus, the objectives of this study are 1) to characterize the ecosystem services from natural landscapes and resources as they affect agricultural lands, and 2) to demonstrate empirically how the hedonic method can be used to estimate the privately captured value of land-based ecosystem services using data from southwestern Michigan, USA. Of particular interest is testing the impact of surrounding rural landscapes on farmland prices.

The next section discusses the characteristics of landscape-linked ES based on property rights and economic value theory. Section 3 proposes a conceptual model for agricultural land valuation using the hedonic method. Section 4 shows the data, empirical model and results of an empirical study in southwestern Michigan. Section 5 summarizes the conclusions and policy implications.

2. Categorizing Ecosystem Services from Agricultural Landscapes and Surroundings

To better understand 1) what kinds of ecosystem services can be generated from agricultural lands and surrounding landscapes, and 2) which ES can be effectively measured via land prices, a comprehensive framework is needed that characterizes ES by their ownership, beneficiary, and perceptible value to land owners.

2.1. Ecosystem Services and Property Rights

The ability of prices from private land markets to capture the value of ecosystem services flows from the land depend upon the property rights for the ES. ES property rights are directly related to whether and how the ES may be owned and consumed. The key trait of ownership is excludability, the ability to exclude others from consuming the ES without permission (Olson, 1971). The key trait of consumption is rivalness, such that consumption of the ES by one person reduces its availability to others (Olson, 1971).Those ecosystem services that are nonexcludable and nonrivalrous are known as public goods, whereas private goods are the contrary, excludable and rivalrous. Common-pool resources are rivalrous but nonexcludable since the existence of resources is limited. Property rights, which imply enforceable authority to undertake particular actions in a specific domain (Commons, 1968), are poorly defined for services that are nonexcludable. Hence, although the property rights of most agricultural lands are legally delineated, the ecosystem services from those lands may not be. As will be shown, land markets can capture the values of ES for which property rights are complete, but will not fully capture the values of ES for which they are not.

2.2. Ecosystem Services and Economic Value

According to Total Economic Value (TEV) theory, the value of ecosystem services can be categorized by the nature of its interaction with humans (Pearce, 1993). TEV is based on the presumption that individuals can hold multiple values for ecosystems. Some ecosystem services from landscapes and resources have *direct use value* derived from their physical interaction with land owners; some have *indirect use value* derived from their support and protection of activities that have direct use values, while others are simply valued for *existence, bequest and potential for future use/nonuse* (National Research Council, 2005). The value of ecosystem services from rural landscapes is also affected by people's awareness and perceived importance. Those ES proved scientifically might not be well known, and thus appear to have no value to most people. Some other ES deemed to be not important to people might be weakly valued even if they are well observed.

2.3. Categorizing Ecosystem Services from Rural Landscapes

Understanding the potential for land prices to convey economic value estimates of ES requires an integrative framework. Such a framework must integrate economic values and property rights into the context of ecosystem services from agricultural lands (on-site) and surrounding areas (off-site). Fig. 2 uses these concepts to distinguish five categories of ES, as follows:

- *On-site ES with direct use value* (provisioning, recreational and aesthetic ES enclosed by solid line in the center of the figure) have the traits of private goods. The provisioning ES derived from cultivated lands are invested and managed by land owners, who also reap profits from farm products. Landowners can exclude others from on-site recreational ES and aesthetic ES from forests, lakes and wetlands on their properties. These ES are likely to benefit land owners by direct consumption or revenues from selling hunting permits. All those ES are expected to be mostly capitalized in land market. However, on-site resources may also generate disservices to cropland, such as flood, soil erosion and nutrient runoff from on-site rivers.
- *On-site ES with indirect use value* (regulating ES enclosed by dotted line on right) are derived from water resources and diverse natural vegetation. These ES, such as natural pest control and water regulation, are rivalrous, but can be excludable or nonexcludable. They support both directly usable on-site and off-site ES. Land owners only perceive their values through direct-use ES when their influence is notable and significant.
- *Off-site ES with direct use value* (recreational ES and aesthetic ES enclosed by solid line on center left) partly benefit the farmland owners by providing proximate natural amenities, hence could be partly capitalized into land price. The recreational resources are rivalrous and somewhat excludable as land owners may encounter a cost for using resources on other privately or publicly owned lands. The aesthetic ES are mostly nonrivalrous and nonexcludable within a certain range, such as views.
- *Off-site ES with indirect use value* (regulating ES enclosed by dotted line on upper left) support the direct-use ES on agricultural lands and surrounding areas. Although their values may be perceptible through direct-use ES, they are rarely capitalized in the land market due to lack of awareness by land owners or limited effect on direct-use ES.
- *On-site and off-site ES with non-use or option value* (regulating ES and supporting ES enclosed by dash line at the bottom) have the properties of public goods in the sense that they benefit the entire population. Thus, their value is not capitalized into private land price.

There are trade-offs between different categories of ecosystem services provided on agricultural land and surroundings. For example, larger wetland areas and more diverse landscapes on agricultural lands would boost aesthetic ES, recreational ES and some regulating ES such as water regulation and biological pest control, but diminish the provisioning ES of farm products.

3. Valuation of Ecosystem Services Using Agricultural Land Prices

3.1. Conceptual Model of Agricultural Land Valuation

The theoretical value of agricultural land is based on the services that it can provide over a buyer's planning horizon. Agricultural land as a carrier of managed ecosystems simultaneously performs many public and private functions (Henneberry and Barrows, 1990; Xu et al., 1993). Farmers utilize land for agricultural production to earn their livelihood and store wealth. Land also provides a home site for a farmstead and a refuge of rural residents seeking open space to pursuit of a country lifestyle. Rural settings enable recreational activities, such as fishing and hunting, as well as aesthetic views. These amenities are available for consumption to both rural residents and visitors, whether or not they engage in agriculture. Besides the production and consumption functions, agricultural lands have asset option value to developers interested in future development for non-farm uses. Therefore, the value of agricultural land should be estimated from

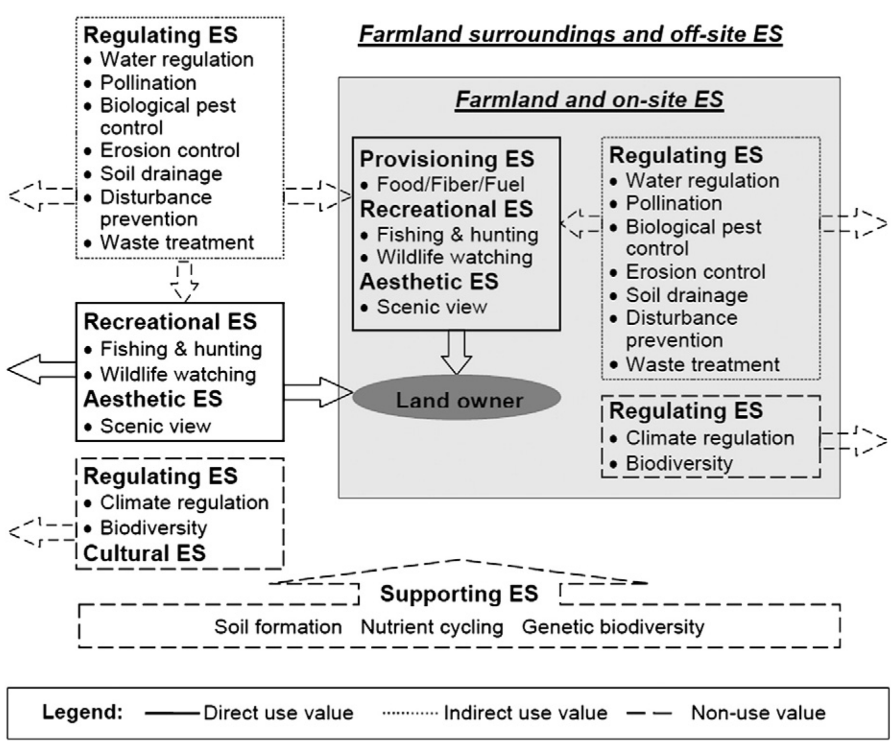

Fig. 2. Ecosystem services from agricultural lands and surrounding areas.

its production, consumption and asset roles. Given the important differences between natural capital and built capital as asset classes (Daily, 1997; World Bank, 2006), subdividing the production and consumption roles into built assets (B) and natural assets (E) enables subsequent estimation of the value of natural resources and landscapes, the proxies for the ecosystem services that they provide.

We develop a conceptual model for agricultural land valuation in a market with sellers and buyers. The land purchaser chooses the parcel of land M to maximize a utility function[1] embodying consumption of built attributes B_c (e.g., on-site residence), consumption of ES amenity attributes E_c (e.g., recreational and aesthetic resources), and other purchased goods N (Eq. (1)). Let $P(Z)$ be the price of the parcel, with Z representing a vector of hedonic price determinants. A budget constrains the expected present value of summed expenses on other purchased goods $P_N N$ plus the land purchase $P(Z)M(T)$ to be less than or equal to the expected present value of income streams from agricultural production, $\pi^b(t)$, and other nonfarm activities, NFI, plus the option value for future development, $\pi(L,s)$. L represents factors related to farm location, T represents the land transaction attributes and r is the interest rate. The buyer's planning horizon is from the present, $t=0$ to $t=s$, where s is the time they convert land from agricultural use to non-agricultural use.

$$\begin{aligned}&\underset{M}{Max}\ U(N, E_c, B_c)\\ &s.t.\ E\left(\int_{t=0}^{s} P_N N e^{-rt} dt\right) + P(Z)M(T) \le E\left(\int_{t=0}^{s} \pi^b(t) e^{-rt} dt\right)\\ &\qquad + E\left(\int_{t=0}^{s} NFI(t) e^{-rt} dt\right) + E\left(\pi(L,s)e^{-rs}\right).\end{aligned} \tag{1}$$

The buyer's expected future profit from production (Eq. (2)) equals discounted farm products revenue $P_y Y$ minus input cost $P_x X$ and fixed cost FC. The production of Y is facilitated by production ES attributes E_p (e.g., soil fertility), productivity-enhancing factors from prior human investments B_p (e.g., land improvements) and other inputs, X.

$$\begin{aligned}&\pi^b(t) = P_y(t)Y(t) - P_x(t)X(t) - FC(t)\\ &s.t.\quad Y = f\left(X, B_p, E_p\right).\end{aligned} \tag{2}$$

The land seller (Eq. (3)) is assumed to maximize profit from the land sale transaction with sale costs depending on the land parcel (M).

$$\begin{aligned}&\underset{M}{max}\ \pi^s\\ &s.t.\quad \pi^s = P(Z)M(T) - C(M,Z).\end{aligned} \tag{3}$$

The agricultural land attributes Z are made up of consumption ES characteristics (E_c), production ES characteristics (E_p), consumption human-built characteristics (B_c), and production human-built characteristics (B_p), subject to product and input prices (Eq. (4)). The farmland sale transaction is carried out by the interaction of purchasers and sellers, and both face location (L) and transaction (T) factors.

$$Z = \left(B_c, B_p, E_c, E_p, L, T \mid P_y, P_x\right). \tag{4}$$

Previous hedonic studies of agricultural land prices have focused on selected attributes of ecosystem services. Many studies addressed farm production with measures such as cropland acres (Elad et al., 1994), cultivated land percentage (Shonkwiler and Reynolds, 1986), or complex productivity indices from soil and land use conditions (Drescher and McNamara, 1999; Nivens et al., 2002). Some studies extended the estimation of farmland production to regulating conditions on water, soil and climate (Faux and Perry, 1999; Maddison, 2000; Mendelsohn et al., 1994; Palmquist and Danielson, 1989). Several other studies took into account land characteristics for consumption use, such as amenities from recreation activities and scenic views (Bastian et al., 2002; Drescher et al., 2001; Nivens et al., 2002; Pyykkönen, 2005).

3.2. Hedonic Method

Hedonic analysis is a powerful revealed preference method for non-market valuation of the environment and natural resources. Based on Lancaster's (1966) view of utility as generated by the underlying characteristics of goods, Rosen (1974) provided the classic theoretical foundation for the hedonic model by exhibiting individual choices in market equilibrium. Let $Z=(z_1, z_2, \ldots z_n)$ 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. The fundamental hedonic equation is $p=h\,(Z)$, where $h\,(\cdot)$ represents the functional relationship between the price of good and its attributes. Regressing observed prices p on all attributes of the good (agricultural land, in this case), while ignoring differences in supplier or consumer characteristics, we can obtain an estimated marginal value of each attribute as $\hat{p}_i = \partial \hat{h}(Z)/\partial z_i$, which is the implicit price that people would pay for a small change in each attribute.

3.3. Proxies for Ecosystem Services

To quantify ecosystem services linked to agricultural land attributes for hedonic analysis, the first-best measures would quantify productivity of individual ES with care. Two factors make it impractical to collect and use such data. First, for many ES, observation is very costly or not measurable with current knowledge (e.g., tracking pest predation by natural enemies). Second, most ES are jointly produced from ecosystems on specific land covers. Hence, even if data on their productivity could be collected affordably, the levels of different ES from the same ecosystem on the same land cover likely would be collinear. Since ecosystem services are sustained by natural resources and landscapes in and near agricultural lands, the presence of, area of and proximity to those resources and land covers can serve as proxy variables for the unobserved ES. For example, the provisioning ES of crop and livestock can be represented by the area of cropland and pasture; the recreational opportunities and aesthetic views can be indicated by presence of lakes, rivers, forest and even flooded cropland. Such proxy variables are easily constructed using Geographic Information System (GIS) databases and remote sensing land cover data.

In the hedonic model, the marginal value of each characteristic $\hat{p}_i = \partial \hat{h}(Z)/\partial z_i$ is theoretically determined by the secondary demand and supply for that particular characteristic (Rosen, 1974). Ideally, with detailed market information on each specific ES, we could observe conditions in which missing property rights cause markets to fail for specific ES. However, from the land price alone, we can only infer the joint value of ecosystem services from the proxy variables. We cannot separate individual ES contributions from the resources and landscapes where they originate. For instance, while forests and wetlands enable outdoor activities, such as fishing, hunting and wildlife watching, they also provide habitat for pollinators and natural enemies of crop pests (Bianchi et al., 2006; Naylor and Ehrlich, 1997; Vaughan et al., 2004). Table 1 lists relevant ES, ideal but unavailable ES measures and the available proxy variables used in this study.

[1] The private preference for rural land use may reflect both benefits for individual (self-regarding preference) and benefits for family, community or future generations (agency preference) as discussed by McLeod et al. (1999). In this study, however, we assume that the typical land purchase decision only depends on the utility related to land buyers themselves, namely the selfish utility.

Table 1
Categories, measures and proxies of ecosystem services related to agricultural lands.
Partly adapted from Kroeger and Casey (2007).

Category	Ecosystem services	Ideal measures	Proxies
Provisioning ES	Commercial products	Crop and livestock population	Cropland and pasture
	Drinking water	Aquifer, surface water quality	–
	Non-commercial goods	Target fish, animal, and plant populations	Lakes, rivers, forest and wetlands
Regulating ES	Disturbance prevention	Property and crop damage	Wetlands, forests, and conservation lands
	Water regulation	Water quality and quantity	Lakes, rivers and wetlands
	Waste treatment	Surface and groundwater, open land	Lakes, rivers and wetlands
	Pollination	Pollinator population	Wetlands, forests, grasslands, and conservation lands
	Biological pest control	Natural enemy population	Wetlands, forests, grasslands, and conservation lands
	Soil drainage	Soil drainage property	Soil quality
	Erosion control	Soil erosion property and securing plants	Soil quality and forests
Recreational ES	Birding/wildlife watching	Bird and wildlife populations	
	Fishing	Fish population and distribution	Lakes, rivers, wetlands, grasslands and forests; conservation lands
	Hunting	Game animal population and distribution	
	Hiking, biking, picnicking	Trail and picnicking areas	
Aesthetic ES	Natural and rural landscapes	Farmlands and natural land covers	Farmlands and natural land covers
Cultural ES	Wilderness, biodiversity, varied natural land cover and rural landscapes	Diversity of species and landscapes	Diversity of different land covers

4. A Hedonic Study of Agricultural Land-Linked ES in Southwestern Michigan

To illustrate the valuation of ecosystem services from agricultural landscapes and surrounding areas using this integrated valuation framework, we conduct a hedonic analysis with land sale data from southwestern Michigan.

4.1. Data and Study Area

This study seeks to estimate the capitalization of ecosystem services embodied in farmland prices in southwestern Michigan of the United States (Fig. 3). It focuses on four counties (Allegan, Barry, Eaton and Kalamazoo) surrounding the Kellogg Biological Station, site of a Long-term Ecological Research project exploring ecosystem services from agriculture (Fig. 4). Lake Michigan is located to the west of Allegan County. Nearby cities of over 35,000 inhabitants include Grand Rapids, Lansing, Kalamazoo, Battle Creek and Holland.

Fig. 3. Study areas in the State of Michigan (Ma, 2010).

Lands in the southwest Michigan are used for a mix of agricultural production, residence and recreation. The last ice age created the regions' topography, sculpting the Great Lakes and leaving heterogeneous soils that became covered by wetlands, prairies, and hardwood forest 15,000–20,000 years ago. The availability of small, open prairies and ease of transportation attracted the European settlers in early 1800s, and oriented them to grain production. As agricultural production expanded in the mid to late 19th century, the landscape was altered by cutting down trees and draining wetlands (Rudy et al., 2008). The production role of agricultural land intensified with expanding demand and technology development through the first half of the 20th century until the recent decades, when the shrinkage of both farmland areas and number of farms emerged (United States Department of Agriculture (USDA), 1950–2007). The changing use of agricultural land is due to the increase in 1) number of households who gradually moved out to the suburbs and rural areas, 2) construction of secondary residences for recreation and retirement amid rural amenities (Michigan Department of Agriculture, 2003), and 3) higher agricultural productivity of lands elsewhere. According to the 2007 Michigan Land Value Survey, the major agricultural factors that influence farmland prices in southwestern Michigan are grain price and farm expansion, while the non-agricultural factors include home sites, hunting access and water access (Wittenberg and Harsh, 2007). Development pressure for commercial and industrial use of farmland near major cities also exists. Thus, this evolving area is a good representation of the production, consumption and asset option value functions of agricultural land and provides a reasonable basis to study the value of different ecosystem services.

For this study, land transaction and parcel information, including land price, appraised value, sales time, contract type and land class, were collected from the County Equalization Office in each of the four counties. These offices are responsible for administration of local property taxes. The associated Geographic Information System 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 (SSURGO) database, the Conservation and Recreation Lands (CARL) dataset, the National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) land cover

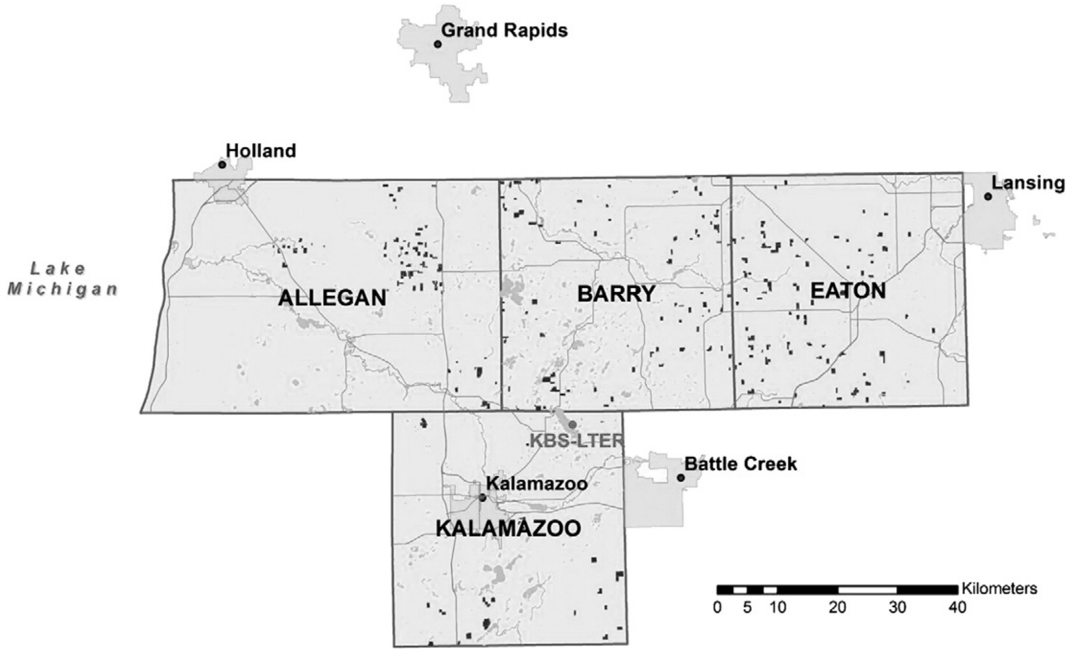

Fig. 4. Detailed location of parcels in the four study counties (Ma, 2010).

database, and other Michigan GIS databases on rivers, lakes, wetlands, cities and major roads. Information covering 337 parcel transactions was collected for the years 2003–2007 (Fig. 4) (for details, see Ma, 2010). Of these, a dataset of 220 parcels that changed hands in arm's length transactions[2] during this five-year period is used for the hedonic analysis.

4.2. Functional Form and Variables

Based on a Box–Cox functional form test, we use a semi-log model with logarithmic transformation of sale price per hectare (P) regressed on the vectors of untransformed independent variables (B_p, B_c, E_p, E_c, L, and T) from Eq. (4):

$$LnP = \alpha_0 + B_p\beta_1 + B_c\beta_2 + E_p\beta_3 + E_c\beta_4 + L\beta_5 + T\beta_6. \quad (5)$$

The dependent variable sale price (P) is the transaction price for all available arms-length sales, including warranty deed and land contract deed, while excluding quitclaim deed (Ma, 2010). The sale price was deflated to 2007 constant prices using the Prices Paid by Farmer Index (National Agricultural Statistics Service, 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 and B_c), ecosystem services attributes (E_p and E_c), location attributes (L) and transaction attributes (T) to estimate their marginal contribution to farmland value. Variables representing the level of ecosystem services (E_p and E_c) were constructed from measures of natural resources and rural landscapes. Summary statistics for all variables can be found in Table 2. The farmland production for crops and livestock is directly related to the farmable area in parcel, specifically the *cultivated land as percentage of parcel* for crops and *pasture as percentage of parcel* for livestock. To measure the influence from nearby farmable lands, we also include a variable of *cultivated land as percentage of surrounding area* calculated from a 1.5 kilometer radius from the parcel centroid. Natural habitats within a radius of 1.5 km could provide services of biological pest control (Gardiner et al., 2009; Thies et al., 2003) and pollination (Kremen et al., 2004; Steffan-Dewenter et al., 2002) that promote agricultural production. This is also within the travel distance of many game animal species that may both provide recreational opportunities and cause crop destruction. An illustration of natural resources and landscapes data in GIS format can be found in Fig. 5.

The natural 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” (United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), 1996). Other features 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) (Schaetzl, 1986). *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 resources are indicated by *river length* and *lake area as percentage of parcel*. Variables measuring recreational effects and off-site irrigation opportunity (Ma, 2010), 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 as percentage of surrounding area* measures the ability both to regulate water resource in parcel and to host beneficial insects. *Grassland as percentage of parcel* and *forest as percentage of parcel* indicate recreational opportunities and possible habitat for beneficial insects. Similarly, *conservation land as percentage of surrounding area*, which could include grassland, forest or wetlands, indicates the service from the neighborhood around the farmland parcel (Ma, 2010). 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

[2] Arm's length transaction refers to “a transaction among parties, each of whom acts in his or her own best interests”. Deals between a husband and wife, between a father and son, and between a corporation and its subsidiaries would NOT be considered arm's length (Friedman et al., 2009).

Table 2
Summary statistics for sale price model variables, 220 parcel transactions, southwest Michigan, 2003–07.

	Unit	Mean	Std. dev.	Min	Max
Land sales price					
Sales price	Dollars	214,173	155,104	15,000	910,000
Sales price per hectare	Dollars	13,343	13,589	1577	108,104
Production and consumption ecosystem services variables					
River length in parcel	Kilometers	0.0499	0.147	0	0.945
Distance to river	Kilometers	1.30	1.18	0.00852	6.03
Distance to lake	Kilometers	1.28	0.748	0.0648	4.05
Distance to recreational land	Kilometers	5.72	2.52	0.66	12.22
Lake% in parcel	%	0.100	0.929	0	12.8
Wetland% in parcel	%	13.1	21.1	0	104
Wetland% in buffer	%	11.3	5.99	0.952	36.0
Conservation land% in buffer	%	1.27	5.70	0	48.4
Cultivated land% in parcel	%	60.4	31.9	0	115.9
Pasture% in parcel	%	15.8	22.0	0	91.2
Forest% in parcel	%	15.9	18.9	0	95.3
Grassland% in parcel	%	0.388	2.44	0	33.0
Cultivated land% in buffer	%	50.8	14.2	8.58	90.6
Pasture% in buffer	%	20.1	8.34	1.20	39.5
Well drained dummy	Binary	0.695	0.461	0	1
Poorly drained dummy	Binary	0.273	0.446	0	1
Prime farmland if drained	Binary	0.318	0.467	0	1
Local important farmland	Binary	0.309	0.463	0	1
Not prime farmland	Binary	0.132	0.339	0	1
Soil loss tolerance factor	Tons	4.52	0.604	2.14	5.00
Production and consumption built variables					
Total acres	Hectares	22.0	13.1	2.3	73.0
Land class: livestock	Binary	0.523	0.501	0	1
Land class: residential	Binary	0.0455	0.209	0	1
Representative slope	Degrees	3.99	2.56	0	15
Building area percent	%	0.780	2.31	0.0	20.7
No. of residential buildings	Number	0.218	0.425	0.0	2.00
No. of agricultural buildings	Number	0.632	1.54	0.0	12.0
Development and transaction variables					
Distance to city	Kilometers	34.0	8.05	12.7	53.5
Distance to road	Kilometers	3.47	2.20	0.128	10.9
Lansing	Binary	0.177	0.383	0	1
Kalamazoo	Binary	0.136	0.344	0	1
Grand Rapids	Binary	0.132	0.339	0	1
Holland	Binary	0.114	0.318	0	1
Developed land% in buffer	%	2.67	2.55	0.250	22.3
Land contract	Binary	0.100	0.301	0	1

hunting and hiking. The influence of managed recreational lands, which are open spaces designated for public recreation, such as parks, beaches and camping sites, is measured by its distance from the parcel centroid along roads, labeled as *distance to recreation land*.

The built attributes for production (B_p) include basic land properties like *total hectares* and *representative slope*, which is the parcel area-weighted average slope in degrees from SSURGO. The baseline *land class*is crop production, with dummy variables for *livestock* production and *residential* farms. Building attributes (B_c) are constructed from aerial photographs (Center for Geographic Information, 2005) combined with information from county equalization offices. *Building area 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.

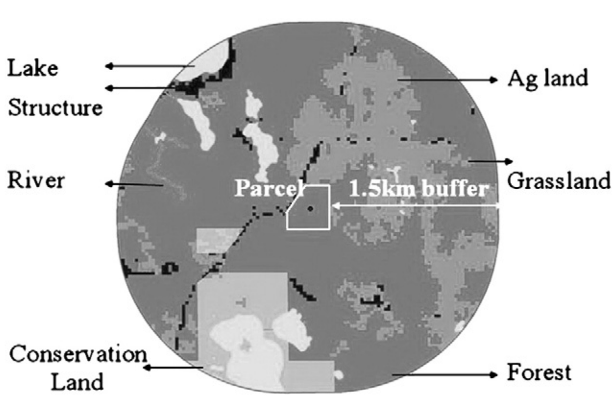

Fig. 5. An example of natural resources and landscapes data on the farmland and its surrounding area with 1.5 km radius in GIS (Ma, 2010).

Variables related to location (L) and transactions (T) 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 urban development pressure disperses from major cities, binary dummy variables indicate if the closest major city of each parcel is Grand Rapids, Lansing, Kalamazoo, Holland or Battle Creek (omitted baseline), each of which has a population greater than 35,000. To better capture the urban access effect, we use a *distance to city* variable measuring the straight line distance to the closest city and a *distance to road* variable measuring the straight line distance from parcel centroid to the edge of the nearest interstate, freeway or highway (Ma, 2010). The variable *developed land as percentage of surrounding area* is used to capture the nearby urbanization effect from high/medium/low intensity developed land cover in the 1.5 kilometer radius. In addition, binary variables are included for sales year, month and transaction instrument type (*land contract* rather than base case of warranty deed). A variable indicating enrollment in farmland preservation programs is not included in the study because a suitable measure was the not available and because the predominant preservation program is voluntary easements,[3] which have been found to have little influence on land prices (Nickerson and Lynch, 2001; Vitaliano and Hill, 1994).

In general, natural and built variables that support land productivity and amenity are likely to have a positive effect on land price. However, due to possible disservices from natural resources and landscapes, such as flood risk from river, the net effects on land price from ES variables depend on the trade-offs between positive and negative impacts. Variables linked to development potential are likely to have a positive effect on farmland price.

4.3. Spatial Autocorrelation and Regression Diagnostics

Spatial dependence is defined as "the existence of a functional relationship between what happens at one point in space and what happens elsewhere" (Anselin, 1988). In an econometric model with inherently spatial data, spatial dependence is both likely and could cause inefficiency in statistical estimation. In this study, we test for spatial autocorrelation using Moran's I tests. The global Moran's I test indicates significant spatial autocorrelation for 37 of the 50 variables. The local Moran's I test suggests that 12 observations exhibit highly significant spatial autocorrelation. Diagnostics on the autocorrelation structure suggests spatial dependence is only due to correlation in the error terms. Thus we adopt a spatial error model with an inverse distance weighting matrix W as follows (Ma, 2010):

$$LnP = \alpha_0 + B_p\beta_1 + B_c\beta_2 + E_p\beta_3 + E_c\beta_4 + T\beta_5 + \varepsilon \quad (6)$$
$$\varepsilon = (I-\lambda W)^{-1}\mu.$$

Where λ denotes the spatial autoregressive parameter, μ denotes a vector of homoskedastic and uncorrelated errors, and all the other terms are defined as in Eq. 5. The cutoff point for inverse distance matrix is set to 600 m, following Moran's I spatial correlogram test and a comparable study (Lynch and Lovell, 2002). Since the eigenvalue matrix cannot be computed due to lack of neighbors within the cut-off distance for more than a half number of parcels, the spatial error model by Maximum Likelihood Estimation cannot be implemented. Instead, we estimate the model by ordinary least squares regression using Stata code by Conley[4] to obtain results with robust errors to account for spatial autocorrelation. The asymptotic covariance matrices are estimated as distance-weighted averages of sample autocovariances (Conley, 1999).

Regression diagnostics also led to some adjustments in the econometric model. Pair-wise correlation and variance inflation factors showed evidence of multicollinearity, leading several variables to be dropped, including forest and grassland in parcel neighborhood, county dummies and some soil productivity measurements. The joint F test for dropped variables was insignificant at a 0.05 probability of Type I error, making it impossible to reject the hypothesis that the coefficients on all dropped variables are jointly equal to zero. Breusch–Pagan tests of heteroskedasticity were also insignificant (Ma, 2010).

4.4. Results

Our results suggest that per-hectare land sale prices depend upon all five categories of variables (Table 3). 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 landscapes 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 5.6% per 1% change in parcel area covered by a lake. This large effect may reflect aesthetic ES of scenic views and recreational ES of swimming, fishing and boating. The land price is also raised by 1.0% 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

Table 3
Proportional marginal effect of agricultural land attributes on land sale price per hectare (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	−0.88**	0.36	−2.44	0.015
Lake area % of parcel	0.056***	0.017	3.29	0.001
Distance to river	−0.058**	0.029	−2.00	0.045
Distance to lake	−0.028	0.056	−0.49	0.623
Wetland % of parcel	0.0050	0.0042	1.21	0.227
Wetland % of surrounding area	0.031***	0.010	3.05	0.002
Conservation land % of surrounding area	0.017**	0.0070	2.36	0.019
Distance to recreational land	−0.0033	0.019	−0.17	0.865
Cultivated land % of parcel	0.011**	0.0048	2.25	0.025
Pasture % of parcel	0.015***	0.0054	2.83	0.005
Forest % of parcel	0.010**	0.0051	2.03	0.043
Grassland % of parcel	0.010	0.010	1.07	0.283
Cultivated land % of surrounding area	0.016***	0.0049	3.14	0.002
Pasture % of surrounding area	0.014**	0.0070	2.05	0.040
Well drained dummy	0.46**	0.23	1.98	0.048
Poorly drained dummy	0.43*	0.22	1.94	0.052
Prime farmland if drained	−0.074	0.11	−0.66	0.509
Local important farmland	0.23**	0.10	2.33	0.020
Not prime farmland	0.50***	0.17	2.98	0.003
Soil loss tolerance factor	−0.14	0.093	−1.45	0.147
Production and consumption built variables				
Total hectares	−0.0024**	0.0010	−2.31	0.021
Land class: livestock	0.083	0.11	0.75	0.455
Land class: residential	0.45***	0.17	2.70	0.007
Representative slope	−0.041***	0.015	−2.72	0.007
Building area %	0.079***	0.016	5.04	0.000
No. of residential buildings	0.13	0.13	1.04	0.299
No. of agricultural buildings	0.011	0.044	0.26	0.796
Development and transaction variables				
Distance to city	0.0083*	0.0047	1.77	0.077
Distance to road	−0.027	0.020	−1.36	0.175
Lansing	0.31**	0.12	2.56	0.010
Kalamazoo	0.40**	0.17	2.41	0.016
Grand Rapids	0.47***	0.13	3.63	0.000
Holland	0.14	0.17	0.82	0.414
Developed land % of surrounding area	0.026	0.018	1.43	0.153
Land contract	0.25*	0.15	1.70	0.090
Constant	5.9***	0.84	6.99	0.000
Number of obs. = 220				
Prob.>F = 0.00				
R-square = 0.48				
Adjusted R-square = 0.33				

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

[3] The dominant form of easement in this region is voluntary restriction of development right in exchange for tax credits, as specified in the Michigan Farmland and Open Space Preservation Program (PA116). 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 would have little impact on land values.

[4] Stata code (V 6.0) 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.

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 (Michigan Department of Natural Resources and Environment, 2007). The recreational value of on-site natural amenities has been discerned in other farmland hedonic studies using measures such as recreational and woodland acres (Petrie and Taylor, 2007), scenic view composition (Bastian et al., 2002), and an amenity index constructed from climate, topography, and water conditions (Drescher et al., 2001).

There are also negative effects from on-site resources. For example, *on-site rivers* reduce land values by 8.8% per 100 m of river in the parcel. Although water resources provide recreational and scenic values as well as irrigation opportunities to land owners, their negative effects, such as field erosion along waterways, reduction of arable areas, and flood risk threatening crop production (Ma, 2010), may outweigh the benefits when present in the parcel. Similarly, the insignificant *on-site wetlands* variable may also indicate a balancing effect of amenities and disamenities. The recreational and aesthetic values of wetlands are likely to be offset by undesirable effects such as taking land away from crop production and the risks of soil erosion and flooding.

Some resources and landscapes in the parcel surrounding areas are also capitalized, reflecting landowner benefits from their surroundings. *Nearby rivers* increase land values by 5.8% per 1000 m 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 (Ma, 2010). Pyykkönen (2005) found similar results with a dummy variable for water bodies on the parcel boundary. He inferred that the irrigation possibility (or some recreational values) increased the land price by nearly 10% at the mean level. In our study, *wetlands* within a 1.5 km radius increase land value by 3.1% 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 United States Environmental Protection Agency (2009), more than half of all U.S. adults (98 million) hunt, fish, watch birds or photograph wildlife in wetlands. Wetlands also provide several regulating services that facilitate agricultural production, such as mitigation of flooding and soil erosion (Carter, 1996). In a similar hedonic study, Nivens et al. (2002) also found that the percentage of water bodies within 10-mile radius would raise farmland price due to recreational opportunities. *Off-site conservation land*, a combination of different natural landscapes, boosts land price by 1.6% per 1% increase in its proportion of the surrounding area. Although abundant ecosystem services can be provided from conservation land, its capitalization into 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 1.1% and 1.5% respectively. This is consistent with many other hedonic studies (Drescher et al., 2001; Elad et al., 1994; Gardner and Barrows, 1985; Nivens et al., 2002; Palmquist and Danielson, 1989; Shonkwiler and Reynolds, 1986; Xu et al., 1993) since these farmable areas are resources that farmers can rely on for farm income, and cropland yields relatively higher returns. A large proportion of farmable area is also likely to reduce the marginal cost of farming due to economies of scale. In addition, land with *well drained or poorly drained soil* has generally higher value than land with over drained soil. *Surrounding cultivated lands* and pasture raise land prices by 1.6% and 1.4% respectively per 1% increase in their proportion, presumably indicating suitability for agricultural production. As pointed out by Chicoine (1981), surrounding farmland could reduce negative externalities of conflicting non-agricultural land use and insure the compatibility of future land-use patterns. Nivens et al. (2002) found a similar positive effect from surrounding cropland and pasture, which they interpreted as an indicator of farmland productivity.

As we discussed in the conceptual model, some ES that cannot be directly used by landowners are capitalized little or not at all. Production-supporting regulating services that provide indirect use value regarding water, soil and local climate may be partially captured in the positive effects of water bodies, forest lands and conservation lands. 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.

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 although they may be aware of the increase deer population.

Third, even if landowners are able to identify some ES with indirect use values, their value may be too small to make a real change in land prices. Consider the example of natural pest enemies. 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. Similarly, ecological research has identified major differences in soil quality and productive potential due to microbial activities associated with crop management (Buckley and Schmidt, 2003). However, our model finds the variables measuring natural soil quality and erosion are not significant or lack the expected effect. It is likely that artificial practices for soil improvement (like fertilizer and intensive tillage) are perceived to make soil biotic properties less important.

In addition to ES variables, built production and consumption attributes also contribute to the land sale price. Consistent with other hedonic farmland value studies, the per-hectare price decreases with total parcel area, 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 7.9%, which may contribute to either production or consumption roles of land. The development effect is well captured by city dummies. The development pressure from proximity to *Grand Rapids* has the largest effect – 47% price increase – while nearness to *Lansing and Kalamazoo* also significantly raise farmland price. The magnitudes of development effects are largely influenced by the population in cities. 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% (Ma, 2010). 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).

5. Conclusion and Policy Implications

This study contributes to the existing literature in three ways. First, we introduce a new, integrated framework for the valuation of ecosystem services linked to agricultural lands according to property rights and type of economic value. As agricultural lands serve as a hub for a wide variety of ecosystem services generated from natural resources and landscapes, this framework informs thinking about the degree that private land transactions reflect social values of ES.

Second, we construct a three-component agricultural land valuation model, which reflects the production, consumption and asset roles of farmland, to reveal the value of ES from the indirect land market. The proxy measures of all ecosystem services from natural resources and landscapes on agricultural lands and surrounding areas are also juxtaposed with their real measures for hedonic valuation in Table 1. Compared to previous farmland hedonic studies, this study deepens understanding of ES value from natural resources and landscapes in surrounding areas.

Third, we apply the hedonic method to agricultural land market data from southwestern Michigan to estimate the value of ES from agricultural lands and their surroundings. The analysis permits inference of those ES that are likely to be capitalized, partially capitalized or not capitalized at all into land prices. Results suggest that ecosystem services are largely capitalized through lakes, rivers, wetlands, forests and conservation lands in southwestern Michigan. Based on our conceptual model, ecosystem services that support direct use values, such as recreational and aesthetic services, are likely to be perceived by land owners and thus realized in land prices. 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. Other ES from the land parcel and its surroundings are unlikely to be capitalized into land prices due to lack of incentive to pay for public goods, unawareness of certain ES, or small perceived value. The capitalization of ecosystem services from rural landscapes is a net effect that depends on the trade-off between different services. While the services and disservices from the same land use or resources are discussed in the paper, the trade-offs between different rural landscapes are beyond the scope of this study.

Based on our conceptual framework and empirical findings, rural landscapes generally produce multiple ES, from which individual land owners, local communities and the public may perceive different values. Same natural resources or landscapes may generate recreational, aesthetic and production-supporting ES for private land owners, but also benefit the general public with regional or global ES, such as wildlife habitat preservation and climate regulation. This study shows that land buyers are willing to pay for such private benefits from farmlands and their surroundings.

Environmental conservation programs often subsidize farmland owners to preserve natural resources and landscapes, such as woodlands, wetlands and grasslands, which support public ecosystem services. As argued by Pannell (2008), cost-effective policy mechanisms aim to encourage environmentally beneficial land-use change should depend on the relative levels of private benefits and public benefits. Results here show that private land owners may willingly provide public goods when jointly provided private benefits are large. For example, many agricultural land owners are willing to pay for some forested areas in their parcels. However, land owners would need a greater economic incentive to preserve wetlands in their parcel due to lower private benefits. Cost-effective public policies that target public goods like carbon sequestration or wildlife habitat should be tailored to landowner willingness to provide these services. Auctions that buy such ES from the lowest bidder, like those used by the U.S. Conservation Reserve and Conservation Security programs, can cost-effectively tailor expenditures to landowner willingness to provide such ES. The significant effects from surrounding natural resources and landscapes revealed in this paper also highlight the benefits that future conservation programs offer local communities via recreational and aesthetic services in addition to regulating services.

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