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Valuing deer hunting ecosystem services from farm landscapes

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ABSTRACT

Agricultural land provides a wide variety ecosystem services to individuals. These agroecosystem services include wildlife and biodiversity, which in turn support recreational opportunities such as hunting and wildlife viewing. Using the random utility travel cost model, we provide an estimate to illustrate the potential value of the white-tailed deer (*Odocoileus virginianus*) provisioning and recreational services provided by these ecosystems to deer hunters, as well as the value of providing deer hunters public access to a percentage of agricultural land.

1. Introduction

Agricultural ecosystems, or "agroecosystems", are perhaps the most important and pervasive type of managed ecosystem (Antle and Capalbo, 2002), and are located on the most productive land covering 30% of the earth's land area (Coleman and Hendrix, 1988). These ecosystems are managed intensively to provide humans with food for consumption, but also provide many other types of goods and services. These other services include direct production factors, such as net photosynthetic capacity, soil fertility, maintenance of water quality and quantity, and nutrient supply, as well as factors such as ecological carrying capacity and biotic regulation (Bjorkluand et al., 1999). Negative impacts from modern agriculture may include soil erosion, salinization, ground and surface water pollution, habitat destruction, and ecological and human health problems (Freemark, 1995).

Though the establishment of agriculture may alter wildlife habitats, agroecosystems can also provide biodiversity services through the provision of recreational opportunities such as hunting and the aesthetic enjoyment of the wildlife that utilize agricultural landscapes. Agroecosystems can provide multiple types of biodiversity and wildlife services to society, with individuals deriving both non-use and use values from the provision of these services. For example, some individuals may value the biodiversity and wildlife services provided by agroecosystems even though the individuals do not engage in any activity in which they encounter or use those services. That is, individuals derive utility from knowing that various types of flora and fauna live in or benefit from the agroecosystem environment. Some individuals may gain value from agroecosystem biodiversity and wildlife services through the direct use of these services. For example, an individual may enjoy viewing wildlife living on or supported by farms, and these values could be expressed through their choice of where to live or through their participation in various types of recreation. These use values might be consumptive (hunting) or non-consumptive (viewing). Managed forest and farm land can provide a mix of these values by providing opportunities for hunters to pursue large game (white-tailed deer, turkey) and small game (pheasant, hare), while also providing non-consumptive users of wildlife the opportunity to view and/or photograph animals. While the agroecosystem provides

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suitable habitat for various game and non-game animals, many animals endemic to the region have become scarce. For example, the demise of prairie avifauna has accelerated as intensive row cropping has emerged since the 1960's (Warner, 1994), with grassland birds declining in relative abundance by up to 85–90% (Robbins et al., 1986).

Just as individuals vary in their preference for and valuation of agroecosystem services, these ecosystems vary in the quality of non-use and recreational services provided to individuals. Farmland that is interspersed with non-agricultural vegetation or set-aside areas is likely to support greater wildlife population levels and biodiversity than farmland consisting primarily of vast, open fields. Remnant woodlands, riparian areas, and wetlands are particularly important components of farmland structure for maintaining wildlife diversity (Freemark, 1995). Bird species richness and abundance increases as field size decreases, as birds primarily utilize the edges of the fields as opposed to the center (Best, 1990). In the Midwest agricultural region, edges created by the interspersion of hardwood forest and agriculture provide excellent white-tailed deer habitat (Gladfelter, 1984). A study by Nixon et al. (1991) on an intensively farmed region of Illinois revealed that deer frequently move between forest patches on both a daily and seasonal basis.

A byproduct of the excellent deer habitat provided by agricultural land is crop damage due to deer browse. The damage is difficult to estimate accurately, partly because of potentially high measurement costs, and also because those experiencing property damage may lack incentives to report damages accurately. Nevertheless, 67% of farmers nationally have reported problems with deer (Conover, 1994), with a rough estimate placing damage to crops nationwide at $100 million annually (Conover, 1997).

Some of the wildlife values associated with various agroecosystem services, in particular the values associated with the production of game species, can potentially be captured by farmers. In the case of deer hunting, agriculture provides food and habitat that enhances populations and also can provide hunters with access (Côté et al., 2004). Certain regions provide farmers with superior opportunities to capture some of these values through the leasing of their land to deer hunters. In Texas, where 99% of land is privately owned and an active market for hunting leases has emerged, lease rates range between $100 and $2000 annually per gun, and depend on the quality of the hunting site, and the quality and type of game (Livengood, 1983). There is also evidence that the quality of hunting on agricultural land in Texas contributes to agricultural land values. Agricultural land values were examined in several counties in Texas and good hunting potential contributes approximately $180 per acre to land prices in these counties (Pope, 1985). Contingent valuation studies have been used to calculate hunter willingness to pay for leases in Kansas and Alabama. In a Kansas study on deer hunting leases, Goodwin et al. (1993) estimate the willingness to pay for private hunting land access to be $31.32 per year. Hussain et al. (2004) estimated the willingness to pay per hunter to be $1.29 per acre in a study on hunting leases in Alabama. These studies support the notion that access to hunting lands is valuable to hunters yet variable, and this access value is likely affected by the quality of the hunting experience associated with the access. Since wildlife move across private property boundaries, game populations supported by agriculture are a type of local public good, which creates a situation where neighboring landowners can free ride on the wildlife habitat and production services of other lands. This suggests that, even where robust lease markets exist, it may not be possible for farmers to fully capture the use values that were enhanced by food and habitat services from agricultural lands.

In this study, we provide illustrative estimates of some of the values of the ecosystem services provided to deer hunters through the deer productivity and hunter access functions of the agricultural land in Michigan's Southern Lower Peninsula. Our primary research objectives are twofold. First, we seek to estimate the potential hunter welfare benefits resulting from the relatively high deer population in the Southern Lower Peninsula. Second, we seek to estimate the value to hunters that would result from increasing public access for deer hunters in the Southern Lower Peninsula. Our study is one of the only ones to use a multiple site travel cost approach to estimate values from deer hunting.

Fig. 1 shows areas of Michigan and identifies the counties considered to be part of the Southern Lower Peninsula for the purposes of this study. The vast majority of the Southern Lower Peninsula of Michigan is considered to be a part of the Midwest Agricultural Region (Gladfelter, 1984). Cropland composes approximately 39% of the total land area in the Southern Lower Peninsula, compared with 21% of land in the Northern Lower Peninsula and about 2.5% of land in the Upper Peninsula (USDA, 2004). Crop lands provide nutritional sources via increased forage that can sustain deer densities above those supported by natural habitats (McShea et al., 1997; Coté et al., 2004), and the Midwest Agricultural Region has a high biological carrying capacity for deer due to a landscape mosaic of nutritious agricultural crops interspersed with forests that provide necessary cover (Gladfelter, 1984). Correspondingly, deer populations are generally higher in the Southern Lower Peninsula of Michigan, though much spatial variability exists and several counties in the Upper Peninsula have very high deer populations. In Illinois, the availability of row crops and small grains for forage within a deer's home range has been shown to have a positive effect on deer density (Roseberry and Woolf, 1998). Also according to Gladfelter (1984), the region's whitetails are in excellent condition, judged by body weight and rack structure/size, due to nutritious foods provided by the crops. These crops likely compose a significant percentage of total dietary intake. A study of deer in Iowa revealed that crops made up 78% by weight, 56% by volume, and 89% by occurrence of deer stomach samples analyzed (Mustard and Wright, 1964). The productivity of white-tailed deer is high in the Midwest Agricultural region as well, with 50% of fawn does and 95% of does breeding successfully (Gladfelter, 1984), and the relatively high fawn pregnancy rates can likely be attributable to the abundant nutritious food supply (Hesselton and Sauer, 1973; Harder, 1980). In Southwestern Lower Michigan, Burroughs et al. (2006) have found very high fawn survival rates and substantial use of agricultural lands by fawns, and conclude that abundant forage from agricultural crops is a contributing factor. Nevertheless, the exact contribution of alternative agricultural land management practices to deer population levels in Michigan counties has not been quantified in the literature.

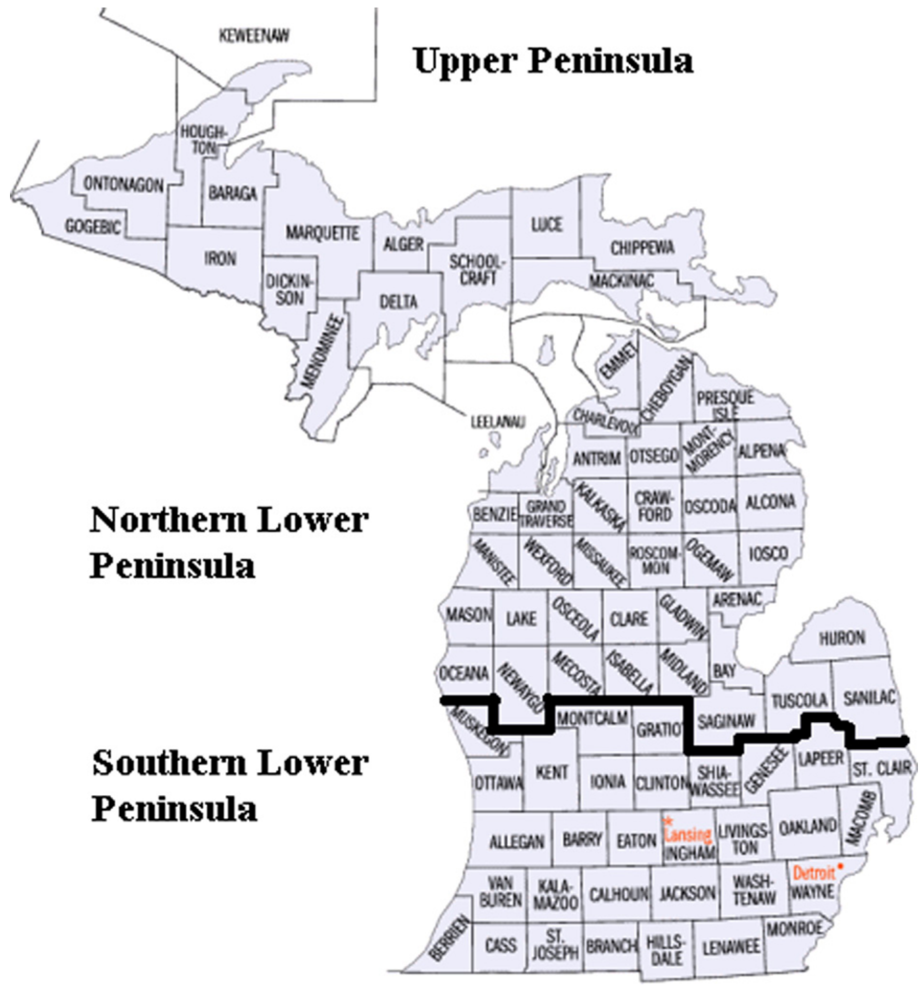

Fig. 1 – Southern Lower Peninsula counties in Michigan.

We conclude from the literature that it is likely that the agricultural ecosystem of the Southern Lower Peninsula is a primary factor in the region's relatively high deer population, although a complete link between agricultural landscapes and deer populations would require more extensive biological modeling and analysis. Our contribution to filling this knowledge gap is to illustrate the value of the ecosystem services provided to deer hunters in this region by estimating the hunter welfare effects resulting from a hypothetical and illustrative 50% decrease in the deer population.

Despite the high deer population, there is very little publicly accessible hunting land in the Southern Lower Peninsula, and it is likely that deer hunters would benefit from increased public access to this region's highly productive deer habitat. Farmers also have the opportunity to benefit financially through the provision of access by charging hunters for the right to hunt on their land. Calculating the benefits to deer hunters resulting from the provision of publicly accessible agricultural land in the Southern Lower Peninsula of Michigan will provide information to several groups. First, the welfare effects could be used by resource management agencies to cost-effectively lease private agricultural land from farmers. The State of Michigan currently leases agricultural land in the region through the Hunter Access Program (HAP) for an average of $5.55 per acre (Oliver, 2005), though this program has realized significant reduction in the number of acres enrolled in recent years and now enrolls less than 20,000 acres, 8% of its peak enrollment (Oliver, 2005). The reduction in the number of acres enrolled is likely due to reduced per-acre payments (in real terms) combined with perceived liability risks to farmers who provide access (Oliver, 2005). Additionally, the welfare effects for providing hunter access could also provide information to farmers regarding the amount that hunters would pay, per-acre, to have access to their land. We will be examining the benefits to hunters resulting from the additional access due to a hypothetical opening of 10% of agricultural land in the Southern Lower Peninsula as publicly accessible hunting land.

2. Methods

In this paper we use the travel cost method (Parsons, 2003) to estimate demand for deer hunting sites, and we adopt the most common multiple site travel cost approach, the Random Utility Model (RUM). The difference between the RUM and the original single-site travel cost model is that in the RUM, the subject of interest is site choice, as opposed to the quantity of trips taken to a single site. With the RUM, when an individual makes the choice of a site to visit on a trip, the individual is assumed to consider both the characteristics of the site, as well as the "price" of the trip, which is the travel cost. The amount of utility derived from a particular site is defined as *site utility*, and can be expressed mathematically as:

$$V_i = \beta_{tc} tc_i + \beta_q q_i + e_i \qquad (1)$$

where tc_i is the cost of reaching site i, q_i is a vector of site characteristics, e_i is a random error term, and the β's are parameters (Parsons, 2003). Since the site utility function $V(\cdot)$ gives the indirect utility conditional upon a visit to the site, it is often referred to as conditional indirect utility. The parameters are the marginal utilities of the site characteristics and can be thought of as the weight attached to the different site characteristics and the trip cost. The more a site characteristic is valued, the greater the parameter will be for that particular characteristic. For example, since travel costs are expenses that could be used for other items that yield utility, the β attached to "trip cost" is expected to be negative and its absolute value serves as a measure of the marginal utility of income. It is also hypothesized that site utility increases with desirable characteristics, such as deer density or public access.

In RUM theory, an individual chooses the site that offers that individual the highest indirect utility. With this assumption, site k would be chosen over another site i when:

$$\beta_{tc} tc_k + \beta_q q_k + \varepsilon_k \geq \beta_{tc} tc_i + \beta_q q_i + \varepsilon_i \quad \text{for all } i \in C \qquad (2)$$

where C is the set of possible sites in a person's choice set. Recognizing that the expressions in Eq. (2) contain random terms, one can formulate an expected demand function for a site based on the probability that expression (2) holds. Upon selecting a distribution of the error terms, the probabilities can then be used to estimate the model parameters.

The model utilized in this Random Utility Travel Cost application is a multinomial logit, sometimes referred to as the Conditional Logit model. Developed by McFadden (1974), this model gives the probability that an individual i chooses site alternative j as a function of attributes that vary by site. The site attributes for this model are the same across individuals, except for the travel cost variable. The equation below gives the probability that individual i selects site j:

$$\Pr_i(j) = \frac{e^{\beta x_{ij}}}{\sum_{k=1}^{J} e^{\beta x_{ik}}}. \qquad (3)$$

The RUM approach can be used to estimate the changes in hunter welfare measures resulting from site quality changes. To do so, one compares the expected maximum indirect utility across sites with and without the change and computes the amount that could be taken from income to equate the two. In the conditional logit, this expression has a closed form solution and is given by

$$\hat{S}_{trip,n} = \frac{\ln\left[\sum_{i=1}^{J} \exp\{\hat{\beta}_{tc} tc_{in} + \hat{\beta}_q q_i'\}\right] - \ln\left[\sum_{i=1}^{J} \exp\{\hat{\beta}_{tc} tc_{in} + \hat{\beta}_q q_i\}\right]}{-\hat{\beta}_{tc}} \qquad (4)$$

where q' is a vector indicating quality changes at some or all of the J sites, a ^ denotes an estimated value using estimated parameter results, the subscript n denotes the value of that variable for individual n and the subscript "trip" refers to the fact that this welfare measure is conditional upon a trip. This measure is commonly referred to as the change in inclusive value indexes; the numerator represents the change in the expected maximum indirect utility, and the denominator converts the expression to monetary units using the estimated marginal utility of income. The measure represents the consumer surplus for the change in q, conditional on a trip being taken (Parsons, 2003).

The model as described captures substitution across sites, but the total number of hunters and the total number of trips per hunter are held constant. Although this type of "conditional on a trip" model of site choice constrains some dimensions of substitution, the site choice level of substitution is considered to be the most important since recreational demand studies that model a broad array of site choices have found that the elasticity of demand at the participation levels are much smaller than at the site choice levels (Kotchen et al., 2006; Parsons et al., 1999).

The aggregate seasonal value can be estimated by multiplying total trips by the average conditional on a trip welfare measure. The equation utilized is

$$S = T^* \bar{S}_{trip} \qquad (5)$$

where $\bar{S}_{trip}$ is the sample mean obtained from Eq. (4), and T is the total number of trips in the season.

3. Data

The data used in this research was obtained from the 2003 Michigan Deer Hunter Survey, which was distributed via mail to 3000 Michigan residents who purchased a deer hunting license in 2002. In order to obtain a satisfactory number of replies from hunters in under-represented regions in Michigan, the survey was designed as a stratified random sample. Upper Peninsula, Northern Lower Peninsula, and Southern Lower Peninsula residents were each sent 1000 surveys. The model estimations and welfare measurements in this paper weight the three strata accordingly so that results are representative of all hunters in Michigan. The sample population for survey administration was drawn randomly from hunters who had, at some point in 2002, obtained a license to hunt white-tailed deer in Michigan. These hunters were asked various attitudinal, behavioral, hypothetical, and demographic questions. Of the 3000 questionnaires sent in the initial mailing, 925 were not returned and an additional 119 were non-deliverable. There were 1955 questionnaires returned out of 2881 valid addresses, yielding a response rate of 67.9%.

The survey asked hunters to list the number of trips and location of two deer hunting sites, defined at the county level. The survey booklets included a detailed map of Michigan with major roads, cities and county boundaries to make it easy for hunters to identify the county a trip was taken to. The trip questions were set up so as to elicit the location and number of trips to their most frequented site within a 50 mile radius of the hunter's residence, as well as the number of trips taken to their most frequented site outside a 50 mile radius of the hunter's residence. These questions asked for trips to be delineated according to whether they occurred in the firearm deer season or the archery deer season (the two seasons do not overlap). Separate site choice models were estimated for each of these seasons. Because some hunters do not hunt in both seasons, the firearm model contains 1416 hunters and the archery model contains 685 hunters.

To specify the model, sites will be identified at the county level. The variables listed in Table 1 were hypothesized to influence a hunter's decision on hunting site location. "Price", which is the travel cost for each hunter, was computed as the roundtrip time and driving costs from each hunter's residence to the 83 different counties. The distance was obtained by calculating the distance from each hunter's residence to the zip code that is closest to the geographic center of each county. Because of the number of observations for this variable (there were 1640 unique zip code origins and 1640*83 = 136,120 data points), these calculations were done utilizing the PC Miler software package. The driving cost is the cost of operating a vehicle, which is calculated as the per-mile operating cost multiplied by the distance. For the per-mile operating costs we used data from the American Automobile Association based on a 2002 Chevrolet Cavalier. According to the American Automobile Association (AAA, 2002), the 2002 per-mile operating costs were 5.2 cents for gas and oil, 3.9 cents for maintenance, 1.5 cents for tires, and 20.4 cents for vehicle depreciation. Thus, the total operating costs was estimated to be 31 cents per mile. The insurance costs were not included in this computation.

The other component of travel costs was time spent traveling to the site, which is time that could have been devoted to other endeavors. These lost opportunities are referred to as the opportunity costs of the travel time. Generally, the income of the individual is used to calculate an individual's opportunity cost of taking the trip. Though an ongoing and active area of research, the recreation literature has generally accepted 1/3 as a lower bound and the full wage as an upper bound on the hourly value of time spent driving (Parsons, 2003). We will use the 1/3 rate. The wage imputation follows the literature by dividing annual income by 2080 h of work time (52 weeks at 40 h per week). The survey utilized for this research did not ask individuals to list their exact income, but rather provided 6 income range options that could be selected. The choices were: 0–$20K, $20K–$40K, $40K–$60K, $60K–$80K, $80K–$100K, and over $100K. To convert the ranges to a continuous variable, we used the midpoint of the range for the first five categories. Individuals indicating an income of over $100K were assigned an income of $150K. To convert distance into travel time, we also follow the convention of using an average speed of 40 miles per hour (Parsons, 2003). The final computation of travel costs is then found by multiplying distance by the per-mile operating costs and adding travel time multiplied by one-third the wage rate.

Data on the deer population per deer management unit was obtained from the Michigan Department of Natural Resources (MDNR). In the Lower Peninsula of Michigan, each county is a deer management unit, except in a select few areas with special management concerns. However, because this is not the case in the Upper Peninsula, some interpolation was necessary in order to map the population of deer in each management unit to the counties. The deer population variable was included in the model because site selection by deer hunters is hypothesized to be influenced by the number of deer in that particular location. The public access variable was calculated by aggregating acres of land publicly accessible to hunters in the form of State Forest land, National Forest land, State Parks and Recreation Areas, and Commercial Forest Act land per county. This variable is included in the model because having more area with public access is expected to increase the number of trips to the county, all else equal. The population per county and the geographic size of each county were both obtained from the U.S. Census Bureau. The human population was included as a proxy for the urbanization of a county, which was hypothesized to have an inverse relationship with the probability of a trip to a site. The inclusion of a measure for county size is important when using aggregate sites (Lupi and Feather, 1998). Regional dummy variables for the Upper Peninsula and Northern Lower Peninsula control for region-specific site characteristics not explained by variables applied in this model.

Table 1 – Description of variables entering the random utility travel cost models

	Variable description
Price	Travel cost from individuals home to each county (see paragraphs below)
Deer	Deer population per county in units of 10,000 deer
Access	Publicly accessible deer hunting land per county in units of 100,000 acres
People	Population of people living in the county in units of 100,000 people
Size	The total size of the county in 1,000 square miles
UP	Dummy variable for Upper Peninsula county (Southern Lower Peninsula is the baseline)
NLP	Dummy variable for Northern Lower Peninsula county (Southern Lower Peninsula is the baseline)

4. Results

Table 2 presents the estimated parameters and *P*-values for the two deer-hunting models, firearm season and archery season. Almost all coefficients are significant at the 1% level for both models. The signs for the coefficients make intuitive sense, with the probability of a deer hunting trip to a county increasing with "desirable" site attributes such as number of deer and acres of public access. Similarly, the probability of a trip to a site was expected to decrease with increased trip cost and higher human population levels, and does so.

Table 3 shows the marginal implicit prices of the *deer* and *access* variables. The marginal implicit prices are computed as the ratio of the parameter estimate for a variable to the absolute value of the travel cost parameter. The marginal implicit prices facilitate comparisons across models because they are independent of any underlying, unidentified, differences in variance across models. The marginal implicit prices are also the marginal value per trip of a unit change in the characteristic at all sites (Hanemann, 1983). Table 3 shows that

Table 2 – Conditional logit results for firearm and archery models

	Firearm model		Archery model	
	Coefficient	P-value	Coefficient	P-value
Price	−0.033	<0.001	−0.039	<0.001
Deer	0.130	<0.001	0.068	<0.001
Access	0.056	<0.001	0.072	<0.001
People	−0.102	<0.001	−0.063	<0.001
Size	−0.449	<0.001	−0.284	<0.014
UP	2.329	<0.001	1.664	<0.001
NLP	0.490	<0.001	0.492	<0.001
	Log L=−27,073.10		Log L=−26,045.91	
	Psuedo R^2=0.347		Psuedo R^2=0.405	
	N=1416		N=685	

a population increase of 10,000 deer in each county provides firearm hunters who make hunting trips with a welfare increase worth $3.94 per trip, with archery hunters realizing a comparable welfare increase of $1.75 per trip. The welfare differences between the two models reveal that firearm hunters place a higher value on deer population as a site attribute relative to archery hunters. Such disparity between models does not exist with the *access* variable. Firearm hunters would realize a welfare increase of $1.70 per trip should the amount of publicly accessible deer hunting lands increase by 100,000 acres in each county, while archery hunters would benefit slightly more given such an increase, realizing a welfare increase of $1.87 per trip.

As an example of how some of the ecosystem services from agricultural lands might be connected to recreation values, we explore policies that illustrate the per-trip benefit and the aggregate seasonal welfare resulting from making publicly accessible for deer hunters 10% of the agricultural land in the Southern Lower Peninsula, as well as the same hunter welfare calculations resulting from a 50% decrease in the deer population in this region. These figures used in the policy analysis are for illustrative purposes only, and are not rigorously derived estimates regarding the feasibility of opening large tracts of private land to public deer hunting or the contribution agricultural land makes to the size of the deer herd. Establishing such linkages would constitute an important and substantial research task.

To derive the seasonal benefits to hunters for the two policy examples, we multiply the estimated per-trip benefit for firearm hunters by 5.6, which is the average number of trips taken by firearm hunters in a season, to obtain a seasonal value per hunter. This seasonal value is then multiplied by the total number of Michigan resident firearm hunters, 684,000 (Frawley, 2003), to obtain the seasonal aggregate welfare measure for the site quality change. The same process is used to calculate the benefits measure for the archery model, multiplying the estimated per-trip benefit by 6.7, which is the average number of archery trips, and by 317,000, which is the number of resident archery hunters in Michigan (Frawley, 2003).

Table 3 – Marginal implicit prices for a change in characteristic

	Firearm	Archery
Deer (10,000 deer)	$3.94	$1.75
Access (100,000 acres)	$1.70	$1.87

Table 4 – Per-trip benefits and aggregate seasonal welfare of public access to 10% of agricultural land in the Southern Lower Peninsula, Michigan

		Per-trip benefit	Seasonal aggregate welfare
Opening 10% of SLP agricultural land as public access for deer hunters	Firearm	$1.91	$8,754,000
	Archery	$2.23	$10,250,000
		Total welfare= $19,004,000	

Our model estimations show that Michigan resident deer hunters pursuing deer with a firearm would realize a per-trip benefit of $1.91, and those pursuing deer with a bow realize a $2.23 per-trip benefit resulting from the opening of 10% of the agricultural land in Southern Lower Michigan to deer hunters (Table 4). Opening 10% of this private agricultural land to deer hunters in this region would result in approximately 480,000 additional acres available for hunting (USDA, 2004). Thus, the seasonal willingness to pay for hunter access to this agricultural land, per acre, is about $39, which is computed by dividing the total benefits by the 480,000 additional acres. Individually, the seasonal willingness to pay per hunter for access to these 480,000 acres is about $25, which is computed by dividing the total benefits by 740,529, the total number of Michigan hunters participating in one or both of the seasons (Frawley, 2003).

As a proxy for the positive effect that agroecosystems have on the number of deer that can be sustained in an area, we consider the value of a 50% reduction in deer numbers in the counties of the Southern Lower Peninsula, since this is the region of Michigan containing the greatest share of agricultural areas. Our estimations show that a 50% reduction in the deer population in the Southern Lower Peninsula of Michigan would result in a welfare loss of about $10 million for firearm hunters and about $4.6 million for archery hunters (Table 5). The aggregate welfare loss for this level of deer reduction is approximately $14.7 million per year. Firearm hunters appear to place a high value on deer population as a site quality attribute, as they experience about twice the per-trip benefit loss of archery hunters.

Table 5 – Per-trip benefits and aggregate seasonal welfare from a 50% reduction in the deer population in the Southern Lower Peninsula, Michigan

		Per-trip benefit	Seasonal aggregate welfare
50% reduction in deer population in SLP, a major agricultural area	Firearm	−$2.20	−$10,083,000
	Archery	−$1.01	−$4,642,000
		Total welfare= −$14,725,000	

5. Discussion

While the literature contains many applications of the travel cost method to value recreation, very few studies use multiple site travel cost methods to value changes in the quality of deer hunting sites (Schwabe et al. (2001) is a notable exception). This is a surprising gap given the prominence of deer hunting in the U.S. Hence, our findings contribute to the applied valuation literature in general, and to the literature on deer hunting specifically. Moreover, the results and policy simulations shed light on some of the recreational use values of the wildlife-related ecosystem services provided by agriculture.

Though our estimates are informative, a complete assessment of the recreational service values that deer hunters derive from agricultural lands would require knowledge of the ecological production function that would relate various agricultural practices to the population of deer. This linkage could then be utilized to fully connect the deer hunting demand models presented here with the recreational services that hunters derive from alternative agricultural practices, including the presence of agriculture compared to other land uses. Lacking an explicit estimate of agriculture's contribution to deer hunting, we develop some hypothetical examples to illustrate the potential magnitude of the value of deer hunting services that agroecosystems may provide to deer hunters in Michigan.

In our first example, the provision of access through a hypothetical opening for public deer hunting access of 10% of the agricultural lands in the major agricultural region of Michigan was estimated to provide extensive benefits to hunters. The estimated aggregate seasonal willingness to pay per acre for this increased access was about $39, which is much higher than the average of $5.55 paid per acre to farmers who enroll in Michigan's Hunter Access Program, a program that has enrolled a declining number of acres for the past 25 years (Oliver, 2005). The total per-acre market value of agricultural products sold for the Southern Lower Peninsula was $443.07 (USDA, 2004). If the full benefits to hunters could be captured by farmers, the results suggest that the farmers may be able to increase their revenue per acre by as much as 7% by providing deer hunters access to their land during the deer hunting season. It is important to remember that this per-acre value is the value of an acre that is publicly accessible. Individual hunters may be willing to pay more for their own private area to hunt, but that would preclude access benefits to other hunters. Some farmers already capture some of the value of private access to agricultural land via private hunting leases, but data on the value and terms of such leases in Michigan is not systematically available.

The landscape mosaic of the Southern Lower Peninsula, and its abundant agricultural lands, provide deer herds with excellent habitat, cover, and nutritious foods. It is likely that the agroecosystem, the most prevalent ecosystem in this region, contributes substantially to the large deer population. While we do not have a spatially explicit empirically derived estimate of agriculture's contribution to the size of the deer population, we illustrate the potential values with a second example. We found that if the agriculture in this region supports a deer herd that is twice as large as there would be otherwise, then the nearly $15 million reduction in hunter welfare for the 50% reduction in the region's deer population illustrates the potential value of deer production services of the agroecosystem.

The study is not without its caveats. First, we do not know how many deer are supported by agroecosystems, and we have not uncovered any literature upon which to base a credible estimate to quantify the link between deer population and agricultural land. As such, our policy examples must be taken as illustrative of some of the non-market values associated with these lands. Second, we are using measures of publicly accessible land, lands that are largely non-agricultural, to infer what the value of additional public access to agricultural lands would be worth. However, it is possible that hunting on these lands is not valued the same by hunters. Third, because our model uses aggregate areas as sites (counties), it is possible that there may be errors introduced through the aggregation process. Fortunately, the policies examined here affect broad areas rather than individual sites within aggregate groups, so they are less likely to compound any aggregation errors (Lupi and Feather, 1998). Finally, another caveat of the modeling has to do with the trip data. We collected up to two sites for each hunter so our model is not based on complete trip information. While few RUM approaches have complete trip data, this may omit some important variation in trip patterns and it may depress actual trip numbers. In our case, 87% of all hunters surveyed indicated they hunted deer in two counties or fewer, and less than 1% hunted deer in more than four counties. Nonetheless, we may be underestimating total number of trips.

There are numerous marketed and non-market services associated with agriculture. While marketed services such as the food production capacity of agriculture are most often considered when examining outputs related to agriculture, non-market agricultural services such as biodiversity, cultural heritage associated with farming, and recreational opportunities such as hunting are important services as well. Accurate estimation of agroecosystem services requires a complex set of information. A biological model is needed to estimate the changes in ecosystem services as a result of changes in agriculture production, and an economic model is needed to estimate how changes in ecosystem services change the monetary value of ecosystem services. In this paper we make assumptions about the relationship between agricultural production and ecosystem services in order to illustrate the potential welfare impacts to deer hunters resulting from changes in agricultural policies or practices. Clearly, estimating the specific impacts of agroecosystems to all non-market services constitutes a large and complex research agenda. In this paper we have contributed to the task by showing how one part of the non-market values of agroecosystem services could be valued using a recreation demand model.

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