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A socio-economic-ecological simulation model of land acquisition to expand a national wildlife refuge

Amanda A. McDonald, Jianguo Liu *, Harold Prince, Kiersten Kress

Department of Fisheries and Wildlife, Michigan State University, 13 Natural Resources Building, East Lansing, MI 48824, USA

Abstract

Land acquisition is a common practice for establishing and expanding protected areas such as wildlife refuges. However, the socioeconomic feasibility and ecological consequences of an acquisition project are rarely assessed before the project is executed. In this paper, a socio-economic-ecological model (SEELAND) was developed to simulate the socioeconomic feasibility and ecological consequences of a land acquisition project, using the Shiawassee National Wildlife Refuge in Michigan (USA) as a case study. The refuge is managed by the US Fish and Wildlife Service (USFWS) primarily for waterfowl. An adjacent area of 3035 ha has been proposed to add to the current refuge of 3680 ha. The vast majority of the proposed acquisition area is privately owned. SEELAND consists of three main components: sociological (e.g. landowners' attitudes toward selling their land), economic (e.g. fair market value and incentives), and ecological (e.g. land-cover types, soil types, parcel sizes and locations). Simulation results indicated that most of the high-priority land was not available for purchase and the priority set by the USFWS could not be achieved. Many purchased land parcels were not connected to each other or to the existing refuge, resulting in small isolated patches, which are not good for habitat connectivity and refuge management. Furthermore, landowners' attitudes towards selling their land significantly affected the amounts and types of land purchased. Without using incentives, less than half of the proposed acquisition area would be purchasable within the next 20 years.

Keywords: Land acquisition; Simulation; Wildlife refuge; SEELAND; Modeling; Socioeconomic feasibility; Ecological consequences

1. Introduction

More than 12 700 protected areas (e.g. parks and wildlife refuges) have been established around the world, accounting for 13.2 million km^2 (greater than the US) or 8.8% of the Earth's land surface (World Conservation Monitoring Centre and IUCN Commission on National Parks and Protected Areas, 1998; Liu et al. 2001). In the US, there is a long history of conserving wildlife in protected areas (Dompka, 1996). The first national park, Yellowstone National Park, was created in 1872 (Yellowstone National Park, 1998). Since then, many parks and wildlife refuges have been established by federal, state, and local governments. The National Wildlife Refuge System in the US includes more than 500 wildlife refuges (United States Fish and Wildlife Service, 2000).

* Corresponding author. Tel.: + 1-517-3551810; fax: + 1-517-4321699.

E-mail address: jliu@panda.msu.edu (J. Liu).

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The size of protected areas is a very important factor in conservation (Noss, 1996). Although issues regarding the size of protected areas have been widely debated, many people believe larger protected areas are necessary to effectively conserve habitat and species diversity (Noss, 1983; Grumbine, 1990) because larger protected areas contain more wildlife habitat (Saunders et al., 1991) and generally buffer the core area from human disturbances more than smaller ones (DellaSala et al., 1996). As a result, many existing protected areas have increased or are proposing to increase their land holdings (United States Fish and Wildlife Service, 1996). For instance, Yellowstone National Park was expanded twice to increase the amount of wintering habitat for elk (Yellowstone Archives, 1943).

To expand protected areas in the US, purchasing adjacent private land has become a common approach (Ramsey and Addison, 1996; Wright and Tanimoto, 1998) since 80% of the land in the US is privately owned (McGhie, 1996). Land acquisition is a common technique used both by private and public conservation organizations to create and expand protected areas such as wildlife refuges, which attempt to counter habitat degradation and destruction (Reinecke et al., 1989; Terbough and van Schaik, 1997; Liu et al., 1999). Although some private landowners may donate their property in order to reduce property taxes or achieve the goal of conservation because of their environmental awareness, in most cases, land additions to protected areas are achieved through purchase from private landowners. The Nature Conservancy, United States Fish and Wildlife Service (USFWS), and state organizations such as the Michigan Department of Natural Resources have all used land acquisition to establish and expand protected areas for wildlife (Michigan Department of Natural Resources (Wildlife Division), 1990; Press et al., 1996; United States Fish and Wildlife Service, 1996).

Land acquisition from private landowners may be constrained by three main factors: ecological attributes (e.g. the suitability of land), sociological attributes (e.g. landowner's willingness to sell the land), and economic attributes (e.g. money needed to purchase the land). Ecological attributes determine how useful the land additions would be to achieve ecological objectives. A landowner may or may not be willing to sell his/her parcels of land at fair market value. When a landowner is not willing to sell his/her land parcels, incentives may be needed to stimulate the landowner's willingness to sell. A major source of revenue, which federal parks and refuges use to purchase lands is the Land and Water Conservation Fund Act of 1965, introduced in 1963 by President J.F. Kennedy. The act also provides federal assistance to states in their own planning and acquiring of lands (Fish and Wildlife Service LWC, 1998).

Since the issues related to land acquisition are very complex, computer-based models have become a good tool. For example, Wright and Tanimoto (1998) used a geographical information system (GIS) to prioritize land conservation actions in the North Cascades National Park Complex in the Stehekin River Valley of the State of Washington. Their objective was to measure and rank the ecological importance of specific land parcels. Although it is necessary to assess the feasibility and consequences of an acquisition project before money and time are invested into purchasing land parcels, no computer-based models have been developed to specifically explore the socioeconomic feasibility and ecological consequences of land additions to wildlife refuges.

The goal of this study was to develop a spatial simulation model that can be used for evaluating the socioeconomic feasibility and ecological consequences of a land acquisition project. The model (SEELAND) integrates Socio-Economic-Ecological attributes of private LAND. As a case study, we have chosen a land acquisition project that is currently underway. In this paper, we introduce model structure, as well as methods for modeling, simulation and result analyses. We also present results under different scenarios.

2. Methods

2.1. Study area

Our study area was Shiawassee National Wildlife Refuge (hereafter refuge, Fig. 1) in Saginaw County, Michigan. The refuge was initially authorized in 1953 as a migratory bird sanctuary and flood containment unit. It consists mostly of managed wetlands located at the juncture of four rivers: the Shiawassee; the Titabawassee; the Cass; and the Flint (Fig. 1). Presently, the goals of the refuge include providing a migratory staging area for waterfowl, maintaining biodiversity, and containing floods (United States Fish and Wildlife Service, 1996).

The refuge currently consists of 3680 ha and is managed by the USFWS. The USFWS is interested in purchasing land to expand the refuge (United States Fish and Wildlife Service, 1996). The area of interest for the acquisition has been bounded and consists of 3035 ha extending outwards on three of the four major rivers: the Shiawassee; the Titabawassee; and the Cass Rivers (Fig. 2). Each parcel of land in the proposed acquisition area has been classified as high priority, medium priority, or low priority based on its evaluated habitat potential for both upland and wetland species (United States Fish and Wildlife Service, 1996). Most of the proposed acquisition area is owned by adjacent farmers. The landowners are being selectively contacted for the land acquisition project. Acquisition of lands for the refuge would be on a willing-seller basis (United States Fish and Wildlife Service, 1996). Landowners choosing not to sell would retain all the rights, privileges, and obligations of land ownership.

2.2. General structure of SEELAND

The general structure of SEELAND is shown in Fig. 3 and contains three major components: ecological; sociological; and economic. The inputs to SEELAND include the specific objectives of the user and parameterization of the three components. Outputs from this model are attributes of

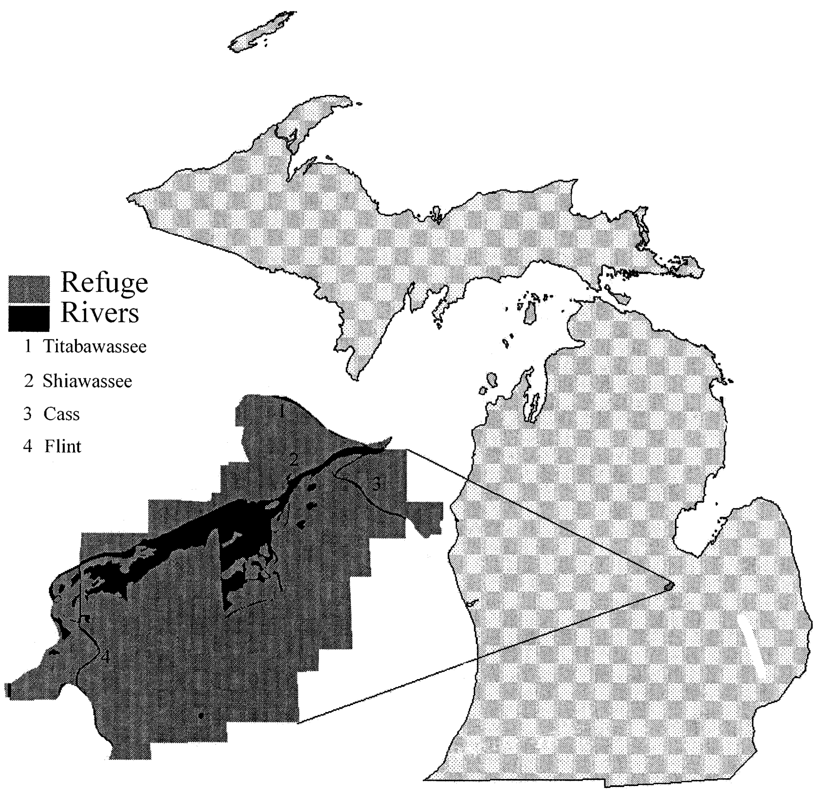

Fig. 1. Location of Shiawassee National Wildlife Refuge in Michigan.

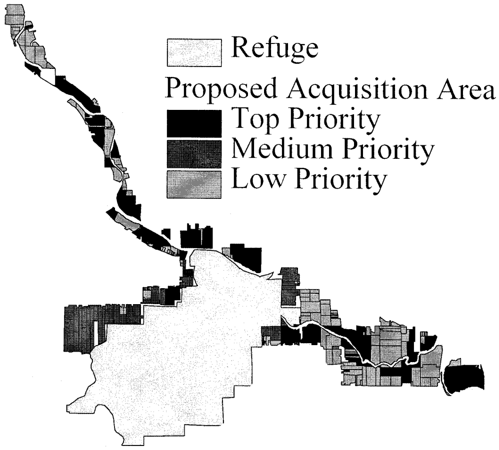

Fig. 2. Map of Shiawassee National Wildlife Refuge and the proposed acquisition area defined by land parcels (from United States Fish and Wildlife Service, 1996). The proposed acquisition area was classified into high-priority (1089 ha), medium priority (613 ha), and low priority (1332 ha) based on habitat potential.

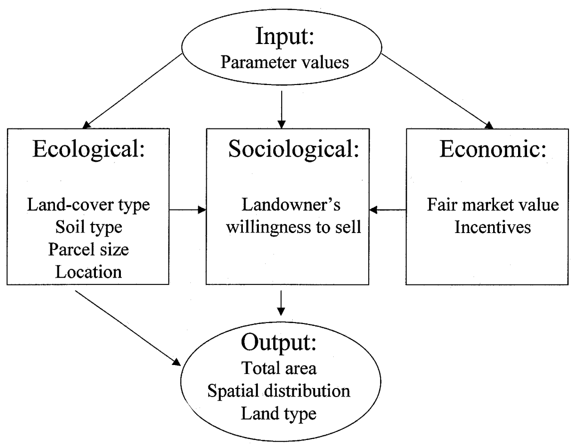

Fig. 3. General structure of SEELAND.

the land parcels purchased and non-purchased (e.g. types, numbers, sizes, spatial distribution).

2.3. Ecological component

The ecological component of SEELAND contains information such as size, location, soil type, and land-cover type of each land parcel. The size and location information was acquired from the USFWS. The soil information was derived from a digital soil map of Saginaw County (Soil Survey Geographic Database) acquired from the United States Department of Agriculture (USDA). Soil was divided into two major types, hydric soil and nonhydric soil. The hydric/nonhydric designation separates potential wetland habitats from upland habitats. Hydric soil areas represent places that were historically wet and could be restored into wetlands through hydrological reversion. Hydric soils are key indicators of wetland habitats since they are 'formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part' (Soil Survey Staff, 1999).

The land-cover data were digitized from the 1997 aerial photos (in slide format) acquired from the USDA Farm Service Agency in Saginaw County and corrected against a digital 1978 land-cover map of Saginaw County created at the Center for Remote Sensing and Geographic Information Systems, Michigan State University. Since the area had not changed overly much, the 1978 land-cover map was used to help determine classifications that were difficult to ascertain from a visual inspection of aerial photos. The older map also aided in the determination of wetland habitats. However, forested wetlands were still difficult to identify so they were classified as forested lands. Driving through the area, we also compared the map layer with what was actually present on-site to prevent errors such as classifying a housing development as forested because of the neighboring woody vegetation. The final map had five land-cover types (Table 1): developed/urban lands, agricultural lands, grasslands, forested lands, and non-forested wetlands.

The final land-cover map was combined with the hydric soil map to create a new map layer that divided each land-cover type into hydric and nonhydric sub-units. Two of the land-cover types (developed lands and non-forested wetlands) did not have the split sub-units. The developed lands were consistently nonhydric. Wetlands had hydric soils and, therefore, lacked a nonhydric counterpart. The combined layer allowed us to determine how much of each land-cover type is wet or potentially wet. The proposed acquisition area includes 284 ha developed lands, 1287 ha nonhydric agricultural lands, 546 ha hydric agricultural lands, 144 ha nonhydric grasslands, 36 ha hydric grasslands, 590 ha nonhydric forested lands, 65 ha hydric forested areas, and 83 ha non-forested wetlands. Adding hydric areas together yields 647 ha of existing and potential wetlands.

2.4. Sociological component

The sociological component of SEELAND includes attitudes of landowners towards selling their land. Since the USFWS cannot 'take' the land or force the owners to sell their land, land acquisition has to depend on willing sellers. Thus, it is essential to know how many land owners are willing to sell their land to the refuge at a fair market value, how many are willing to sell their land with some incentives (e.g. fair market value plus additional amount of cash), and how many landowners are not willing to sell their land no matter what amount of money is offered to them. In other words, among the interested parcels of land, it is necessary to know how many land parcels are absolutely for sale, how many parcels are possibly for sale, and how many parcels are not for sale.

Table 1
Types of land cover adjacent to the Shiawassee National Wildlife Refuge

Type of land cover	Definition
Developed/urban lands	Lands that have been built upon by humans (houses, factories, parking lots, etc.)
Agricultural lands	Lands have been farmed with obvious disturbance to the natural vegetation and topsoil (tractoring and plowing).
Grasslands	Lands that are non-wet, non-forested, and non-farmed, and have no tall woody vegetation
Forested lands	Lands that contain clumped trees with a dense canopy.
Non-forested wetlands	Lands that are seasonally or permanently inundated, but have no tall woody vegetation. This category contains both emergent marshes and deep-water systems

To assess landowners' attitudes towards selling their land to the refuge within the next 20 years (McDonald et al., in preparation), we conducted a mail survey of landowners within the proposed acquisition boundary. A mailing list of the 198 private owners of potential acquisition lands was obtained from the USFWS. From the 104 responses (a response rate of 52.5%), we found that 49.5% of the respondents said that they would be willing to sell their land to the USFWS (38.9% of the respondents replied that they would be willing to sell their land at appraised value, while the remaining willing sellers demanded a price higher than appraised value). A 37.9% of the respondents replied that they would definitely not sell their land to the refuge. Undecided landowners accounted for 12.6%. Furthermore, a higher percentage (56.5%) of responding landowners with parcels that included wetlands were willing to sell their land parcels than landowners without wetland parcels (33.8%), probably because the government has more strict regulations regarding wetland use (e.g. development) that encourage landowners to sell.

2.5. Economic component

Willing sellers would be compensated for their lands at the appraised fair market value. The proposed acquisition project has been approved by the USFWS and the funds would come from the appropriation of the US Congress. To make SEELAND simpler, we assumed that a sufficient amount of money would be available for purchasing lands from willing sellers.

Since some landowners were undecided or explicitly stated that they would need a price higher than fair market value, they could be persuaded to sell their land given sufficient incentives. The incentives could be extra cash above the fair market value. To simplify the model, SEELAND did not specify the amount of extra cash or types of incentives. Instead, it used the proportion of undecided landowners to define incentive levels. Higher incentive levels would encourage a higher proportion of undecided landowners to sell their land and thus would result in higher amounts of land purchased.

2.6. Acquisition scenarios

2.6.1. Baseline simulation

The baseline simulation used the landowner attitude survey results as input to the sociological component. The attitudes of respondents were assumed to represent those of non-respondents. Furthermore, land acquisition was conducted at fair market value and no economic incentive was provided.

2.6.2. Effects of non-respondent probabilities of sale

A 47.5% of the landowners did not respond to the mail survey. It was not clear whether non-respondents had the same patterns of willingness to sell their land as the respondents, although in the baseline simulation we assumed that the respondents were representative of the non-respondents in terms of probabilities of sale. In order to assess the effects of different non-respondent probabilities of sale on land acquisition, we developed two other scenarios and compared them with the baseline simulation. In the first scenario, we assumed that the non-respondent probability of sale was 0.500, which was even as there was no difference between owners with wetland-containing parcels and those without wetland parcels. In the second scenario, non-respondents' attitudes were reversed or opposite to those of respondents (i.e. landowners with wetland-containing parcels had a probability of sale = 0.338, while those without wetland parcels had a probability of sale = 0.565.)

2.6.3. Uniform probabilities of sale

In the baseline simulation, the probabilities of sale by the owners with wetland parcels and those without wetland parcels differed according to the mail survey. In situations where no survey was conducted, probabilities of sale would be most likely assumed to be the same among different types of landowners for the sake of simplification and due to the lack of prior knowledge. To assess the effects of uniform probabilities of sale across different types of landowners, we examined two uniform probabilities of sale. The first uniform probability of sale was assumed to be 0.500 (half of the landowners would sell their land), whereas the second uniform probability of sale was set at 0.333 (one-third of the landowners would sell their land). We chose the specific values because the high uniform probability (0.500) was close to the probability of sale by owners with wetland-containing parcels (0.565), and the low uniform probability (0.333) was similar to the probability of sale by owners without wetland-containing parcels (0.338). We compared the outcomes from the uniform probabilities with those of the survey-derived probabilities of sale to assess the importance of the survey information. Specifically, we compared the total amount of land purchased, the number of parcels purchased, the distribution of land types purchased, and the amount of hydric and nonhydric soil areas purchased.

2.6.4. Land acquisition under different levels of incentives

Three acquisition scenarios were simulated. The first scenario was default (no incentives as in the baseline simulation), whereas incentives (low and high) were provided in the other two scenarios. The survey-derived probabilities of sale were increased by including some or all the undecided landowners. The low incentive level assumed that half of the undecided landowners would sell. Since 26.1% of the landowners with wetland-containing parcels were undecided, half of this number (0.130) was added to the original probability of 0.565 and yielded 0.695 as the new probability of sale. Similarly, landowners without wetland-containing parcels had a new probability of sale (0.438). The high incentive level assumed that all of the undecided landowners would sell. Thus, landowners with and without wetland had higher new probabilities of sale (0.826 and 0.538, respectively). Of course, the total amount of land purchased was expected to increase with increase in probabilities of sale, but it was not intuitive whether amounts of different land types (e.g. wetlands and hydric areas) purchased would differ under different incentive levels. Existing wetlands and hydric areas were of particular interest because they would be good habitats for waterfowl and the refuge is maintained primarily as a migratory staging area for waterfowl.

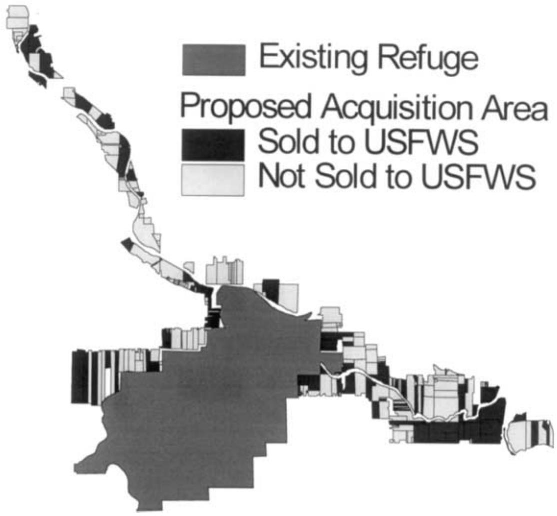

Fig. 4. Example of spatial distribution of purchased and non-purchased land parcels from a baseline simulation.

Table 2
Proportion of the 3035 ha area and parcels purchased from each category of habitat priority set by the United States Fish and Wildlife Service (1996)

Habitat priority	Percent of area purchased (mean ± S.E.)	Percent of parcels purchased (mean ± S.E.)
High	48.07 ± 2.55	43.15 ± 1.27
Medium	44.64 ± 2.34	38.04 ± 1.62
Low	50.43 ± 1.05	40.97 ± 0.67

2.7. Methods for modeling, simulation, and analysis

SEELAND was developed to simulate land acquisition within the proposed acquisition boundary using the programming language Avenue (ArcView 3.1, Environmental Systems Research, Inc., 1996). In order to determine which parcels would be acquired, an Avenue script combined spatial data contained in the GIS map layers, the economic component, and landowners' attitudes towards selling their land.

Each scenario was simulated 100 times because of the stochastic nature of the model. As the time frame regarding landowners' willingness to sell their land was 20 years, simulation results were for a period of 20 years. An analysis of variance (ANOVA) was used to test for significant differences under different scenarios, in terms of the simulation results such as the number of parcels purchased, the total area purchased, the existing wetland area purchased, and the hydric-soil areas purchased. Tukey's test was used to determine where the differences lay.

3. Results

3.1. Spatial distribution of purchased land

In the baseline simulation using survey-derived probabilities of sale, the acquired parcels were scattered within the proposed acquisition area creating a matrix of purchased and non-purchased parcels (see an example in Fig. 4). In other words, many purchased parcels were not connected to each other or to the refuge.

The land acquired (Table 2) did not follow the priority order set by the USFWS (Fig. 2). In terms of total area, only 48% of the high-priority habitat was acquired, while a similar percentage (50%) of the low-priority habitat was purchased. In examining the number of land parcels, 43% of high-priority land parcels and 41% of the low-priority land parcels were purchased. Percentages of acquired medium-priority land (number of parcels and total area) were slightly lower than those of acquired high- and low-priority land. Acquired high-, medium-, and low-priority land accounted for 35, 19, and 46% of the total amount of acquired land, respectively.

3.2. Effects of non-respondent probabilities of sale

In examining the effects of the non-respondent probability of sale on land acquisition, we compared the total amount of acreage purchased, the amount of existing non-forested wetlands purchased, and the amount of hydric areas purchased (Table 3). The results from the even non-respondent probabilities were significantly different from those generated in the other two scenarios ($P < 0.01$). The total purchased area using the reversed non-respondent probabilities was over 150 ha lower than the other two scenarios even though the average number of parcels purchased fell between the values for the other two scenarios. The existing wetland area purchased with the reversed non-respondent probability was significantly lower ($P < 0.01$) than in those other two scenarios. The hydric-soil area purchased under the reversed probabilities was significantly lower than the area purchased under the even non-respondent probabilities but was not significantly lower ($P > 0.10$) than the hydric-soil area purchased under the survey-derived probabilities.

3.3. Effects of uniform probabilities of sale

The total area purchased increased with the probabilities of sale — from 1025 ha (under low uniform probability), 1289 ha (under survey-derived probabilities), to 1543 ha (under high uniform probability). The amounts of nonhydric

Table 3
Effects of non-respondent probabilities of sale on land acquisition (mean ± S.E.)

Types of non-respondent probabilities of sale	Parcels purchased (number)	Total area purchased (ha)	Area of existing wetlands purchased (ha)	Area of hydric-soil areas purchased (ha)
Survey-derived	138 ± 1	1444 ± 13	45 ± 1	328 ± 5
Reversed	148 ± 1	1292 ± 13	26 ± 1	317 ± 6
Even	159 ± 1	1533 ± 15	41 ± 1	354 ± 6

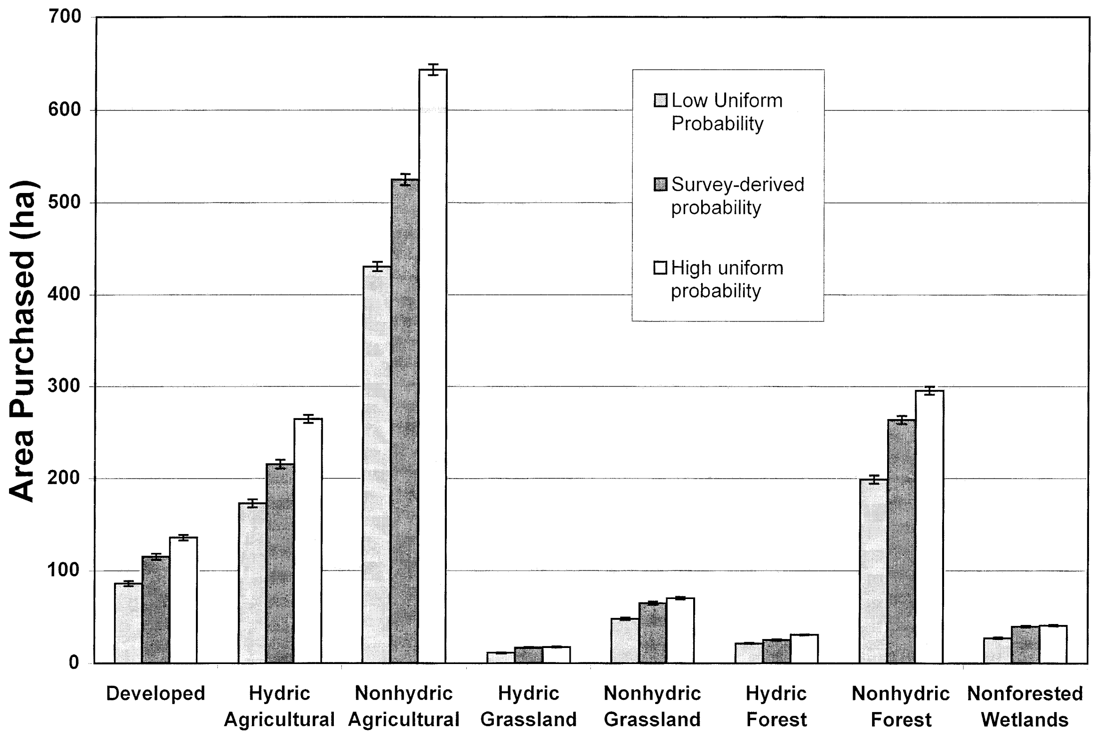

Fig. 5. Effects of uniform probabilities of sale on the amount of each land type purchased (means ± 1 S.E.).

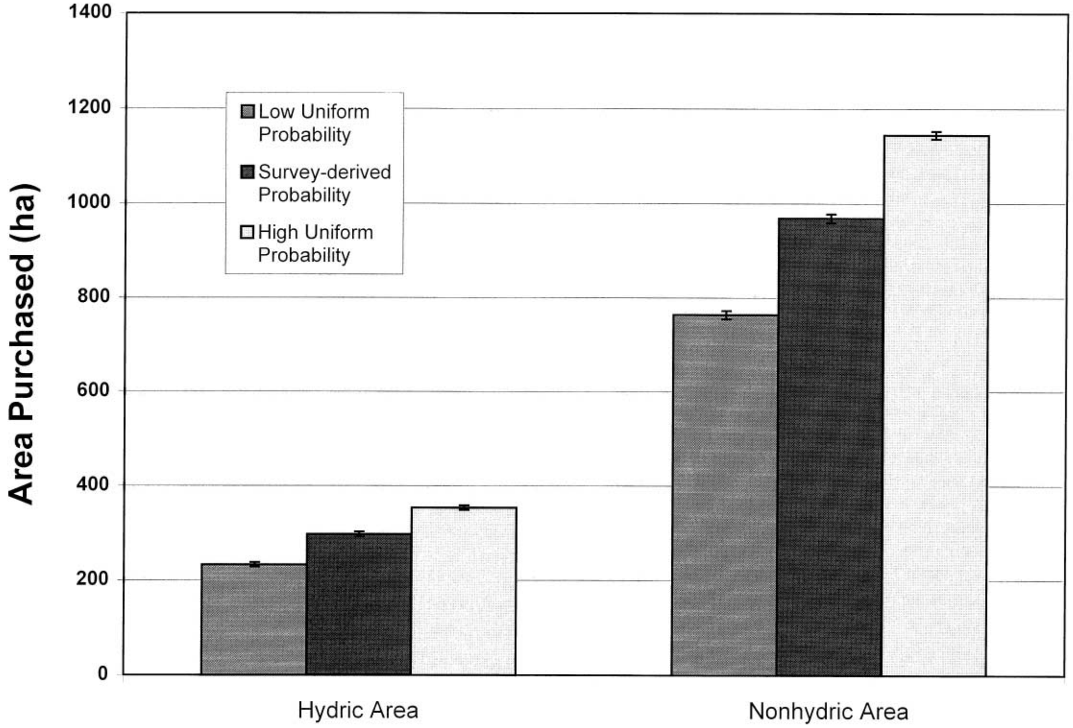

Fig. 6. Effects of uniform probabilities of sale on hydric versus nonhydric soil areas purchased (means ± 1 S.E.).

agricultural lands, nonhydric grasslands, and non-hydric-forested lands purchased showed a similar trend (Fig. 5). In the non-forested wetlands and the grasslands (both hydric and nonhydric), however, the survey-derived probabilities produced similar results to the high uniform probability. Grouping the purchased land into hydric and nonhydric categories (Fig. 6), we found that both categories approximated a linear increase from low uniform, to survey-derived, to high uniform probabilities of sale.

3.4. Effects of incentives

As expected, the total amount of land purchased increased with the increasing incentive levels, going from 1289 (under no incentive), to 1632 ha (under low incentive), and to 1945 ha (under high incentive). The types of land purchased using the different incentive levels, however, were not as straightforward as the total amount of land purchased. As indicated in Fig. 7, the amount of agricultural land purchased increased the most. This was to be expected since the proposed acquisition area falls within a highly agricultural community. All of the land types showed an increase in the amount of land purchased with the increasing incentive levels, however, the degree of increase was different for each land type and each incentive level. Grouping purchased land into hydric and nonhydric categories (Fig. 8) showed that both categories increased by similar increments when levels of incentive varied (from no incentive to low incentive, and from low incentive to high incentive).

4. Discussion and conclusions

The socioeconomic feasibility of the proposed acquisition project is low, as indicated in our results. Only 42% of the proposed acquisition area and 46% of existing or potential wetlands was available for purchase within a period of 20 years.

Furthermore, the availability of high-priority habitats did not follow the priority order set by the USFWS (Table 2).

In terms of ecological consequences of the proposed acquisition project, the unavailable parcels were interspersed within the matrix of the acquisition area (Fig. 3) and this distribution interferes with habitat connectivity. Although a primary goal of the refuge is to create and maintain wetlands for waterfowl habitat, many available land parcels containing wetlands are not adjacent to the refuge. Since small isolated units may be too costly and difficult to manage for the USFWS, even available hydric (but not currently wet) areas would not be converted to wetlands until more land around them could be acquired.

Our simulation results showed that the survey information was important because the survey-derived probabilities of sale generated different distributions of types of land purchased than did the uniform probabilities of sale. Also, the non-respondent probabilities were influential in determining the number of parcels purchased, the total area purchased, and the distribution of existing and potential land types purchased. Thus, future studies on the feasibility and consequences of land acquisition projects should carry out non-respondent follow-ups to assess whether the respondents were representative of non-respondents in terms of their attitudes towards selling their land.

Simulation results using the survey information indicated that less than half of the proposed acquisition area would be purchasable without using incentives. These results demonstrated that providing incentives to undecided landowners is necessary in order to complete the proposed acquisition project. Although offering extra cash to the landowners directly would be impossible because USFWS's policy is to buy land at fair market value, other forms of incentives such as relocation assistance might encourage undecided landowners to sell their land. Furthermore, the

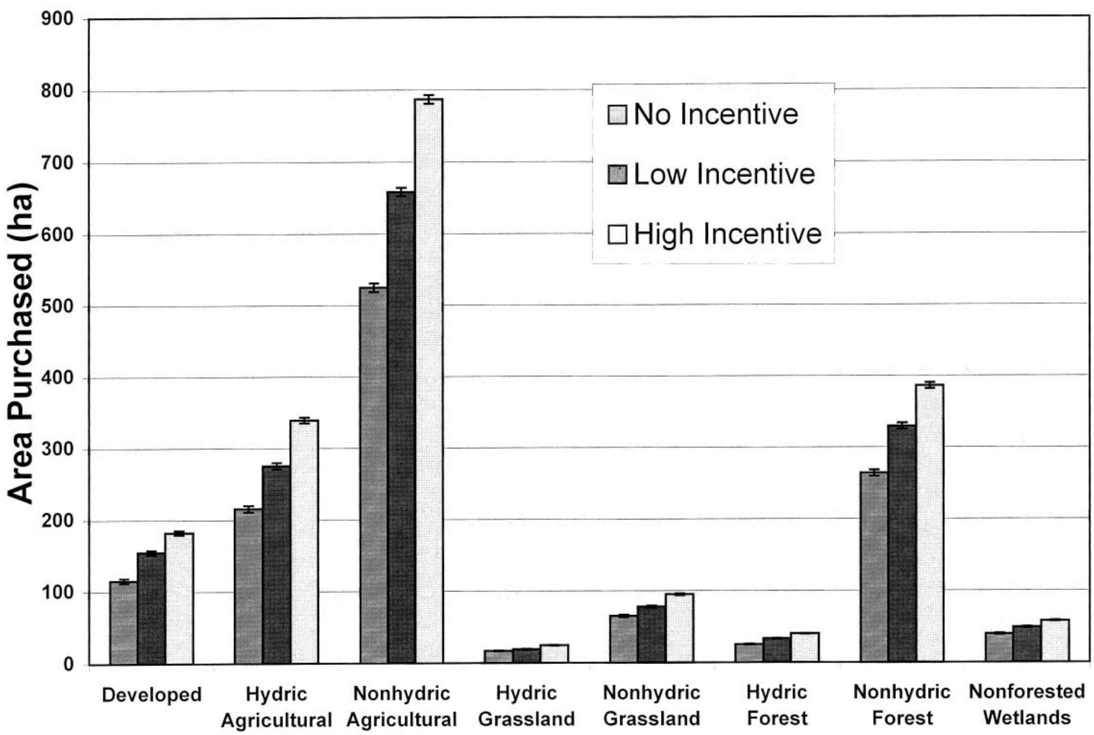

Fig. 7. Effects of incentives on the amounts of different land types purchased (means $\pm$ 1 S.E.).

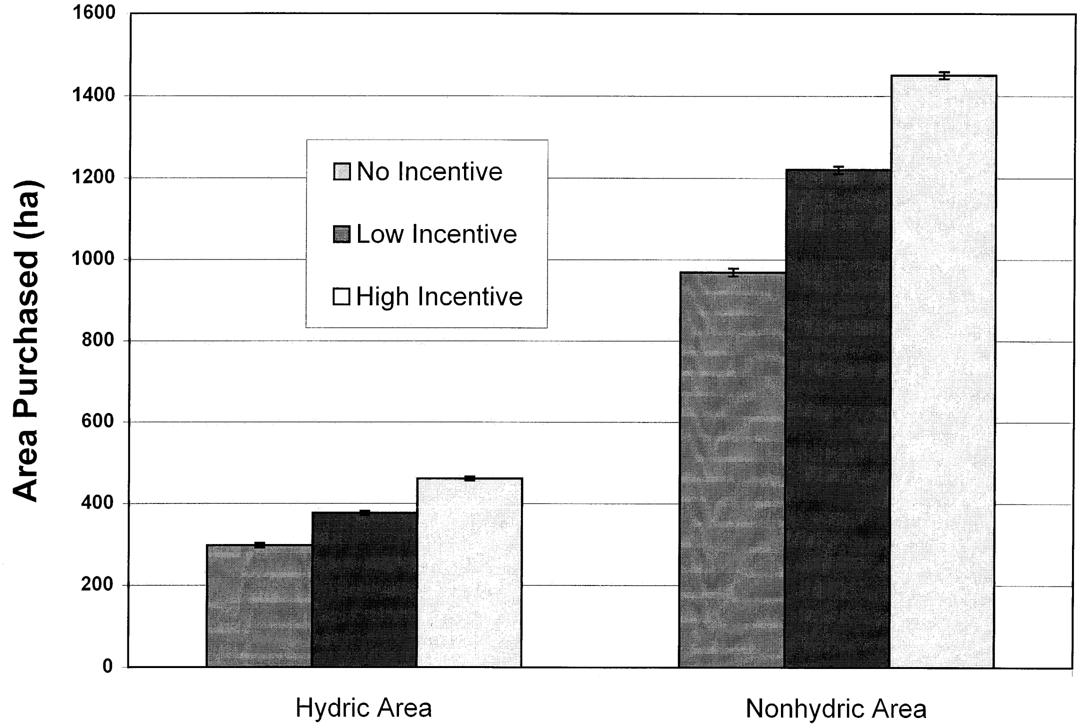

Fig. 8. Effects of incentives on hydric versus nonhydric soil areas purchased (means ± 1 S.E.).

incentives would have to be tailored to each landowner for the greatest effectiveness as different landowners may have different needs. For those landowners who are not willing to sell their land, it is necessary to understand their reasons and develop alternative strategies to change their attitudes. For example, increasing the contact between USFWS personnel and landowners would be helpful, as Ramsey and Addison (1996) suggested that contacting landowners with purchase offers would accelerate the land acquisition process.

Like many other models, data limitation in SEELAND was inevitable. For example, in our model, we used landowners' attitudes toward selling their land as surrogates for the actual selling behaviors. We realize that behaviors are often not entirely correlative with attitudes (Ajzen and Fishbein, 1980), but the collection of data regarding selling behaviors would take much longer as behavior information cannot be collected until actual land selling takes place. Nevertheless, SEELAND is a valuable tool for assessing socioeconomic feasibility and ecological consequences of land acquisition. The simulation results from SEELAND provide important insights regarding whether the goal of a land acquisition project can be achieved and what alternatives need to be developed in order to achieve the project goal.

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