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An hedonic analysis of southwestern Louisiana wetland prices using GIS

Baifu Xu
Louisiana State University and Agricultural and Mechanical College, fordxxuu@gmail.com

AN HEDONIC ANALYSIS OF SOUTHWESTERN LOUISIANA WETLAND PRICES USING GIS

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by
Baifu Xu
B.S., Wuhan University, China, 1991
M.S., East China Normal University, China, 1994
M.S., Louisiana State University, 2004
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ABSTRACT

Louisiana is the beneficiary of more than 30% of the U.S. coastal wetlands, but the state's wetland loss accounts for about 90% of the total throughout the continental United States. The Coastal Wetlands Planning, Protection and Restoration Act of 1990 and the $1.9 billion that has recently been dedicated by Congress for coastal restoration activities will certainly aid in restoration efforts. However, these dedicated funds are but a small fraction of the total monies that will be required to maintain/restore Louisiana's degraded wetlands. Recent estimates suggest restoration activities will cost, at a minimum, about $14 billion.

The research, based on 119 wetland property transactions throughout Southwest Louisiana, develops an hedonic model which relates price to various property characteristics. These characteristics include type of property (i.e., fresh marsh, intermediate marsh, brackish and saline marsh, open water, and "other" property), distance from the nearest road, distance from the coast, and whether the property is in an area where projected wetland loss during the next 50 years is anticipated.

Results indicate that fresh marsh and "other" land (this is a "catchall" category for property that is not specifically delineated as wetlands or open water) is valued more than open water (on a per acre basis) in the private market. However, intermediate marsh is valued less than open water in the private market. Depending upon the model specification, brackish and saline marsh is valued in the private market as either higher than open water or the same as open water (in a statistical sense). Results further suggest that buyers will, at least to some extent, discount properties in those areas where future wetland loss is anticipated (i.e., prices of properties in these areas are less after controlling for the influence of all other factors). This discounting increases as the rate of projected loss increases. Whether this discounting of future losses reflects previous losses remains untested.

CHAPTER 1 INTRODUCTION

Wetlands, historically considered as worthless waste land, are now considered among the most important natural resources in the United States and throughout the world. As we, as a society, have begun to appreciate the importance of wetlands, increased emphasis has been placed on maintaining existing wetlands and, where possible, restoring those wetlands that have been lost or seriously degraded. The task of maintaining and restoring wetlands is not only a technological challenge but will also be costly to society in terms of scarce resources that will need to be employed.

The majority of wetlands in both Louisiana and throughout the nation are privately owned. Yet, it is generally the public, rather than the private landowners, who receive most of the benefits accruing from "healthy" wetlands. This market failure suggests that private investment by landowners (for maintenance and restoration activities) is likely to be less than that amount which is socially optimal. Hence, there may be a role for government in stimulating investment. However, there are numerous means by which the government can potentially stimulate investment (e.g. tax credits, subsidies) and the efficacy of the different methods are likely dependent on how the private market demand changes in response to investment. Hence, a more detailed understanding of the market demand for Louisiana's wetlands, and factors influencing this demand, is relevant in the decision-making process.

1.1 Definitions and Functions of Wetlands

There are a variety of formal wetland definitions which can be used to define wetlands. In general, these definitions fall into one of two categories: legal definitions and scientific definitions (Mitsch and Gosselink, 2000).

Legal wetland definitions are based on criteria set forth in the Federal Manual for Identifying and Delineating Jurisdictional Wetlands (FICWD, 1989). The FICWD indicates that an area is considered a jurisdictional wetland only if three criteria are simultaneously met. First, the soils must be considered hydric or waterlogged. Second, the soils must show demonstrable evidence of hydrologic conditions associated with flooding or ponding of water. Finally, 50% of the dominant plants found growing on the site must be those commonly found in wetlands. Areas that fail to satisfy any one of these three wetland criteria are not considered jurisdictional wetlands.

Wetland scientists, however, are more interested in a flexible definition that helps delineation, classification, inventory, and research. For example, the U.S. Fish and Wildlife Service defines wetlands as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water…wetlands must have one or more of the following three attributes: (a) at least periodically, the land supports predominantly hydrophytes (water-adapted plants); (b) the substrate is predominantly undrained hydric soil (waterlogged soils); and (c) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year" (Cowardin et al., 1979). This definition suggests that areas meeting any one of these three criteria should be considered wetlands.

A number of goods and services provided specifically by wetlands have been identified and are now widely recognized. Wetlands can provide habitat and food for diverse range of species, aid in groundwater recharge and water retention, provide erosion and sedimentation controls between adjacent ecosystems, improve water quality through filtering sediment and metals from groundwater, and cycle nutrients to terrestrial and aqueous environments within the wetlands and between ecosystems. Wetlands are also important global sources, sinks, and transformers of various elements in the earth's various biogeochemical cycles (Mitsch and Gosselink, 2000; Greb and DiMichele, 2006). Specifically wetlands, as transitional zones between land and water, provide a natural protection against extreme floods and storm surges.

It is estimated that every kilometer of wetlands can reduce or lower storm surge by 5-7 centimeters (Stokstad, 2005).

1.2 Louisiana Coastal Wetlands and Types

Louisiana's coastal wetlands, one of the world's largest deltaic systems, were built by the deltaic processes of the Mississippi River. Louisiana's wetlands are bordered on the east by Mississippi, on the west by Texas, and on the south by the Gulf of Mexico. These wetlands, which total about 3.6 million acres, represent a significant natural and economic resource to Louisiana and the nation. Louisiana's coastal wetlands account for about 30% of the U.S. total and are termed "America's Wetlands." It is in these wetlands that 95% of all marine species in the Gulf of Mexico spend a portion of their life cycles. Louisiana's coastal wetlands contain an extraordinary diversity of habitats that range from narrow natural levee and beach ridges to expanses of forested swamps and freshwater, brackish and saltwater marshes.

Unlike in most states, where coastal wetlands represent a relatively narrow transition boundary between solid land and water, wetlands in Louisiana are vast, often extending for many miles. The "vastness" of Louisiana's wetlands, while enhancing the benefits to citizens of the state and nation (from both consumptive and non-consumptive activities), has presented a challenge to those state and federal agencies charged with managing them in a manner commensurable with sustainable benefits.

Louisiana's commercial seafood landings - including shrimp, crabs, menhaden and other commercial finfish - exceed one billion pounds per year and, in 2001, had a dockside value of $343 million. Louisiana's commercial seafood harvest accounts for approximately 30% of the total catch by weight in the lower 48 states (USDOC, 2002). Fur production from coastal Louisiana has averaged about $2 million annually in recent years (LADWF, 2004) and alligator harvests generate approximately $30 million annually in gross revenues to the hunters (LADWF, 2003). Louisiana's coastal wetlands also provide the basis for much of the annual recreational fishing expenditures, estimated to range from $703 million (USDOI and USCB, 2003) to $1.2 billion (Gentner et al., 2001), hunting-related expenditures estimated to equal $446 million annually, and wildlife-watching expenditures of approximately $168 million annually (USDOI and USCB, 2003). Louisiana's coastal wetlands provide habitat and food for over five million migratory waterfowl (LADWF, 2000). More importantly, the coastal area is home to more than 2 million residents, representing 46 percent of the state's population.

Wetlands have been classified variously over the past several decades on the basis of hydrology, geography, and/or plants. This research studies privately owned coastal marshes of Louisiana, which are areas dominated by grasses, sedges, and rushes, often interspersed with patches of open shallow water. Depending upon their soil, water, and salinity conditions, five major types of coastal wetlands are identified in Louisiana: swamps, fresh marsh, intermediate marsh, brackish marsh, and saline marsh.[1] The different types of wetlands generally occur in bands parallel to the shoreline. Each salinity regime and habitat type supports a specific community of plants and the associated wildlife and fish that depend upon the different wetland types for habitat and food.

1.3 Wetland Loss in Louisiana

Despite a growing recognition of the contribution of wetlands to the welfare of society, loss of wetlands continues to be significant. According to a survey performed by the U.S. Fish and Wildlife Service, the 48 contiguous states had approximately 221 million acres of wetlands in 1780. Since then, wetlands have declined significantly and only an estimated 104

[1] Of the 3.6 million acres of coastal wetlands, about 1.0 million are defined as swamp, 941 thousand are classified as fresh marsh, 724 thousand are classified as intermediate marsh, 585 thousand are classified as brackish marsh, and 375 thousand are classified as saline marsh (LCA, 2004). The relative percentages, however, vary significantly across the coast with, for example, almost no swamp acreage being reported in the most western parishes in the state.

million acres, or 47% of the original wetlands, currently remain in “functional” forms (Dahl, 2000). During the decade ending in 1990, wetland loss of the U.S was estimated to be 58,500 acres annually (Dahl, 2000), or more than one-half million acres over the decade.

While wetland loss in some states is as high as 80% to 90% (Mitsch and Gosselink, 2000), Louisiana has the largest coastal wetland loss, accounting for nearly 90% of all current coastal land loss in the lower 48 states. The U.S. Geological Survey (USGS) and the U.S. Army Corps of Engineers (USACE) reported that Louisiana lost 1,900 square miles from 1932 to 2000, roughly an area of the state of Delaware. During the last 50 years, more than 1,500 square miles have been lost, and the estimated land loss rate, at times, has exceeded 40 square miles per year. The USACE estimates that the present rate of coastal land loss is 25 square miles a year. The U. S. Fish and Wildlife Service places the figure even higher at about 34 square miles a year, based on measuring the loss in coastal land area between 1978 and 1990 (Dahl, 2000). With current restoration efforts taken into account, it is estimated that the state will lose an additional 500 square miles wetlands over the next 50 years (Barras et al., 2003), and the 120-year (1930-2050) loss will total almost 1.7 million acres or 34% of Louisiana's historic coastal wetlands (excluding wetland loss from Hurricanes Katrina and Rita in 2005 that has yet to be fully documented).[2] The rate of land loss in Louisiana is thought to be the highest in the world (ASCE, 2004).

Wetland loss of coastal Louisiana has increased storm vulnerability and amplified risks to lives, properties, and economies -- a fact underscored by Hurricanes Katrina and Rita. It is estimated that Hurricane Katrina resulted in over $90 billion in physical losses in southeastern Louisiana while over $5 billion in physical losses in southwest Louisiana resulted from Hurricane Rita (USACE, 2006).

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[2] It is estimated that Hurricanes Katrina and Rita resulted in the loss of an additional loss of 217 square miles of coastal wetlands which, to the extent that the loss is permanent, exceeds the projected coastal wetland loss during the next 20 years (USACE, 2006).

1.4 Wetland Protection Programs and Issues

As the social and economic values associated with well functioning coastal wetlands became increasingly recognized, especially after Hurricanes Katrina and Rita in 2005, the efforts to preserve and restore them become more apparent. A recent survey conducted by Louisiana State University indicates that 49% of U.S. residents residing outside of Louisiana believe that Louisiana's coastal wetland loss is a "very important" issue while an additional 28% believe that the loss of wetlands in Louisiana is an "important" issue. Overall, 61% of the survey respondents hold the belief that coastal wetland loss in Louisiana has an impact on their daily lives (LSU, 2007).

The current federal investment in preserving and restoring Louisiana coastal wetlands, through Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA), is about $50 million annually (ASCE, 2004). The CWPPRA was passed by the U.S. Congress in 1990, and the funding associated with this Act has become the primary source for addressing Louisiana's coastal wetland loss. Among other things, the CWPPRA plans call for (a) diverting the water and sediment of the Mississippi River to build new deltas and smaller splays to mimic spring floods and restore subsiding marshes; (b) restoring barrier islands; and (c) instituting measures to protect many smaller wetlands with dikes, plantings, and disposing of dredge spoil (Turner and Boyer, 1997). Under the CWPPRA, about 129 federal and state restoration projects are currently active. These projects are diverse, ranging from providing an economic incentive associated with the trapping of nutria[3] to building new marshes with dredged silt.

The CWPPRA led to the Louisiana Coastal Wetlands Conservation and Restoration

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[3] Nutria (*Myocastor coypus*) are a semi-aquatic, fur-bearing rodent which are native to South America. They were introduced into Louisiana in the 1930's. A fecund species with few natural predators (other than alligator), the population quickly grew and contribute to coastal erosion due to their feeding habits (i.e., roots of marsh vegetation). Aerial surveys conducted in 2003, for example, indicated that nutria activities had negatively affected at least 80 thousand acres of coastal marshes (Marx, et al., 2003). After various efforts to enhance the market for nutria, the Louisiana Department of Wildlife and Fisheries obtained funds through CWPPRA to offer a bounty of $4.00 per tail to registered participants in the program.

(LCWR) plan, which was completed in 1993, and the subsequent Coast 2050 plan in 1998. However, the Coast 2050 plan for restoring Louisiana's increasingly-degraded wetlands in 30 years was turned down by the Bush administration in August 2004. Instead, the administration requested a short-term plan, called Louisiana Coastal Area (LCA) Plan, that committed only $1.9 billion dollars over 10 years (Schliefstein, 2004).

While significant expenditures related to coastal restoration efforts have been made since 1990, the annual CWPPRA expenditures of about $50 million are, according to some estimates, providing less than 10% of the funding necessary to adequately address the multitude of issues associated with wetland diminution and loss throughout coastal Louisiana. An early Louisiana study stated that the nation needs to spend $14 billion over the next twenty years to achieve "no net loss" of coastal wetlands (Dunne and Knapp, 2005).

The costs of wetland preservation and restoration are high compared with the limited budget of wetland planning projects. Because of the comparatively small budget relative to overall needs, the CWPPRA projects benefit only a small fraction of the degraded Louisiana coastal wetlands. In short, because of the high costs associated with the current restoration system, which relies highly on engineering projects, the CWPPRA cannot be expected to effectively address the wetland loss crisis of coastal Louisiana. Given the limited budget, therefore, it is logical to seek more innovative, cost effective alternative restoration opportunities.

Approximately 75% of all coastal Louisiana wetlands are privately owned (McBride, 1992). Though federal-and- state-sponsored programs, such as the CWPPRA, are being implemented in an attempt to reverse (or at least reduce) wetland degradation, more active participation by landowners may contribute to any policy goal (e.g., reduce wetland degradation). As such, it may prove useful to develop a mechanism to encourage private landowners to restore and enhance existing wetlands. Because of the economic reality of diminishing surface and sub-surface incomes, increasing regulatory constraints, and current tax structure which fails to adequately delineate the use value of coastal property, owner-initiated alternatives are very limited in coastal Louisiana. For example, a coastal Louisiana survey indicated that most coastal landowners earned little or no income: 38% reported no surface revenues from coastal wetland properties while an additional 34% reported incomes of less than $10 per acre (Coreil, 1995).

Economic incentives, such as direct subsidies and tax credits, could potentially encourage private landowners of coastal Louisiana to preserve and restore wetlands. It is important for policy makers to understand those economic factors which affect wetland restoration of coastal Louisiana. An understanding of the economic structure of private wetlands is a difficult task because wetlands, as a natural resource, generate public and private goods which are difficult to directly value through market transaction prices, and many of the services provided by wetlands are not traded in a market.

1.5 Objectives

Generally speaking, this study attempts to provide an economic understanding of property value in the coastal wetlands private market in order to devise and implement cost efficient economic incentive mechanisms for private landowners.

More specifically, this study has the following three objectives. The first objective is to identify the underlying characteristics affecting the price per acre or values of coastal wetland properties in coastal southwestern Louisiana. The second objective, based upon completion of the first objective, is to determine the marginal implicit prices associated with wetland characteristics and other variables that influence coastal wetland prices. The final objective is to assess whether incentive programs that could be offered to landowners need to be tailored to specific wetland characteristics.

Based on data from southwestern Louisiana, this thesis uses the Geographic Information

Systems (GIS), statistical tools and the hedonic method to estimate the hedonic price function. This research uses the hedonic property price model to "capture" the private valuation of coastal Louisiana wetlands by studying the effects of wetland characteristics on the price of property. Unlike most hedonic modeling research that examines the value of wetlands, wetlands are considered components of properties in this study rather than the more extensively studied influence of wetland proximities on neighborhood residential housing prices. The characteristics of wetlands - like acreage, location, wetland type - determine whether the wetland outputs are amenities or disamenities to the property owners. This study asks whether property prices have a negative relationship with wetlands within these properties, and whether different types of wetlands and other characteristics are associated with increases or decreases in property prices.

To accomplish the goals and objectives outlined for this thesis, a review of the relevant literature is presented in the next chapter (i.e., Chapter 2). Then, attention is given to providing a description of the study area, data collected and utilized in the analysis, and variables included in the hedonic price analysis. Chapter 4 introduces the hedonic method and provides an overview of statistical issues that need to be considered to assure property model specification. Results, including the estimated models and associated implicit prices, are presented in Chapter 5. Finally, a brief summary of research findings and suggestions for future research in this area are presented in Chapter 6.

CHAPTER 2 REVIEW OF LITERATURE

2.1 Economic Valuation of Wetlands

With an increased understanding of the functional importance of wetlands, researchers and decision makers have, over the past several decades, increasingly focused on means of preventing further wetland loss and, where possible, reestablishing previously degraded wetlands. Researchers have conducted numerous engineering studies to evaluate alternative means for protecting/restoring wetlands and have more recently turned attention to assessing the functional values associated with created wetlands vis-à-vis natural wetlands. Likewise, governmental agencies, at both the state and federal levels, have enacted numerous programs over the past couple of decades, generally in the form of regulatory measures and economic incentive measures, with a goal of protecting and restoring wetlands. Although these programs have made some progress toward the goal of "no net loss," the goal has not yet been achieved.

The social and ecological functions attributable to wetlands - such as flood control, sentiment retention, aesthetics, and open space - indicate that wetlands have public-goods characteristics. The majority of goods and services provided by wetland ecosystems are not traded and, hence, revealed in the market place. Market failures associated with wetlands (both their public good nature and positive externalities) have, historically, resulted in wetlands being undervalued by society and, from an economic efficiency perspective, underinvestment in protection/restoration activities.

As early as in 1926, Percy Viosca, a fishery biologist, estimated the monetary value of Louisiana wetlands $20 million annually for the functions of fishing, trapping, and other collecting[4] (Vileisis, 1997). However, few additional wetland valuation studies were conducted during the subsequent four decades until Hammack and Brown (1974) valued the

[4] The author does not specify what "other collecting" activities might entail.

wetlands of the U.S. Pacific western flyway for the benefits associated with waterfowl hunting. Since then, a large number of wetland valuation studies have been conducted. Brander et al. (2006) found that eight wetland valuation studies were completed in 1970s, 25 studies were conducted in 1980s, 124 studies in 1990s, and 32 after the year of 2000.

During the 1970s and 1980s, according to Brander et al. (2006), wetland valuation attempts primarily focused on quantifying wetland values through estimating the value of specific function(s) or contribution(s) of wetland ecosystems with the earlier studies during this timeframe primarily focusing on only one function. Hammack and Brown (1974), for example, valued wetlands in relation to their role in hunting while Gosselink et al. (1974) estimated the value of Louisiana wetlands for tertiary waste treatment. Batie and Wilson (1978), by comparison, valued Virginia coastal wetlands in terms of their contribution to oyster production while Bertelsen and Shabman (1979) quantified the amenity value of wetlands for residential development. In the 1980s, Lynne et al. (1981) valued the Florida coastal wetlands for fishery production; Farber (1987) valued Louisiana wetlands for hurricane protection, and Farber (1988) estimated the value of Louisiana wetlands for recreational use.

By the middle of 1980s, according to Brander et al. (2006), some researchers had begun to estimate the functional values of two or more services provided by wetlands. Farber and Costanza (1987), for example, tried to estimate the total social value of Louisiana wetlands for three functions: commercial fishing and trapping, recreation, and storm protection, and aggregated these values to derive a total value estimate. Amacher et al. (1989) estimated the value of Lake St. Clair and Saginaw Bay wetlands for fishing and real estate.

Entering the 1990s, there were still a vast number of studies that concentrated on only one function of wetlands, but a significant number of studies quantified the value of wetlands for two or more functions. Several studies, (e.g., Leitch and Hovde, 1996; Blomquist and

Whitehead, 1998), aggregating all important goods and services valued by society[5], estimated the total value of wetlands. Even Costanza et al. (1997) ambitiously estimated the total value of all goods and services of the globe's wetlands ecosystem to be about $9 trillion annually, and wetlands were found to be 75% more valuable than lakes and rivers, 15 times more valuable than forests, and 64 times more valuable than grasslands and rangelands. A listing of functions that are provided by wetlands and which are valued by society is provided in Table 2-1 (Larson et al., 1989; Barbier, 1991; Barbier et al., 1997; Woodward and Wui, 2001; and Brander et al., 2006).

Like other environmental and natural resources, wetlands can be valued with techniques developed by scientists and economists (Freeman, 1993). A diverse range of techniques have been employed over the years to value wetlands. As indicated by Brander et al. (2006), there are seven primary valuation methods that have been applied to wetlands: contingent valuation (CV), hedonic pricing and travel cost, production function, net factor income (NFI), replacement cost, opportunity cost, and market prices

There is no widely accepted wetland valuation method which is "preferred" in all situations since every valuation technique has its own biases and limitations. Brander et al. (2006), in a meta-analysis of 191 wetland valuation studies, found that the CV technique produced the highest estimates of wetland values, followed by the replacement cost method, NFI, and travel cost.[6] The lowest value estimates were produced by production function method and hedonic pricing.[7] In contrast to the results provided by Brander et al. (2006),

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[5] This comment is, of course, premised on our current understanding of the functions of wetlands. As science progresses, wetland services, not currently readily apparent, are likely to become important.

[6] One should recognize that the replacement cost value may not reflect "value," as defined by the resource economics profession, since it does not necessarily "capture" benefits.

[7] One might anticipate relatively low estimates of wetland value associated with hedonic modeling vis-à-vis other techniques because it does not "capture" consumer surplus (assuming the wetlands are used for consumer activities). In theory, if the wetlands are used in the production process and the owner is able to "capture" all of the income that might be generated from the wetlands, then the hedonic price model should capture the discounted stream of net income that could be derived from the property over time.

Woodward and Wui (2001), based on a meta-analysis of 39 wetland valuation studies, concluded that the CV method tended to yield a lower estimated wetland value than replacement cost or hedonic pricing method. Furthermore, there was no statistically significant difference between the CV and the travel cost or NFI methods.

Table 2-1 Wetland Functions and Applicable Valuation Methods

(Sources: Larson et al., 1989; Barbier, 1991; Barbier et al., 1997; Woodward and Wui, 2001; and Brander et al., 2006)

Function	**Economic Valuable Goods & Services**	**Value Type**	**Typically Used Valuation Method***
Flood and flow control	Flood protection	Indirect use	Replacement cost Market prices Opportunity cost
Storm buffering	Storm protection	Indirect use	Replacement cost Production function
Sediment retention	Storm protection	Indirect use	Replacement cost Production function
Groundwater recharge / discharge	Water supply	Indirect use	Production function NFI Replacement cost
Water quality maintenance / nutrient retention	Improved water quality Waste disposal	Indirect use Direct use	CV Replacement cost
Habitat and nursery for plant and animal species	Commercial fishing and hunting Recreational fishing and hunting Harvesting of natural materials Energy resources	Direct use Direct use Direct use Direct use	Market prices, NFI TC, CV Market prices Market prices
Biological diversity	Appreciation of species existence	Non-use	CV
Micro-climate stabilization	Climate stabilization	Indirect use	Production function
Carbon sequestration	Reduced global warming	Indirect use	Production function
Natural environment	Amenity Recreational activities Appreciation of uniqueness to culture / heritage	Direct use Direct use Non-use	HP, CV CV, TC CV

*CV: Contingent Valuation, HP: Hedonic Pricing, NFI: Net Factor Income; TC: Travel Cost.

2.2 Hedonic Property Price Model

The hedonic model concept, as a means of measuring values of non-market goods, can be traced back to Court (1939). The basic premise of the hedonic method is that the price of a marketed good is related to its characteristics, or the services it provides. A good can be valued by looking at changes in willing to pay for that good as individual characteristics change.

Rosen (1974) developed a theoretical hedonic model that now serves as the basis for empirical estimation of marginal prices associated with product characteristics. According to Rosen (1974), equilibrium prices in housing markets are determined such that buyers and sellers are perfectly matched. Property values are influenced by home characteristics, economic conditions, and nearby amenities (or disamenities). Rosen considered hedonic prices as “the implicit prices of attributes” and suggested that they “are revealed to economic agents from observed prices of differentiated products and the specific amounts of characteristics associated with them.” Since then, Rosen’s theoretical model and its two-stage estimation procedure have been the standard for analyses using an hedonic model technique.

Subsequent to Rosen’s (1974) work, Palmquist (1984) outlined procedures to estimate demand schedules of the underlying characteristics that are “captured” in the hedonic price model. Brown and Rosen (1982) questioned whether a marginal bid price function, using simple linear functions as a derivative of bid function, could be identified. Scotchmer (1985, 1986) proved that it was impossible to distinguish the bid price function from the hedonic price function even in the case of a homogeneous consumer. Palmquist (1989) further extended Rosen's theoretical model to consider land as a differentiated factor of production. Freeman (1993) provided a useful summary of the theoretical aspects of the hedonic property price models.

The first step of Rosen’s two-stage procedure of the hedonic price model has been widely applied. A number of recent studies have used the hedonic methods to examine the relationship between environmental characteristics and differentiated goods, including many types of properties (e.g., farmland and rural land). With respect to the use of the hedonic price model to “capture” differentiated property characteristics, the approach, based on regression analysis, aims at explaining the specific contribution of each attribute of a property (Can, 1990; Can, 1993; Dubin, 1998). From a conceptual point of view, land and property prices are a combination of externality effects and location rents (Hickman, et al., 1984; Shefer, 1986; Yinger, et al., 1987; Strange, 1992; Can, 1993; Dubin, 1998).

Several hedonic studies have focused on the impact of soil characteristics on farm land prices. For example, Miranowski and Hammes (1984), in an analysis of Iowa's farmland prices, found that three measures of topsoil quality - topsoil depth, potential erosivity, and pH - had the expected signs and the signs were statistically significant. Studies by Ervin and Mill (1985) and Gardner and Barrows (1985) concluded that land values were not predictably related to actual or potential erosion. Palmquist and Danielson (1989), however, found that land values were significantly affected by both potential erosivity and drainage requirements.

Other studies have focused on the relation of residential housing prices to local amenities/disamenities. Kohlhase (1991), for example, concluded that people would pay to live farther from toxic waste sites. Palmquist (1992) found that property values were reduced by noise from nearby highways. Reichert (1997) found that being within 6,750 feet of the landfill resulted in a significant decline in property value and that the reduction in value was directly related to the proximity to the landfill during the peak publicity period. In many cases, environmental degradation, a type of environmental change, can directly impact property values. For example, Palmquist et al. (1997) found that proximity to hog farming operations reduced property values.

With respect to property values, much of the original hedonic modeling attempts, as noted, focused on the impacts of farmland characteristics on farmland prices or the impacts of externalities and/or location rents on residential properties. Recently, however, a large number of studies have been conducted to examine how residential housing prices are influenced by the proximity to wetlands.

Four studies (Doss and Taff, 1996; Lupi et al., 1991; Mahan et al., 2000; Earnhart, 2001) applied the hedonic method to estimate the value of urban wetlands to nearby property owners. All of the studies found that proximity to wetlands positively influenced property values. Doss and Taff (1996) suggested that neighborhood residents "will respond positively to policies that that preserve scrub-shrub and open-water wetlands." The authors, however, also found that "[r]esidents may respond negatively to policies that preserve forested wetlands and may have little response to policies that preserve emergent-vegetation wetlands (p. 128)." Lupi et al. (1991) found that changes in wetland acreage were valued higher in areas where wetland acreage was low than where wetland acreage was high. Mahan et al. (2000) concluded that wetlands influenced property values differently than other amenities and that increasing the size of the nearest wetland to a residence by one acre increased the residence's value by $24. Similarly, reducing the distance to the nearest wetland by 1,000 feet increased the residential property value by $436. Mahan et al. (2000) also found that home values were not influenced by wetland type. Earnhart (2001) combined a hedonic analysis with conjoint analysis to study the value of wetlands in Fairfield, Connecticut. The author found that restored wetlands generated large positive increases in nearby property values while disturbed wetlands resulted in a reduction in property value.

There have also been a limited number of hedonic wetland price analyses conducted in rural settings and these studies have tended to generate mixed findings. Reynolds and Regalado (1998), for example, found that forested and emergent wetlands in Florida, which accounted for 94% of the wetlands in the study, had negative effects on rural land values. However, scrub-shrub and shallow pond wetlands had a positive effect on land values. Shultz and Taff (2003) found that farmland prices in North Dakota with wetlands were $209 per acre less than those without wetlands; a decrease of almost one-half of the average local cropland value from 1995-2002. Bin and Polasky (2005) found that proximity to inland wetlands lowered property values while proximity to coastal wetlands (i.e., proximity to Pamlico Sound) increased property values.

CHAPTER 3 STUDY AREA, DATA AND VARIABLES

3.1 Study Area

Twenty parishes are located in the Louisiana's coastal zone: Ascension, Assumption, Calcasieu, Cameron, Iberia, Jefferson, Lafourche, Livingston, Orleans, Plaquemines, St. Bernard, St. Charles, St. James, St. John the Baptist, St. Martin, St. Mary, St. Tammany, Tangipahoa, Terrebonne, and Vermillion (Figure 3-1). The population of these parishes exceeded two million prior to Hurricanes Katrina and Rita.

The Louisiana's coastal zone is made up of two wetland ecosystems: the Deltaic Plain and the Chenier Plain. In the Louisiana Coastal Area Final Study Report (LCA, 2004), the coastal zone is divided into four subprovinces, with the Deltaic Plain comprising Subprovinces 1, 2, and 3, and the Chenier Plain comprising Subprovince 4 (Figure 3-2). The latter Plain (Subprovince 4), which extends from the Teche/Vermillion bays to Louisiana's western border with Texas, is the focus of this research. The wetlands of three parishes - Calcasieu, Cameron, and Vermillion (with a very small exception along the eastern most portion of the parish) – are included in this area (LCA, 2004).

With 30% of the nation's coastal wetlands, Louisiana's coastal zone is among the most important and productive natural assets of the United States. Wetland loss in the Louisiana coastal zone is large, however, accounting for about 90% of the total coastal wetland loss in the lower 48 states. Land loss from 1932 to 2050 is illustrated in Figure 3-3 (USGS, 2007)[8].

While the permanent land loss resulting from Hurricanes Katrina and Rita in 2005 is still unknown (because the transitory impacts of the hurricanes will be minimized after several years), preliminary estimates indicate that an additional 217 square miles of wetlands were lost as a result of the two 2005 hurricanes (Barras, 2006). Resulting land loss from the 2005

[8] The figure and its study were completed before 2005, so the wetland loss and land change by Hurricanes Katrina and Rita were not counted.

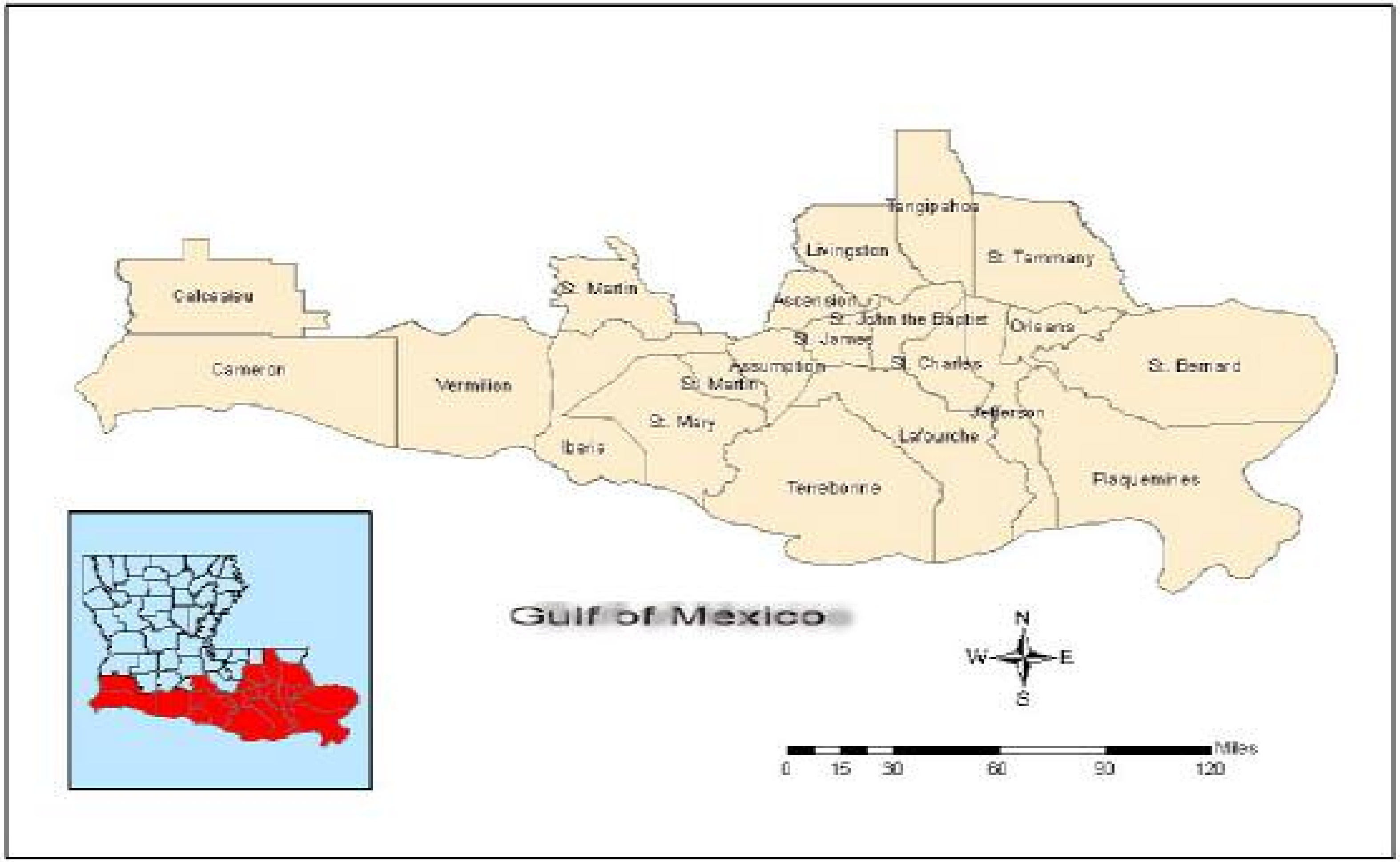

Figure 3-1 Louisiana's Coastal Area

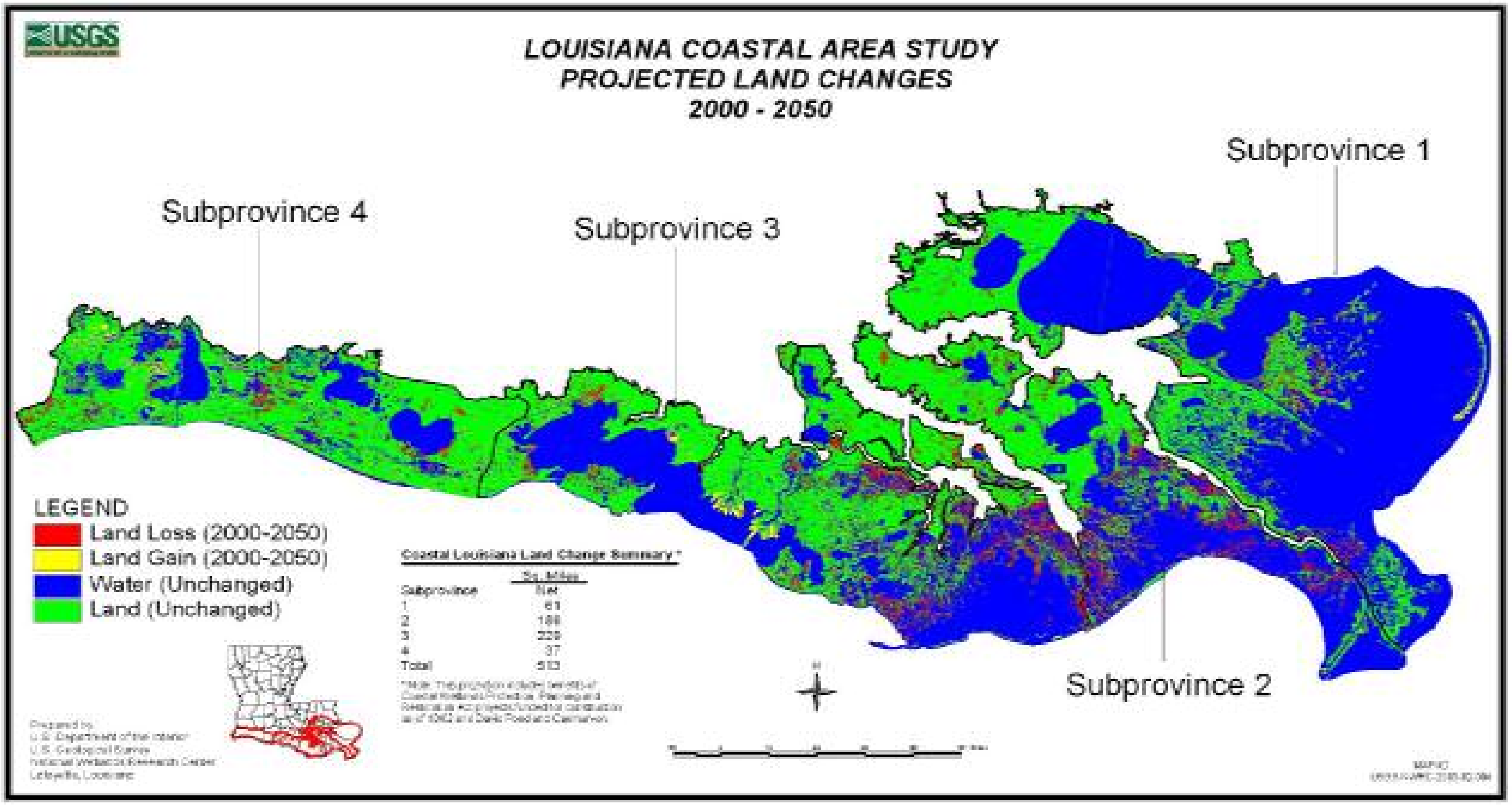

Figure 3-2 Four Subprovinces of Louisiana's Coast Area (Source: USGS, 2007)

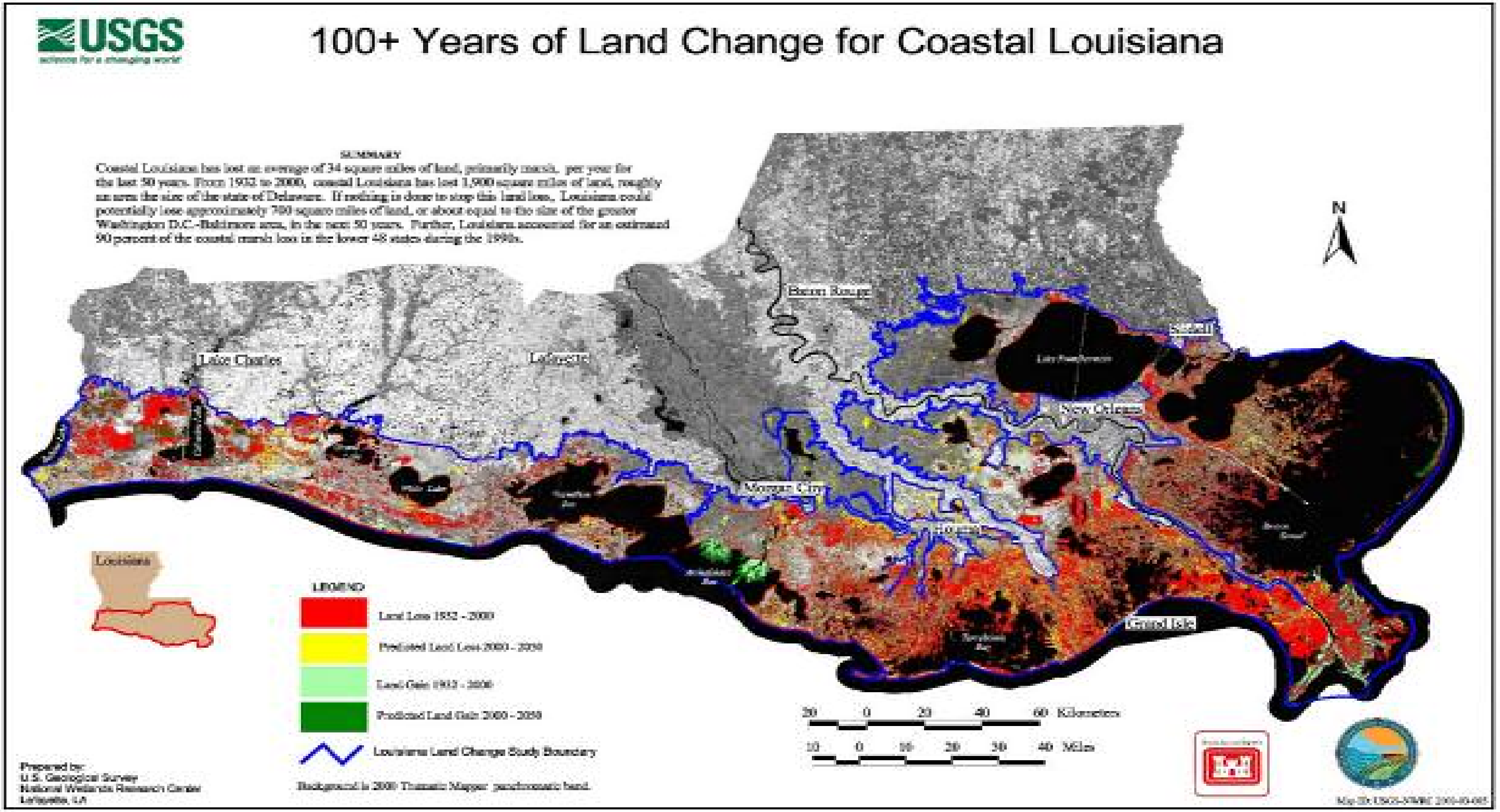

Figure 3-3 Land Changes for Coastal Louisiana from 1932 to 2050 (Source: USGS, 2007)

hurricanes is illustrated in Figure 3-4.

The study area is the Chenier Plain or Subprovince 4, which contains Calcasieu, Cameron, and Vermillion parishes (Figure 3-5).[9] These parishes are in southwest of Louisiana and north of the Gulf of Mexico. The study area is almost entirely comprised of the Calcasieu/Sabine Basin and the Mermentau Basin. As indicated by the information contained in Figure 3-5, only Cameron Parish and Vermillion Parish are adjacent to the Gulf of Mexico and the coastline.

Cameron Parish is the largest parish, by area, in southwest Louisiana. The total area of the parish is 1,932 square miles, 1,313 square miles of which is land and the remaining 619 square miles constitutes water. In percentage terms, 32.0% of the Parish is considered water. Approximately 75% of the parish's acreage is wetlands. As of the 2000 census (USCB, 2002), there are 9,991 people, 3,592 households, and 2,704 families residing in the parish. The population density is approximately eight per square mile. There are 5,336 housing units at an average density of four per square miles. Primary commodities produced in the parish include rice, cattle and calves, beef cows, soybeans, and hay-alfalfa (USCB, 2002).

The reported land area of Calcasieu Parish is 1,071 square miles and its population density is 157 per square mile. Primary commodities produced in the parish include rice, beef cattle, soybeans, sugarcane, crawfish, and sorghum.

The total mass area of Vermillion Parish equals 1538 square miles. Seventy-six percent of this total (1174 square miles) is land while water constitutes 24% of the total (364 square miles). Its population density is 42.6 per square mile. Most of Vermillion Parish is located in the Chenier Plain or Subprovince 4, though some of the eastern most portion of the Parish is in Subprovince 3 of the Deltaic Plain.

Wetland loss in subprovince 4 over the past 100 years is illustrated in Figure 3-3. While

[9] Because not all Vermillion Parish is located in the Chenier Plain, some properties in Vermillion are in Subprovince 3 and the study area extends a little bit to the Deltaic Plain. As such, the study area is not strictly in the Chenier Plain.

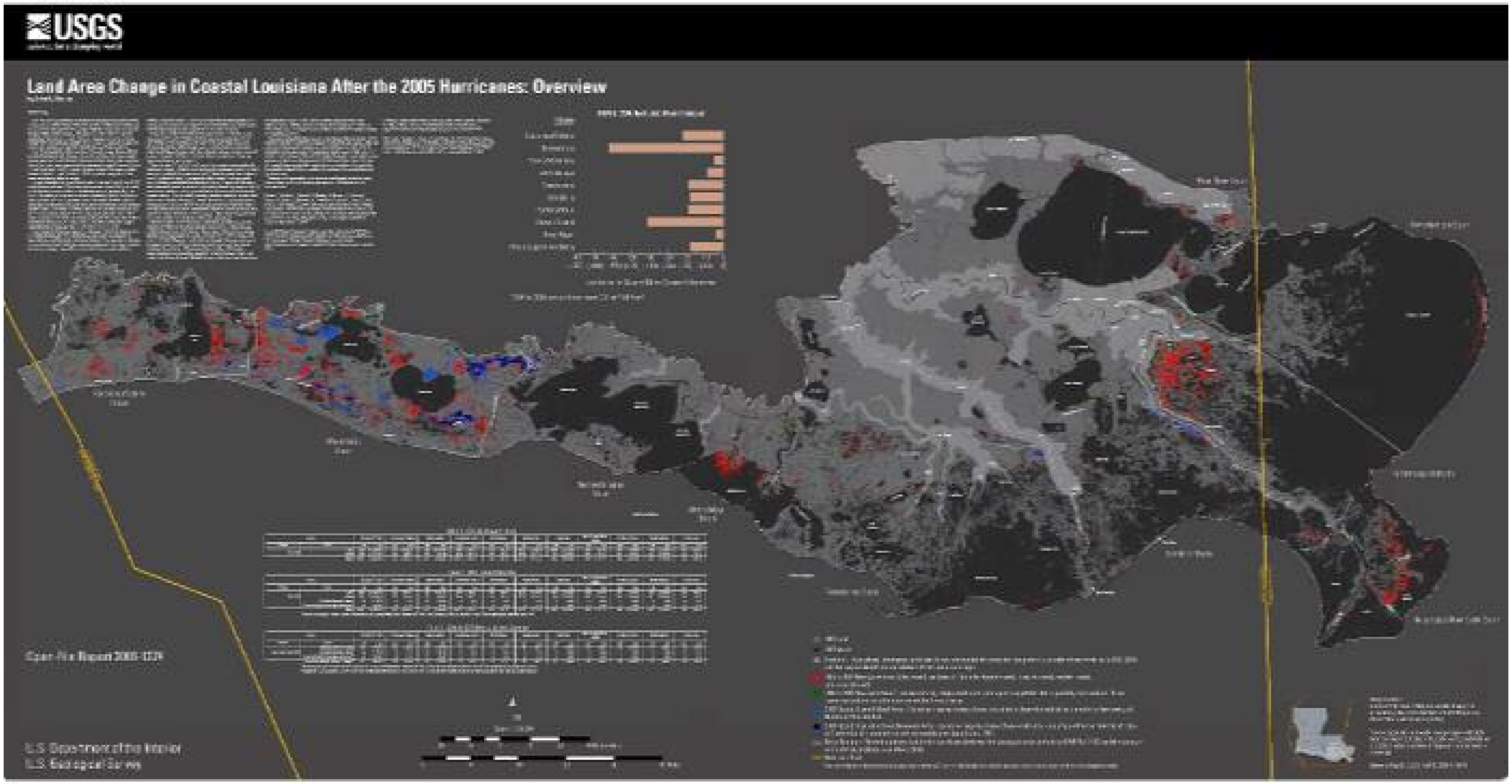

Figure 3-4 Land Changes of Coastal Louisiana Affected by the 2005 Hurricanes Katrina and Rita (Source: Barras, 2006)

Figure 3-5 The Study Area

many factors account for the loss, a considerable portion of the loss is argued to be the result of extensive hydrologic alterations. While there has been wetland loss in this subprovince (the Chenier Plain), it has been, as indicated by the information in Figure 3-3, significantly less than that in eastern coast region of the Louisiana coast area (the Deltaic Plain).

It is estimated that 164 square miles of wetlands were lost in subprovince 4 as a result of Hurricane Rita. This represents about one half of the expected total land loss resulting from the two hurricanes (i.e., Hurricane Katrina and Hurricane Rita) that impacted Louisiana in 2005 (Barras, 2006).

3.2 Data Collection and Transformation

This study is based on primary data collected and transformed in order to make it meaningful for analysis. Doing so required the following steps. First, wetland property transactions were collected from the relevant courthouses (Cameron, Calcasieu, and Vermillion). Second, the boundaries associated with each property were mapped using the Geographic Information Systems. Third, the maps associated with each property were merged with other data sets (e.g., the U.S. Geological Survey wetland database) in order to generate relevant property characteristics (e.g., acres of different types of wetlands). The completion of these three steps provided the relevant information (i.e., data) needed to estimate the regression analyses associated with the hedonic pricing model. The procedure of data collecting and processing is shown in Figure 3-6.

3.2.1 Collecting Conveyance Transaction Deeds

The study collected relevant information pertaining to property transfers from conveyance deeds available at the respective courthouses (i.e., courthouses in Calcasieu, Cameron and Vermillion parishes). These conveyance records provided information on each transaction including, but not limited to: (a) the boundary of property included in the

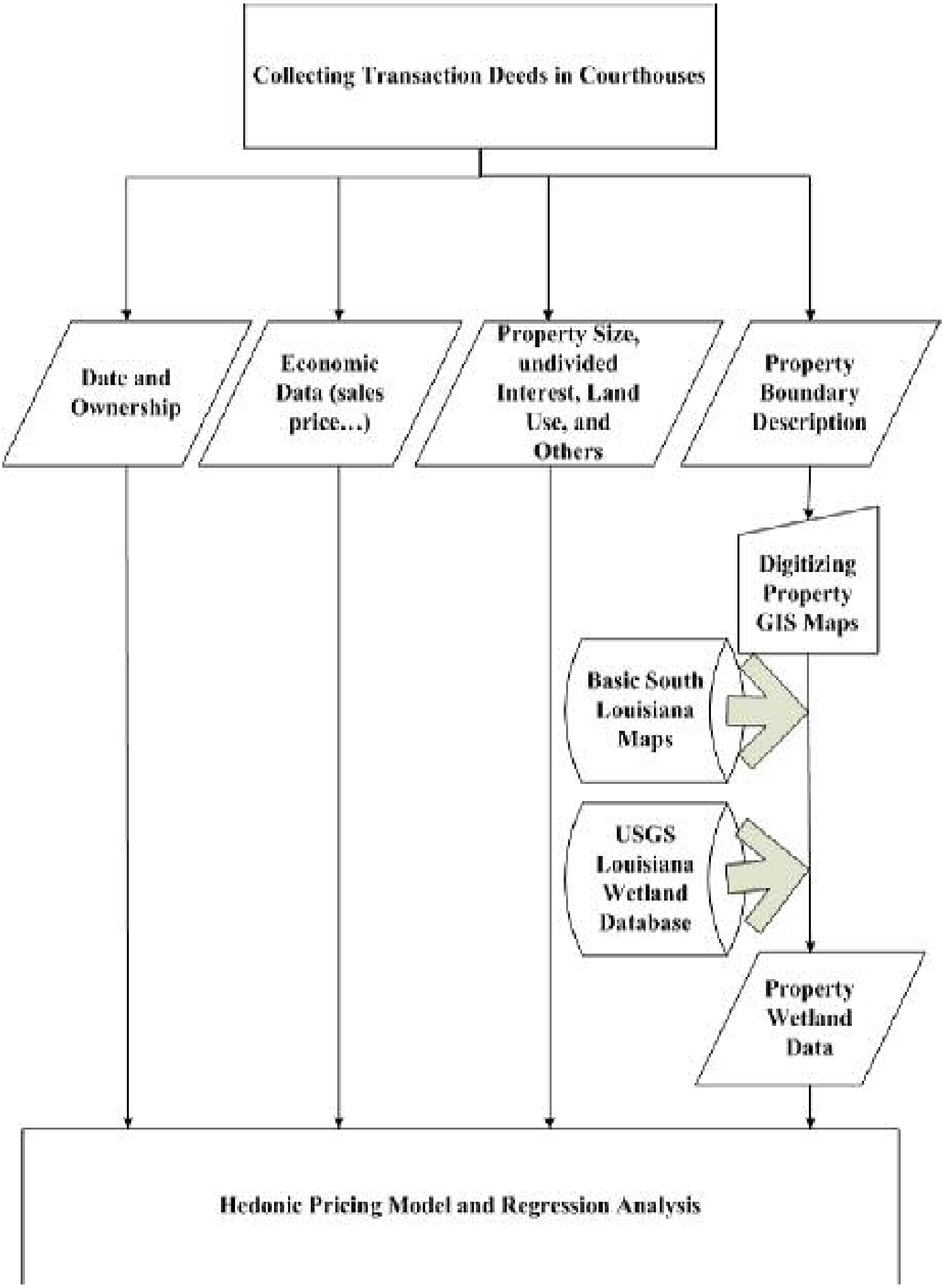

Figure 3-6 Data Collecting and Processing Procedure

transaction[10], (b) acreage included in the transaction[11], (c) proportion of interest in property that is being sold[12], (d) the number of parcels included in the transaction[13], (e) the price associated with the property being transferred, (f) the transaction date, and (g) the relevant names and addresses of both sellers and buyers. Data collected from these deeds of particular interest to this study included: the property boundaries, sales price information, features associated with the transfer (e.g., acres and proportion of interest in property that was being transferred), and transaction date (Figure 3-6).[14]

Thousands of property conveyance deeds are recorded in the courthouses of the three parishes of southwest Louisiana.[15] Correspondingly, the transactions collected in the study comply with some criteria or rules. First, sales of relatively small wetland properties (generally, less than about 40 acres) were excluded from the analysis. Second, transactions with vague description of property boundaries were eliminated since digitizing these properties proved to be exceeding cumbersome[16]. Other transferred properties were not considered for inclusion in the analysis because of exceptionally low (or high) specified sale

[10] Descriptions of some property boundaries in their conveyance deeds are hard to follow the drawing and digitizing, and they cannot be used in this research.

[11] The acreage information on many of the conveyance deeds was considered "unofficial" and did, in some instances, differ from that estimated after mapping the property boundaries.

[12] Sometimes a property seller sold the buyer a share of a property which is shared with others and undivided. If a buyer purchases a whole property, the undivided interest for the buyer is 100%, or 1; if he or she purchases half of an undivided property, the undivided interest is 50%, or 0.5.

[13] In many instances more than one parcel was sold under a given transaction.

[14] Determination of whether the transaction was "arms length" was often made at the initial stage of the process (i.e., when collecting the deeds from the respective courthouses).

[15] The number of wetland properties that were transferred was, however, relatively limited. In an effort to facilitate research, we focused on those wards where wetland acreage was known to be large. To some extent, these wards were selected based on tax assessment records as well as with help from personnel in each of the tax assessor's offices.

[16] For example, boundaries for some properties were specified in terms of boundaries of other properties. Hence, to determine the boundaries for the property of interest (i.e., that property that was sold), boundaries of several properties would need to be digitized. In other instances, boundaries were specified in terms of some physical object (e.g., pipeline or canal) for which information was not readily available.

prices.[17] Finally, transactions used in the analysis were limited to those occurring during the 1990 through 2006 period. There were two primary reasons for limiting the analysis to these years. First, while information on transactions occurring prior to 1990 was available, transfers prior to this period were infrequent. Second the probability of significant structural shifts, not included in the estimation process, increases in conjunction with the timeframe used in the analysis. As such, inclusion of property transfers prior to 1990 was deemed 'unwise.'

Overall, a total of 130 individual property transactions meeting the conditions previously stated (i.e., size and date) were identified during the collection process. For reasons discussed in a later section, however, the number of observations utilized in the hedonic price model was less than the available 130 properties for which information was collected.

3.2.2 Digitizing Property Maps

The relevant property transfers were collected and then entered into a GIS system with the ArcGIS system. The time-consuming step converted the text boundary descriptions of the studied properties, with or without manual paper maps, into digital GIS maps. Figure 3-7 displays every collected property as an area or polygon, rather than as a single point on the map.

3.2.3 Acquiring Wetland and Distance Data of Properties

Another data source used in the current analysis is the wetland database developed and maintained by the United States Geological Survey (USGS), National Wetland Institute[18]. This database is a high resolution source providing relevant wetland features including types of marsh by area, open water by area, historical wetland loss by area, and projected loss during the 2000-2050 period. Projected wetland loss is provided on the basis of three

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[17] Low prices likely reflect attempts to evade paying capital gain taxes on property sales or transfers that were not at "arms length" (even though the buyer and seller had different names). There were relatively few property transfers with abnormally high prices.

[18] The U.S.G.S. databases give relevant wetland information for four years: 1956, 1978, 1988, and 2000.

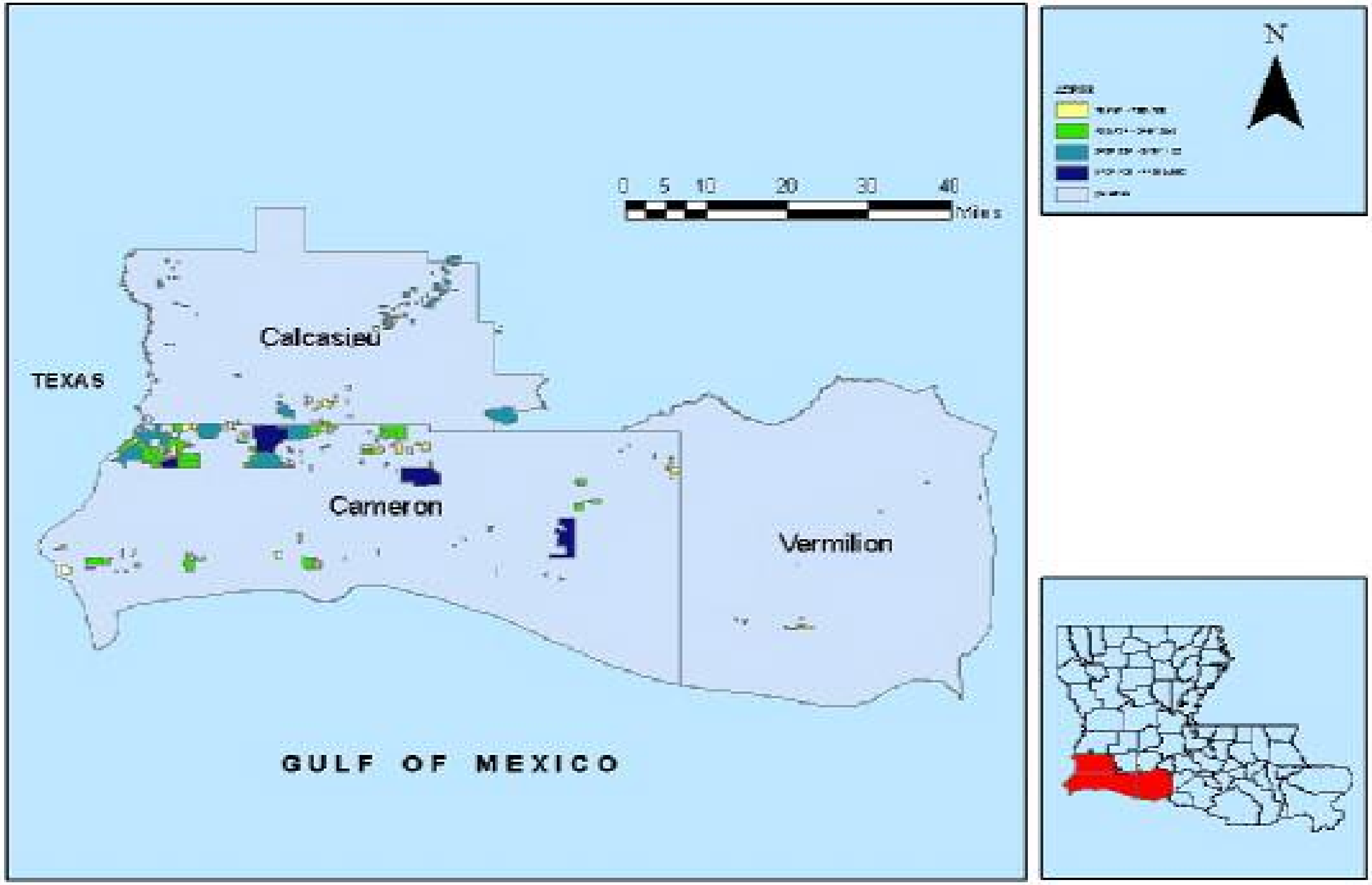

Figure 3-7 Property Distribution Map

categories (four categories if "no loss" is included): nominal, moderate, and extreme.[19] The projected wetland loss along Louisiana's coast during the period 2000-2050 is illustrated in Figure 3-8.

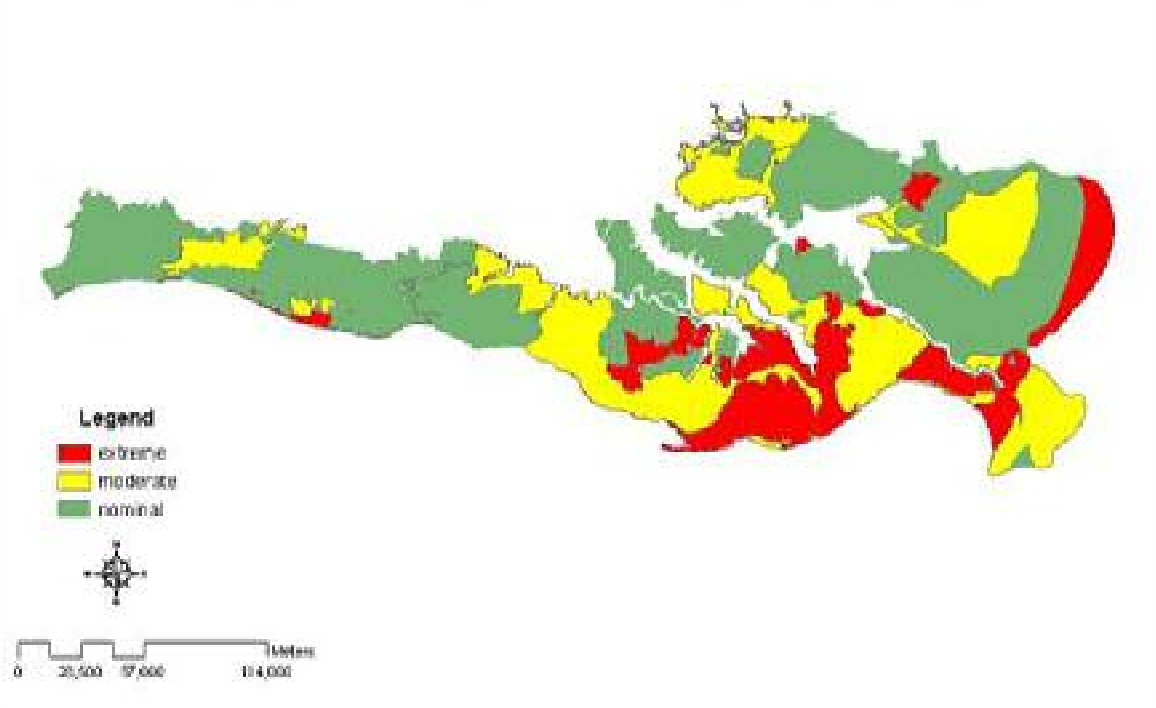

Figure 3-8 Projected LCA Wetland Loss for 2000-2050

Merging the 130 digitized properties with the USGS wetland databases permitted the estimation of wetland characteristics associated with each individual property - such as open water acreage, fresh marsh acreage, intermediate marsh acreage, brackish marsh acreage, and saline marsh acreage. In addition, merger of the databases allowed for estimation of changes from land to open water (or vice versa) associated with each individual property during the 1956-2000 period.[20]

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[19] A detailed discussion of the estimation procedure used to calculate projected wetland loss is found in Barras et al. (2003).

[20] As discussed in greater detail in a subsequent section, losses of land to open water (or vice versa) during the 1956-2000 period were insignificant (if any) for all considered properties. While wetland loss in the western coastal portion of the state is known to be less than along the eastern portion, the finding of no significant wetland loss was still somewhat unexpected. This unexpected finding is somewhat disturbing in that it may indicate some self-selection bias associated with properties being transferred. Specifically, it may indicate that properties of lower quality (i.e., those with a large land loss rate) are not being transferred due to a lack of interest among potential buyers. As indicated in Figure 3-7 and Figure 3-8, most, but by no means all, of the transfers in Cameron Parish are in the northwest where one might hypothesize a lower rate of wetland loss.

Finally, combining the digitized property information into the relevant Louisiana GIS basic maps (road, land and water, coast, city and town, population, stream, and lake, etc.) produces the requisite accessibility characteristics data associated every individual property[21]. Such information includes distance of each property to the nearest primary local road, distance of each property to the coastline, and distance of each property to the nearest city, town or village which has a population in excess of 1,500.[22]

Of the 130 digitized properties, a total of 119 were used in the analysis. Among the 11 discarded properties, seven were not included in the coastal zone[23] and, hence, were not represented in the USGS database. One property was deleted since it was traded with cash and other goods. Three properties were removed since their transfer prices, expressed on a per acre basis, were exceptionally high. Among the 119 transactions used in the analysis, 105, or 88%, are from Cameron Parish; 5 from Calcasieu; 9 from Vermillion.

Of the 119 properties used in the analysis, 95, or 80% represented the transfer of a single piece of property. The remaining 24 represented the transfer of two or more pieces of property; often not contiguous in nature. While one might consider deletion of those transfers representing noncontiguous properties, such action was not taken in the current study due to the relatively small sample size.

3.3 Description of Variables Used in Hedonic Analysis

The hedonic model seeks to estimate the "true price" – that dollar value agreed upon by willing buyers and sellers, each with full information and no coercion- based upon property

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Closer examination suggests that a large portion of 'central" Louisiana is part of the Sabine Wildlife Refuge while land along the coast is generally owned by a relatively few "large" landowners.

[21] For a noncontiguous property (with two or more separated parcels), the nearest distance of each parcel to primary roads, coastline, or cities/towns are calculated, and the shortest is chosen as the nearest distance of the property to primary roads, coastline, or cities/towns.

[22] While distance to the nearest town or cit y was estimated, it was not used in the analysis since it was not expected to significantly influence property prices.

[23] The USGS database has no land or water information for most or all part of these properties.

(and other) characteristics. In theory, only “arms length” transactions should be included in the analysis. Insufficient information existed to determine whether each of the 119 observations included in the analysis represented an ‘arms length’ transfer but a cursory examination of the transactions did not explicitly indicate any ‘less than arms length’ transactions[24]. Hence, no observations were deleted due to concerns regarding transactions that may have been coerced or otherwise not accurately representing willing buyers and sellers.

There are four primary wetland categories found in the Southwest Louisiana coastal zone: fresh marsh, intermediate marsh, brackish marsh, and saline marsh.[25] A description of each of these marsh types is presented in Table 3-1. As indicated, fresh marsh tends to be found further inland than the other marsh types while saline marsh is found closest to the Gulf of Mexico. Being further inland, the salinity associated with fresh marsh is relatively low and, hence, the property is more conducive to income-generating activities, such as trapping, alligator hunting, and the collection of alligator eggs. In a survey of coastal wetland owners, for example, Roberts et al. (2000) found that that annual gross revenues derived from Louisiana’s coastal wetlands averaged less than $2.00 per acre and ranged from $0.28 per acre for saltwater marsh to $2.23 per acre for freshwater marsh (net revenues would be considerably less).[26]

[24] For example, no property transactions occurred between individuals, groups of individuals, corporations with the same last names or addresses. Many of these properties were deleted during the initial screening process at the respective courthouses.

[25] According to the LCA report (2004), there are an estimated 803 thousand acres of wetlands in Subprovince 4. Of this total, 347 thousand constitute fresh marsh, 285 thousand constitute intermediate marsh, 138 thousand constitutes brackish marsh, and 30 thousand constitutes saline marsh. Less than 4 thousand acres is considered swamp.

[26] Analysis by Roberts et al (2000) included only surface-right revenues. Complicating the situation is the fact that considerable oil-and-gas revenues are derived from some of the coastal properties. However, sub-surface revenues are independent of surface characteristics of the property (e.g., conversion from wetlands to open water, while likely to result in a change in surface revenues, will not result in any change in sub-surface revenues except in the extreme event where the property reverts back to the state).

Table 3-1 Coastal Louisiana Wetland Categories

	Location	**Average Salinity (ppt)**	**Plants found**	**Animals found**
Fresh	Farthest inland	0.5-1.0	maidencane, bulltongue, alligatorweed, cattails, and spikerush	frogs, turtles, ducks, alligators, muskrats, mink, otters, egrets, herons, and hawks
Intermediate	Seaward of fresh	3.3	spikerush, three-corner grass, arrowhead, cordgrass, wiregrass, roseau cane, deer pea, and water hyssop	waterfowl, wading birds, marsh hawks, and fur bearers, brown shrimp, blue crab, and gulf menhaden
Brackish	Between intermediate and saline	8	Cordgrass and wiregrass	Blue crab, shrimp, speckled trout, redfish, muskrats, raccoons, mink, and otters
Saline	Closest to and along shoreline	16	Oyster grass	Redfish, speckled trout, blue crabs, and shrimp

A summary with a brief description of all variables used in the current study are presented in Table 3-2. Price associated with the transaction (PRICE2K) and price per acre (P2KPACRE) are the untransformed dependent variables used in the analysis.[27] As indicated, the average transactions price (PRICE2K) among the 119 properties used in the analysis equaled $300 thousand, which translates to $593 when evaluated on a per acre basis (P2KPACRE). There was, as indicated, considerable variation in the per acre price with price per acre ranging from a low of $44 to a high of $2,939. As discussed in greater detail below, the deflated price (PRICE2K) and deflated price per acre (P2KACRE) are the untransformed dependent variables used in the hedonic analysis.

For each property sale there is a set of associated explanatory (exogenous) variables that are used to explain the sales price of the property (either in total or on a per acre basis). The first one of relevance is the size of the property (ACRES), expressed in acres. As indicated, the average property size was 913 acres with a range from 36 acres to more than 11 thousand acres. On average, each property consisted of 346 acres of open water, 82 acres of fresh marsh, 301 acres of intermediate marsh, 92 acres of brackish and saline marsh, and 94 acres

[27] For purposes of this study, all prices and prices per acre have been adjusted for inflation based on the 2000 Consumer Price Index as calculated by the U.S. Department of Commerce.

of “other” property. For purposes of discussion, these different wetland components will be referred to as wetland characteristics variables.

Table 3-2 Symbols and Descriptive Statistics Associated with the 119 Coastal Properties Used in the Analysis

Symbol	Variable	Mean	Minimum	Maximum	Standard Deviation
PRICE2K	Price adjusted by the 2000 CPI ($)	300047.72	3507.90	3369130.40	555668.09
P2KPACRE	Price per acre adjusted by 2000 CPI ($)	593.67	43.57	2938.65	530.19
ACRES	Size of property (acres)	913.19	36.21	11395.48	1730.63
OPENW	Open water (acres)	345.78	0	6551.26	988.62
FRESH	Fresh marsh (acres)	81.87	0	2778.18	333.95
INTER	Intermediate marsh (acres)	300.52	0	4139.19	665.09
BS	Brackish and saline marsh (acres)	91.51	0	1700.89	234.77
OTHER	“Other” land (acres)	93.51	0	1663.51	264.28
DROAD	Distance to the nearest road (meters)	3871.20	0	17333.12	5141.07
DCOAST	Distance to the nearest coastline(meters)	27530.55	5451.50	46634.91	10856.81
INTEREST	Share of all property	0.956	0.03	1	0.172
YR	Transaction Year (year minus 1986)	13.41	4	20	3.02
DUMCOUNTY	Parish (% of properties located in Vermilion divided by 100)	0.076	0	1	0.266
DUMNOLOSS	No projected wetland loss (% of properties divided by 100)	0.176	0	1	0.383
DUMNOMLOSS	Nominal projected wetland loss (% of properties divided by 100)	0.782	0	1	0.415
DUMMODLOSS	Moderate projected wetland loss (% of properties divided by 100)	0.042	0	1	0.201
DUMSECT	Percent of transactions including non-contiguous properties	0.202	0	1	0.403

As indicated by the information in Table 3-2, the standard deviations associated with the five wetland characteristics (e.g., open water, fresh marsh, intermediate marsh, brackish and saline marsh, and “other” property) are large, generally exceeding the mean values of each of these variables by a factor of two to three. Given the nature of these variables, these large standard deviations are to be expected. Specifically, recall that fresh marshes are generally found furthest inland while brackish and saline marshes are found closest to the coast. For this reason, the observance of fresh marsh on a given property decreases the probability of also observing brackish and saline marsh. As the information in Table 3-2 suggests, minimum values for all wetland characteristic variables are zero reflecting the (to some extent) mutually exclusive nature of the wetland characteristic variables.[28] Overall, of the 119 properties used in the analysis, only two properties (1.7%) had positive values for all five wetland characteristics variables. An additional 14 properties (11.8%) had positive values for four of the five wetland characteristics variables. A total of 47 properties (39.5%) had three of the five wetland characteristics variables. The remaining 56 properties exhibited only one (4 properties) or two (52 properties) of the five wetlands characteristics.[29]

As indicated by the information in Table 3-3, open water, with 41 thousand acres, accounts for almost 40% of the total acreage (i.e., 108,670) among the 119 properties used in the current analysis while intermediate marsh represents an additional 33%. Fresh marsh accounts for an additional 9% of the total acreage among the 119 properties while similar figures apply for both the brackish and saline marsh category and the "Other" category[30] (Table 3-3).

As noted, the 119 properties included in the analysis totaled 109 thousand acres. This total, however, includes both open water and "other" and these categories do not represent wetlands. Subtracting these two categories from the total provides an estimate of wetland acreage equal to 56,395 acres. This total constitutes approximately seven percent of the 803 thousand total wetland acres as reported in the LCA report (2004). This relatively small percentage reflects two factors. First, privately held wetland properties are not frequently sold; particularly in light of the fact that a few large corporations (e.g., Miami Corporation, Apache

[28] As discussed in Chapter 4, the large number of zero values associated with wetland characteristics variables can lead to problems in estimating reliable parameters and associated standard errors.

[29] Of the 119 properties used in the analysis, 113 of the total (95%) had a positive value for open water. By comparison only 29% of the 119 observations had a positive value associated with fresh marsh, 49% of the observations had a positive value for intermediate marsh, 37% of the observations had a positive value for brackish and saline marsh, and 55% of the properties had a positive value associated with "other" property.

[30] Brackish marsh and saline marsh are separated in the USGS database of wetland characteristics. Less than 0.4 percent of the acreage (totally 393.94 acres saline marsh for all 119 studied properties) transferred in the study constituted saline marsh based upon USGS information. Brackish marsh has the most familiar features with saline marsh among 3 other marshes. Hence, saline marsh was combined with brackish marsh to create a single marsh designation in the current study.

Corporation) own large tracts. Second, a sizeable amount of the coastal property in Subprovince 4 is owned by the state (e.g., the Rockerfeller Refuge) and, thus, is not traded.[31]

Table 3-3 Summary Statistics Associated with Wetland Characteristics Variables

	Open Water	Fresh	Intermediate	Brackish & Saline	Other	Total
Acreage(acres)	41,148	9,743	35,762	10,890	11,128	108,670
Mean (acres)	345.78	81.87	300.52	91.51	93.51	913.19
Percent (%)	38	9	33	10	10	100

Other variables associated with wetland characteristics that are used in the current analysis relate to the 2000-2050 projected wetland loss. As the information in Table 3-2 indicates, about 18% of the 119 properties used in the current analysis are expected to exhibit no land loss during the 2000-2050 period. Another 78% are expected to exhibit a nominal loss. Finally, about four percent are expected to exhibit moderate loss during the 50-year period ending in 2050.

The variable YR, representing a simple time trend, is used to “capture” changes in price that occur on a systematic basis and that are not captured by other variables included in the model. In general, one would expect a derived demand for at least a portion of wetland properties and the derived demand is related to the income-generating potential of the property.[32] If the income-generating potential has increased over time, one would expect

[31] According to the information in the LCA report (2004), about 43% of the total wetland acreage is comprised of fresh marsh which is a significantly higher percentage than the 17% (i.e., 9,743/56,395) being used in the current study. Conversely, about 63% of the wetland acreage in the current study is comprised of intermediate marsh which is almost twice the percentage of that reported in the LCA report (35%). Reasons for the observed differences may reflect a large number of factors including, but not limited to: (a) fresh marsh may be sold less frequently vis-à-vis intermediate marsh, (b) a large share of the state property may be comprised of fresh marsh, or (c) wetland acreage maintained by large corporations may be overwhelmingly fresh marsh.

[32] The demand would be “derived” in nature if the property is used in income-generating activities. Some properties are likely used exclusively for recreational activities (e.g., duck hunting). Changes in demand for these properties for recreational purposes would also be captured by the variable YR if the change is systematic.

price to be positively related to the time trend.

Distance of the property from the coast is measured by the variable DCOAST while distance of the property from the nearest primary road is measured by the variable DROAD. In some instances, the property being sold may have multiple owners and only one owner is selling his share of the property. Furthermore, some sales included multiple properties. The variable INTEREST represents the proportion of the property that is being sold,[33] while the variable DUMSECT represents a binary variable indicating whether the sale represents two or more noncontiguous properties (DUMSECT equal to one if the sale involves two or more non-contiguous properties). Finally, DUMCOUNTY is a binary variable equal to zero if the property is located in either Cameron Parish or Calcasieu Parish and one if the property is located in Vermilion Parish.

In general, economic theory provides only limited guidance regarding the influence of the exogenous variables included in this analysis on price (in total or on a per acre basis). Unambiguously, an increase in total acres (comprised of any of the five wetland categories) should result in an increase in the total price (i.e. the amount for which the property was transferred). Hence, one can conclude that an increase in acreage of any of the five wetland characteristics variables (open water, fresh marsh, intermediate marsh, brackish and saline marsh, or "other" acres) should result in an increase in the total price (PRICE2K). Furthermore, given their higher income generating potential (or use in recreational activities), one might anticipate that FRESH and OTHER to have the largest positive influence on total price (PRICE2K) after controlling for all other factors that might influence price. The relative influences of the other three wetland characteristics variables (OPEN, INTER, and BS) on PRICE2K are more difficult to discern, *a priori*.

Economic theory would also suggest that property values should be discounted in

[33] For example, a property that is being offered for sale may be jointly held by two owners, each with a 50% share. If only one of the owners is selling his/her share, the value for the variable INTEREST would be 0.5.

relation to expected degradation.[34] The binary variables used to “capture” this expected degradation include DUMNOLOSS[35], DUMNOMLOSS, and DUMMODLOSS. Properties associated with either DUMNOMLOSS and DUMMMODLOSS are expected to be valued lower by buyers and sellers than those properties associated with DUMNOLOSS and the variable DUMMODLOSS is expected to have the greatest negative influence on PRICE2K.

One would also hypothesize that PRICE2K increases in relation to the share of the property being traded (INTEREST), *ceteris paribus*. Conversely, one would hypothesize a decline in price (PRICE2K) as the distance to the nearest primary road (DROAD) increases. The expected relationship between PRICE2K and distance to the coast (DCOAST) is ambiguous as is relationship between PRICE2K and the time trend (YR).[36]

While much of the discussion relating total price (PRICE2K) to the influence of the various exogenous factors remains the same when examining the relationship between price per acre (P2KPACRE) and those exogenous variables, there are some differences that need to be considered. Specifically, the five different wetland characteristics variables (OPENW, FRESH, INTER, BS, and “OTHER”) are expected to influence the price per acre in different directions, depending upon the value associated with each independent characteristic. Given the expected higher income generating potential (or recreational consumptive value) associated with FRESH and “OTHER,” one could hypothesize that these variables would

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[34] One exception to this generalization would be if open water acreage is considered more valuable to the wetland owner than marsh acreage or “other” acreage. In this case, a premium may be paid on property that is expected to be degraded over time.

[35] These three variables are discrete in nature. As discussed in greater detail in the next Chapter, the variable DUMNOLOSS is deleted from the hedonic modeling analysis in order to avoid a singular matrix.

[36] More relaxed duck hunting regulations over time (e.g., an extended season and a higher bag limit) might suggest that PRICE2K is positively related to YR (regardless as to whether the property is being leased to others for hunting privileges or used by the buyer for hunting activities). However, the change in other income generating activities over time is unknown.

exhibit a positive influence on price per acre. However, other wetland characteristics variables may be expected to exhibit a negative influence on price per acre.[37]

[37] In accordance to the theory associated with the hedonic model, there is a value associated with each individual characteristic that comprises the "good" being considered. When considering the five wetlands characteristics in the current analysis, one characteristic will have an 'average" value while other wetland characteristics variables will have values either above or below this "average." For those with values above the 'average," the relationship between those characteristics variables and price per acre will be positive. For those with values below the "average," the relationship will be negative.

CHAPTER 4 METHODOLOGY

4.1 Hedonic Price Function

4.1.1 The Basic Model

Most applications of hedonic price function are based on the theoretical framework provided by Rosen (1974). As presented by Freeman (1993), the basic property hedonic price model assumes that each individual's utility is a function of the consumption of a composite commodity denoted by X, a vector of location-specific environmental amenities (E), a vector of structural characteristics associated with the property (S), and a vector of neighborhood characteristics (N). Then the person's utility can be expressed:

$$u = u(X, E, S, N) \tag{4-1}$$

Following Freeman (1993), the basic model assumes that preferences are weakly separable in property characteristics. Hence, the demands for characteristics are independent of the prices of other goods. Furthermore, the hedonic model is premised on the assumption that the property market is in equilibrium, the implication of which is that all individuals maximize their utilities based on the prices of alternative properties. Given all property choices, prices are assumed to clear the market. Under these assumptions, the price of any property can be expressed as:

$$P_h = P_h\left(E, S, N\right) \tag{4-2}$$

Equation (4-2) is regarded as the hedonic price function (Freeman, 1993).

For purposes of the current analysis, most variables selected for inclusion in the respective models can be considered as structural variables. Specifically, all wetland characteristics [acres of open water (OPENW), acres of fresh marsh (FRESH), acres of intermediate marsh (INTER), acres of brackish and saline marsh (BS), and "other" acres (OTHER)] would be included in the vector of structural variables. Similarly, measures of expected wetland degradation (DUMNOLOSS, DUMNOMLOSS, and DUMMODLOSS) would also be considered structural variables, as would the variable designating whether the sale involved two or more properties not contiguous in nature (DUMSECT). Distance from the nearest main road (DROAD) and distance to the coast (DCOAST) could be considered neighborhood characteristics.

4.1.2 Functional Forms

The basic functional form of the hedonic price model (Equation 4-2) is generally nonlinear (Freeman, 1993). When the regression analysis for the hedonic price model is applied in environmental and natural resource researches, mathematical transformation of variables, which transforms nonlinear functions to linear functions, is often necessary for analysis. As such, the choice of functional form has been important in the specification of the hedonic price model. A choice of functional form is the first step for running the hedonic model.

Because economic theory provides little guidance regarding how property characteristics functionally affect the property prices, a best fit functional form is difficult to determine on an *a priori* basis (Halvorsen and Pollakowaski, 1981; Cropper et al., 1988; Smith and Huang, 1995). Freeman (1993) summarized the functional forms used in the earlier literature, including the linear, the quadratic, the log-log, the semi-log, the inverse semi-log, the exponential, and the Box-Cox transformation. Most of earlier studies employed parametric methods for estimation purposes. Graves et al. (1988) concluded that a flexible functional form presented by Box and Cox (1964) provided the better specification for their hedonic models. Wooldridge (1992) listed some flexible functional forms as alternatives to the Box-Cox transformation and suggested that some alternatives provide "better" results.[38]

[38] Recent studies have shown a growing interest in nonparametric and semi-parametric regressions for hedonic price analyses because only weak assumptions on functional forms are required and the relationship among the variables of interest may be directly estimated (Pace, 1988; Iwata et al., 2000; Clapp et al., 2002; Bin, 2005; Bin

For purposes of this study, two alternative hedonic wetland model specifications are proposed. The first model, denoted MODEL 1, uses the total deflated price (PRICE2K) as the dependent variable. Deflated price per acre (P2KPACRE) is used as the dependent variable in the second model specification and is denoted as MODEL 2. For purposes of discussion, MODEL 1 is first considered and then attention is given to MODEL 2.

4.1.2.1 MODEL 1 Functional Form

Since economic theory provides little guidance regarding how property characteristics functionally affect the property prices, a Box-Cox transformation analysis, as suggested by Graves et al. (1988) was used to provide guidance regarding the model specification.[39] The Box-Cox transformation of the dependent variable is given as follows:

$$y^{(\lambda)} = \begin{cases} \dfrac{y^{\lambda}-1}{\lambda}, \ldots \lambda \neq 0 \\ \ln y, \ldots \lambda = 0 \end{cases} \tag{4-3}$$

Given this specification, if lambda is significantly different from one, the model is nonlinear. If equal to one, the model is linear.

Using the Box-Cox transformation procedure, the hedonic model associated with MODEL 1 is given as follows:

$$(PRICE2K^{\lambda} - 1)/\lambda =$$

$$\begin{aligned} &\alpha_0 + \alpha_1 \times OPENW + \alpha_2 \times OPENW^2 + \alpha_3 \times FRESH + \alpha_4 \times FRESH^2 \\ &+ \alpha_5 \times INTER + \alpha_6 \times INTER^2 + \alpha_7 \times BS + \alpha_8 \times BS^2 + \alpha_9 \times OTHER \\ &+ \alpha_{10} \times OTHER^2 + \alpha_{11} \times DROAD + \alpha_{12} \times DCOAST + \alpha_{13} \times INTEREST \\ &+ \alpha_{14} \times YR + \alpha_{15} \times DUMCOUNTY + \alpha_{16} \times DUMNOMLOSS \\ &+ \alpha_{17} \times DUMMODLOSS + \alpha_{18} \times DUMSECT + \varepsilon \end{aligned} \tag{4-4}$$

where PRICE2K is the deflated sales price of the property; OPENW refers to open water

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and Polasky, 2005; Martins-Filho and Bin, 2005)

[39] Only the first stage of Rosen's (1974) two-stage hedonic price function is considered in the current study.

(expressed in acres); FRESH refers to fresh marsh (expressed in acres); INTER refers to intermediate marsh (expressed in acres); BS refers to brackish and saline marsh (expressed in acres); OTHER refers to “other” land (expressed in acres); DROAD refers to the distance to the nearest primary road (expressed in meters); DCOAST refers to the nearest distance to the coast (expressed in meters); INTEREST refers to the share of property that is being transferred; YR is a time trend (defined as the year of sale minus 1986); DUMCOUNTY is a discrete variable representing the parish in which the property is located (equal to one if Vermillion Parish and zero, otherwise); DUMNOMLOSS is a discrete variable equal to one if the expected rate of land loss between 2000 and 2050 is “nominal” (otherwise zero); DUMMODLOSS is a discrete variable equal to one if the expected rate of land loss between 2000 and 205 is “moderate” (otherwise zero); DUMSECT is a discrete variable equal to one indicating if two or more non-contiguous properties are included in the transaction (zero otherwise); α_0- α_{18} represent parameters to be estimated; and ε represents the error term.

A number of features associated with Equation 4-4 are worth noting. First, total acreage (ACRES) is not included in the model specification. While not directly included in the model, the sum of wetland variables characteristics (OPENW, FRESH, INTER, BS, and OTHER) will sum to the total number of acres.[40] However, the impact of a unit change in any of the five wetland characteristics variables (i.e., a one acre change) on deflated price can be determined by differentiating Equation 4-4 with respect to any of the variables.

A second feature of Equation 4-4 worth considering is the number of squared terms considered in the analysis (one for each of the wetland characteristics variables). These squared terms were included to provide more flexibility to the functional form, given the fact that little is known regarding the relationship between price and the wetland characteristics variables. For example, depending upon the size and magnitudes of the linear and quadratic

[40] Inclusion of ACRES would, of course, result in a singular matrix.

terms, initial increased acreage may result in total price increasing at an increasing rate (implying an increased price per acre as the number of acres initially increases). Beyond some point, however, the total value may increase at a decreasing rate with further increases in acres of the wetland characteristic.[41]

Finally, as indicated by Equation 4-4, the Box-Cox transformation is applied only to the dependent variable. While one could specify the model such that transformation of the exogenous variables is also permitted, the large number of zero observations associated with the wetland characteristics variables suggested that transformation may be unwise.[42]

4.1.2.2 MODEL 2 Functional Form

In MODEL 2, the dependent variable is the deflated price per acre (P2KPACRE). Given the fact that the sum of the wetland characteristics variables (OPENW, FRESH, INTER, BS, OTHER) sum to total acres (ACRES), this specification presents a special challenge. Some researchers have "handled" this problem by dividing each relevant variable by total acres (in this case, dividing each of the wetlands characteristics by total acres) and deleting one of the transformed variables to avoid the "dummy variable trap." Such a procedure is problematic, however, because the interpretation of partial derivative of price with respect to any of the transformed variables is of a questionable nature. Specifically, when taking a partial derivative with respect to any given variable, other variables are assumed to be held constant. Since the transformed variables sum to 100 (in percentage terms) by design, however, it is impossible to change one variable without other variables also changing by the same magnitude (though in the opposite direction). In the current analysis, for example, if all wetland characteristics variables (OPENW, FRESH, INTER, BS, OTHER) were divided by

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[41] In the extreme the total price may actually decline with additional acreage. This result, of course, could not be "backed up" by economic theory.

[42] Specifically, the log of zero is, of course, undefined. Therefore, one needs to replace zero values with some arbitrarily small (positive) value. Some preliminary runs suggested that the value selected did tend to significantly alter some parameter estimates (especially those parameters whose associated variables had a high percentage of zeros).

total acres (ACRES), evaluating the impact on price per acre as fresh marsh (as a percent of total acres) increases by an arbitrarily small amount becomes problematic unless the values associated with the other wetland characteristics variables are reduced in proportion.

As noted, there are five wetland characteristics variables. Given the five wetland characteristics variables, one approach to estimate the price per acre (P2KPACRE) hedonic model would be to normalize wetland characteristics variables. This was conducted with respect to MODEL 2 by dividing each of the wetland characteristics variables by open water (OPENW).[43]

$$(P2KPACRE^{\lambda} - 1)/\lambda =$$

$$\begin{aligned}
&\beta_0 + \beta_1 \times Ln(FRESH/OPENW) + \beta_2 \times Ln(INTER/OPENW) \\
&+ \beta_3 \times Ln(BS/OPENW) + \beta_4 \times Ln(OTHER/OPENW) \\
&+ \beta_5 \times Ln(DROAD) + \beta_6 \times Ln(DCOAST) + \beta_7 \times Ln(INTEREST) \\
&+ \beta_8 \times Ln(YR) + \beta_9 \times DUMCOUNTY + \beta_{10} \times DUMNOMLOSS \\
&+ \beta_{11} \times DUMMODLOSS + \beta_{12} \times DUMSECT + \varepsilon
\end{aligned} \tag{4-5}$$

where all variables, other than P2KPACRE (deflated price per acre), are identical to those used in the total price specification (i.e., MODEL 1) and the term *Ln* represents the natural log. β_0- β_{12} represent the parameters to be estimated.[44]

MODEL 2, like MODEL 1 uses the Box-Cox transformation of the dependent variable. Unlike MODEL 1, however, the continuous exogenous variables in MODEL 2 are expressed in terms of the natural log. The reason for this specification reflects the large number of zero values associated with the wetland characteristics variables. Specifically, unless the log transformation is imposed, many of the normalized wetland characteristics variables would tend to become "excessively" large in those instances where open water (i.e., the variable

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[43] This variable was selected for normalization purposes because it had relatively few zero values (a total of six).

[44] Total acres is not included in this specification because a linear combination of all wetland variable characteristics (in linear form) would equal total acres.

used for normalization) approaches zero.[45]

Finally, as noted, many of observations associated with the five wetland characteristics variables are equal to zero. How to treat zero values when transformed to natural logarithms presents a challenge. This is particularly the situation in the current analysis because (a) there are large number of zero observations, and (b) the sum of the individual wetland characteristics variables should sum to the total acres (ACRES). In order to preserve model homogeneity, therefore, the modified Aitchison procedure, as discussed by Aitchison (1986) was utilized. A description of this procedure is presented in the Appendix.

4.1.3 Marginal Implicit Prices

The parameter estimates derived from the hedonic price model can be used to estimate the marginal implicit price of each characteristic of the product being considered. The marginal implicit price is defined as the partial derivative of the hedonic price function with respect to any one-unit change in the characteristic being evaluated. That is, the marginal implicit price of each characteristic is an estimate of any change which is paid for the good (in this case the wetland property) brought about by a one-unit change in that characteristic, *ceteris paribus*. For purposes of this study, only MODEL 1 is used to determine marginal implicit prices.

For the continuous variables in MODEL 1 that do not include quadratic terms (i.e., DROAD, DCOAST, INTEREST, and YR), the partial derivatives, which are the marginal implicit prices, are given by the following:

$$IX_i = \frac{\partial P}{\partial X_i} = \alpha_i \times P^{(1-\lambda)} \qquad (4\text{-}6)$$

By substituting into Equation 4-6 the mean value of each variable (at the mean price and mean level of all exogenous variables over all observations), an estimate of the implicit

[45] The use of the Box-Cox procedure in instances where exogenous variables are expressed in a natural log basis is unclear.

marginal price can be derived (Kennedy, 1995).

For the wetland characteristics variables (OPENW, FRESH, INTER, BS, and OTHER) which each has a quadratic term, the marginal implicit price is given as follows:

$$IX_i = \frac{\partial P}{\partial X_i} = P^{(1-\lambda)} \times (\beta_i + 2 \times \beta_{is} \times X_i) \qquad (4\text{-}7)$$

where β_{is} represents the coefficient estimate of the squared term associated with each of the wetland characteristics variables (X_i).

For discrete variables, the study interprets them as proportion by which property value changes when the discrete variable is equal to one rather than zero (or vice versa). The formula for estimating this percentage change is provided in Equation 4-8:

$$ID_j = [(1 + \frac{\lambda \times c_j}{1 + \lambda \times Y_0})^{\frac{1}{\lambda}} - 1] \times 100\% \qquad (4\text{-}8)$$

Where ID_j is the estimated price change, expressed on a percentage basis, associated with a change in the discrete variable from zero to one, c_j is its estimated coefficient, λ is the best estimate for the Box-Cox transformation, and Y_0 is the value of the right side of Equation 4-4 when other continuous or dummy variables are held constant (here mean values are selected).

4.2 Regression Assumptions and Testing

For a successful estimate of parameters of a classical linear regression model (i.e., Ordinary Least Squares), a set of assumptions regarding the variables and the random disturbance term must be satisfied. When these assumptions are violated, results are likely to be misleading. The first step of the hedonic price study, after collecting necessary data, should not be to estimate the regression model parameters but, rather, to evaluate the underlying assumptions. It is often overlooked by researchers, and few articles reported whether these assumptions had been tested (Osborne et al., 2001).

As Greene (2003) indicated, there are five primary assumptions that should be considered when evaluating the classical linear regression model. These assumptions are considered below.

4.2.1 Linearity[46]

Let Y be a vector of dependent variable, let X be a matrix of independent variables or regressors, β the vector of parameters, and ε the vector of random terms. Then the linearity assumption can be expressed:

$$Y = X\beta + \varepsilon \tag{4-9}$$

A nonlinear relationship between the dependent and independent variables would distort the estimations of the model. There are two primary methods for detecting nonlinearity. The first is to routinely run regression analyses that incorporate curvilinear components (squared and cubic terms). The second is to examine the residual plots (plots of the standardized residuals as a function of standardized predicted values) to determine whether nonlinearities are present.

4.2.2 Full Rank

This assumption is that the independent variable matrix X is full rank. If it is of full rank, there are no exact linear relationships among the exogenous variables. When one exogenous variable is perfectly correlated with another (or subset of exogenous variables), multicollinearity will result in a singular matrix. As correlation among the exogenous variables increases, the ability to separate the influence (on the endogenous variable) of one exogenous variable from another is lessened. This generally results in less precision associated with the estimated parameters and increases the standard errors associated with the estimates.

Looking at variance inflation factors (VIF), or the tolerances, is a generally accepted

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[46] Given that a Box-Cox transformation was performed on the dependent variables in both hedonic models (MODEL 1 and MODEL 2), the issue of linearity becomes less meaningful.

practice for testing for multicollinearity. Let R be the multiple correlation, known as the coefficient of determination. Then, the R^2 represents the total amount of variance accounted for in the dependent variable by the independent variables, and the tolerance is calculated as $1-R^2$.

$$VIF = \frac{1}{1-R^2} \tag{4-10}$$

There is no 'critical' value for which one could conclude with any certainty that multicollinearity is a 'significant' problem. A rule-of-thumb widely used is that the largest VIF should not be larger than ten (Wetherill et al., 1986; Ryan, 1997). Multicollinearity becomes a 'significant' issue (i.e., one that would 'trigger' reconsideration of the model specification) when the VIF is greater than 10.

4.2.3 Independence

This assumption states that the expected value of the disturbance at any observation is not a function of the independent variables. The independent variables cannot carry useful information for prediction of random terms. The disturbance is assumed to have conditional expected zero value at any observation.

$$E[\varepsilon_i \mid X] = 0 \tag{4-11}$$

This assumption also states that the exogenous variables X, constant or random, is generated by a mechanism that is unrelated to the disturbance ε.

4.2.4 Spherical Disturbances

This assumption states that each disturbance has the same finite variance and is uncorrelated with every other disturbance. In other words,

$$Var[\varepsilon_i \mid X] = \sigma^2, \qquad \text{for all } i=1,\dots,n \tag{4-12}$$

$$Cov[\varepsilon_i, \varepsilon_j \mid X] = 0, \qquad \text{for all } i \neq j \tag{4-13}$$

Equation (4-12) suggests a constant variance of the error term, called homoscedasticity. If the variance is not constant, then model heteroscedasticity is present. Equation (4-13) shows the uncorrelatedness across observations, known as non-autocorrelation.[47]

For purposes of testing for homoscedasticity, the White's test is conducted (see Greene, 2003 for a description of this test). If the probability of White's test is greater than 0.05, the null hypothesis of homoscedasticity cannot be rejected.

4.2.5 Normality

As indicated by Equation 4-14, the assumption of normality implies that the disturbances are normally distributed.

$$\varepsilon \mid X \sim N\left[0, \sigma^2 I\right] \qquad (4\text{-}14)$$

The Shapiro-Wilk statistic (see Hair et al., 1998 for a description of this test) is often employed for normality test for sample sizes of 2,000 or less. If the probability of the statistic is less than 0.05, the null hypothesis of normal distribution of random disturbance is rejected.

Although normality can help to obtain exact statistical results for multiple linear modes, it is not necessary to estimate the unbiased and efficient coefficients. The other four assumptions assure that the least square coefficient estimates are BLUE (best linear unbiased estimation).

[47] Given the nature of this study (i.e. non time-series data), the issue of autocorrelation generally associated with time-series data becomes irrelevant. However, the model specification could exhibit spatial autocorrelation. The presence of spatial autocorrelation is not considered in this study.

CHAPTER 5 ANALYSIS AND RESULTS

5.1 Regression Assumption Testing

Before discussing the results of the two hedonic regression models, the regression assumptions should be tested to provide some "validity" to the estimated parameters. Violations of Ordinary Least Squares (OLS) assumptions can, in some instances, result in biased parameter estimates and/or standard errors. Biased standard errors can result in erroneous conclusions with respect to hypothesis testing (e.g., concluding that an estimated parameter is statistically different from zero when it is not or, conversely, concluding that an estimated parameter is not significantly different from zero when, in fact, it is). Violation of an OLS assumption may warrant (a) adjustments being applied (e.g., correcting for heteroscedasticity using, say, the White procedure), or (b) modifying the basic model in order to satisfy the OLS assumptions.

As presented in the previous chapter, there are five primary regression assumptions that need to be considered. They are (a) linearity, (b) independence, (c) multicollinearity, (d)normality, and (e) homoscedasticity. Typically most assumptions can be tested through visual plots. Here the first two assumptions are found to be satisfied via plots.[48] For the other assumptions, this study tests them with calculation-based techniques instead of visual plots.

(1) Multicollinearity Assumption Testing

When an independent variable or regressor has a completely or nearly linear relationship with another regressor or a combination of other regressors in the model, the affected estimates are unstable and have high standard errors. This problem is called multicollinearity.

As suggested in the previous chapter, the variance inflation factors (VIF) method is commonly used to test the multicollinearity assumption. Of the 18 VIF values of the independent variables of MODEL 1, all variables that do not have both linear and square

[48] The Box-Cox procedure, as discussed in the previous chapter, automatically satisfies the linearity issue.

terms, (i.e., DROAD, DCOAST, INTEREST, YR, DUMCOUNTY, DUMNOMLOSS, DUMMODLOSS, and DUMSECT) exhibit VIF values between 1.19 and 2.21 (Table 5-1). All wetland characteristics variables and their associated squared terms have relatively high VIF factors (in excess of 10 with the exception of BS). The relatively large VIF factors associated with the wetland characteristics variables is not surprising given that squared terms are always somewhat correlated with linear terms.

As a "rule of thumb' VIF in excess of 10 may give the researcher cause for concern. Specifically, large VIF factors may imply instability of the parameter estimates. The "rule of thumb" number, however, is somewhat arbitrary and, at times, little can be done even with high VIF numbers. This is the case here.[49]

Table 5-1 VIF Values for Variables Included in MODEL 1

	OPENW	**$OPENW^2$**	**FRESH**	**$FRESH^2$**	**INTER**
VIF	14.03	15.99	39.70	27.84	12.39
	$INTER^2$	**BS**	**BS^2**	**OTHER**	**$OTHER^2$**
VIF	11.08	6.78	6.32	14.76	13.15
	DROAD	**DCOAST**	**INTEREST**	**YR**	**DUMCOUNTY**
VIF	1.65	1.46	1.19	1.32	1.34
	DUMNOMLOSS	**DUMMODLOSS**	**DUMSECT**		
VIF	2.21	1.52	1.29		

See Equation 4-4 and related discussion for variable definitions.

Table 5-2 VIF Values for Variables Included in MODEL 2

	Ln(FRESH/OPENW)	**Ln(INTER/OPENW)**	**Ln(BS/OPENW)**	**Ln(OTHER/OPENW)**
VIF	1.41	1.46	1.27	1.72
	LDROAD	**LDCOAST**	**LINTEREST**	**LYR**
VIF	1.41	1.26	1.25	1.23
	DUMCOUNTY	**DUMNOMLOSS**	**DUMMODLOSS**	**DUMSECT**
VIF	1.32	1.93	1.43	1.15

See Equation 4-5 and related discussion for variable definitions.

Of the 12 VIF values of the independent variables included in MODEL 2, the largest is equal to 1.93 (Table 5-2). This suggests that multicollinearity is not of concern with respect to the model specification.

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[49] As discussed momentarily, furthermore, the standard errors associated with all of the five wetland characteristics parameter estimates are relatively small. This is an indication that multicollinearity is not a serious concern.

(2) Normality Assumption Testing

As noted in the previous chapter, an additional OLS assumption is that the disturbance term should be normally distributed (independent variables are not required to be normally distributed). Because the number of observations employed in the current analysis (i.e., 119) is below 2,000, the normality of the error term can be tested with the Shapiro-Wilk test. The test results indicate that the p-values of the Shapiro-Wilk test for MODEL 1 and MODEL 2 are similar (equal to 0.9518 and 0.9752, respectively). Assuming an alpha level of 0.05, the null hypothesis that the error term is normally distributed cannot be rejected.

(3) Homoscedasticity Assumption Testing

This assumption, as noted in the previous chapter, implies that the variance of the errors is constant across observations. If the errors have constant variance, the errors are called homoscedastic. Standard estimation methods are inefficient when the errors are have a non-constant variance (i.e., are heteroscedastic).

The White's test is employed to test the homoscedasticity assumption. The White's test results indicate that the p-values are equal to 0.5524 for MODEL 1 and 0.2695 for MODEL 2, which are greater than 0.05. This indicates that there are more than half chances for MODEL 1 or almost 2,700 chances for MODEL 2 to fail to the null hypothesis of residual homoscedasticity from total 10,000 events, and the null hypothesis fails to be rejected.

5.2 Parameter Estimates and Marginal Implicit Prices

5.2.1 MODEL 1

MODEL 1, as specified in Equation 4-4, considers sales price in aggregate. Maximum likelihood estimation of the Box-Cox transformation found the maximum likelihood for the log-likelihood function to be -1342.2, with an associated lambda value equal to 0.25. The model performs adequately as judged by the adj-R^2 value of 0.80. The computed F-statistic, equal to 27.85, suggests that all exogenous variables, when considered jointly, have a statistically significant influence on the deflated price (PRICE2K) at the 99% confidence level (Table 5-3).

Table 5-3 Parameter Estimates Associated with MODEL 1

Variable	Parameter Estimate	Standard Error	t-Value	Pr>|t|
INTERCEPT	49.091310*	11.4877	4.27	<.0001
OPENW	0.032220*	0.0042	7.66	<.0001
$OPENW^2$	-0.000005*	0.0000	-6.21	<.0001
FRESH	0.097360*	0.0210	4.65	<.0001
$FRESH^2$	-0.000030*	0.0000	-3.99	0.0001
INTER	0.019110*	0.0059	3.25	0.0016
$INTER^2$	-0.000004*	0.0000	-2.23	0.0278
BS	0.062800*	0.0123	5.10	<.0001
BS^2	-0.000036*	0.0000	-3.91	0.0002
OTHER	0.103580*	0.0161	6.42	<.0001
$OTHER^2$	-0.000056*	0.0000	-4.97	<.0001
DROAD	0.000124	0.0003	0.45	0.6566
DCOAST	-0.000179	0.0001	-1.45	0.1497
INTEREST	4.986280	7.0200	0.71	0.4792
YR	0.636600	0.4223	1.51	0.1348
DUMCOUNTY	5.804670	4.8342	1.20	0.2327
DUMNOMLOSS	-5.734210	3.9771	-1.44	0.1525
DUMMODLOSS	-10.244300	6.7888	-1.51	0.1345
DUMSECT	-4.603710	3.1257	-1.47	0.1439

R^2: 0.8337, Adjusted R^2: 0.8038, F-value: 27.85.
* indicates significant at the 90% confidence level.
See Equation 4-4 and related discussion for variable definitions.

Eleven of the 19 parameter estimates (including the intercept) were found to be statistically significant at the 90% level and several other parameter estimates fell just short of this criterion. All of the parameter estimates associated with the wetland characteristics variables (both linear and quadratic terms) were found to be statistically significant though the quadratic terms, on an absolute value basis, were very small.

Given that the quadratic terms are relatively small, one can infer the relative values of the wetland characteristics variables (at relatively small acres) by considering only the linear terms.[50] The linear parameter estimates associated with fresh marsh (FRESH) and other

[50] Doing so becomes less tenable as the number of acres associated with any of the wetland characteristics variables becomes larger and the quadratic term becomes more significant.

property (OTHER) are approximately equal (0.097 and 0.104, respectively) and these two parameter estimates are significantly larger than the linear parameter estimates associated with the other three wetland characteristics variables. Likewise, the linear parameter estimate associated brackish and saline marsh (BS) is significantly larger than those found for either open water (OPENW) or intermediate marsh (INTER). The relative value relationship among the five wetland characteristics variables is illustrated in Figure 5-1.

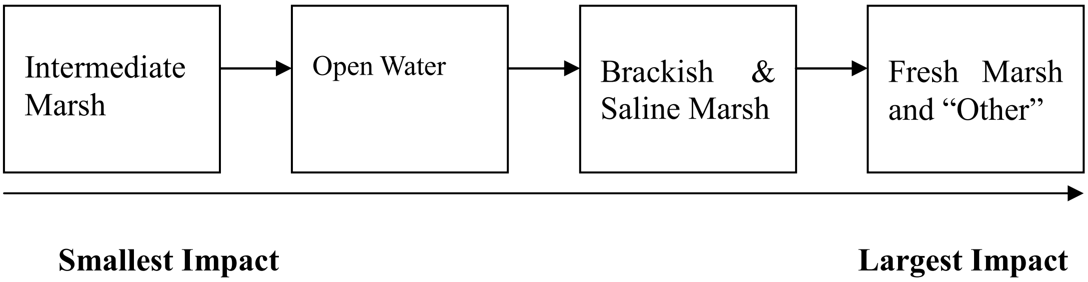

Figure 5-1 Impact of Wetland Characteristics on Property Price (MODEL 1)

As noted in the previous chapter, the specification of MODEL 1 also provides for a large amount of flexibility. With respect to the wetland characteristics variables, the change in total price related to a change in that wetland characteristics variable was examined by setting the values for all other wetland characteristics variables equal to zero while using the mean values for other continuous and discrete variables. For fresh marsh, price (PRICE2K) was found to be increasing at an increasing rate up to almost 1,500 acres after which point it increased at a decreasing rate. For brackish and saline marsh (BS), by comparison, price increased at an increasing rate up to almost 300 acres after which point additional acres resulted in price increasing at a decreasing rate.[51]

Though only marginally statistically significant, the property price does appear to be influenced by expected future wetland degradation. Specifically, the estimated parameter

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[51] Given the model specification, the total deflated price (PRICE2K) was also found to decrease beyond a high level of each of the characteristics variables (i.e., a large number of acres). In general, however, this decline is well beyond the range of most observations.

estimates for both projected nominal wetland loss during the 2000-2050 period (DUMNOMLOSS) and projected moderate wetland loss during the same period (DUMMODLOSS) were found to be negative with the estimate associated with expected moderate loss exceeding that associated with nominal loss (Table 5-3). This would imply that properties with projected moderate wetland loss are discounted more than those with only projected nominal or no loss.

While only marginally statistically significant, property prices were also found to be positively related to the time trend included in MODEL 1 (Table 5-3). This implies that the private wetland property values, after removing inflationary effects, have increased over the period of study, *ceteris paribus*. This finding may be the result of at least two factors, or some amalgam. First, income generating potential of the property may have increased during the period of study. Second, more liberal duck hunting privileges may have resulted in increased demand for wetlands property.[52]

The parameter estimates associated with MODEL 1 (Table 5-3), together with the mean values of relevant variables (Table 3-2) can be used to estimate marginal implicit prices associated with relevant model factors (see equations 4-6 through 4-8 for methods used to calculate these prices). The marginal implicit prices associated with the various exogenous factors used in MODEL 1 are presented in Table 5-4. The marginal implicit prices associated with the wetland characteristics variables (OPENW, FRESH, INTER, BS, and OTHER) represent the influence on property price associated with one additional acre of any of these factors. For example, the estimated marginal implicit price for open water ($369), indicates that at its mean value (345.78 acres; Table 3-2), one additional (less) acre of open water will

[52] In general, it would make little difference whether this property is leased or purchased by the individual/group using it for duck hunting activities. If leased, increased duck hunting privileges would, in theory, translate into increased income generating potential by the owner (i.e., the one who purchased the property for the purpose of leasing). If purchased directly by and individual/group who plan to use it exclusively (or almost exclusively) for duck hunting activities, then more liberal hunting privileges would, in theory, translate into increased demand for wetland property and, hence, a willingness to pay a higher price.

result in a $369 increase (decrease) in expected sales price, *ceteris paribus* (i.e., the value of an additional unit of that attribute at its mean is $369).

Table 5-4 Estimated Marginal Implicit Prices Based on MODEL 1

Variable	Parameter	Pr>|t|	Mean	Implicit Price
OPENW	0.03222	<.0001	345.75	$368.78
FRESH	0.09736	<.0001	80.71	$1,186.13
INTER	0.01911	0.0016	293.87	$214.80
BS	0.0628	<.0001	89.44	$722.56
OTHER	0.10358	<.0001	83.53	$1,207.99
DROAD	0.00012363	0.6566	3871.20	$1.59
DCOAST	-0.0001791	0.1497	27530.55	-$2.29
INTEREST	4.98628	0.4792	0.96	$63,924.78
YR	0.6366	0.1348	13.41	$8,161.29
DUMCOUNTY	5.80467	0.2327	0.08	27.30%
DUMNOMLOSS	-5.73421	0.1525	0.78	-21.30%
DUMMODLOSS	-10.2443	0.1345	0.04	-35.50%
DUMSECT	-4.60371	0.1439	0.20	-18.10%

See Equation 4-4 and related discussion for variable definitions.

As indicated, the marginal implicit prices for fresh marsh (FRESH) and "other" property (OTHER) are nearly identical ($1,186 and $1,208, respectively), and they are considerably higher than those found for the other wetland characteristics variables (OPENW, INTER, and BS). The estimated marginal implicit price associated with open water ($369), while significantly less than that estimated for brackish and saline marsh ($723), is higher than that estimated for intermediate marsh ($215). The relative implicit prices are illustrated in Figure 5-2.

The low estimated marginal implicit price for intermediate marsh vis-à-vis either brackish and saline marsh or open water is unexpected, given that the income generating potential of intermediate marsh is likely to be higher than that of open water or brackish and saline marsh (similarly, one would hypothesize that intermediate marsh is more conducive to duck hunting than brackish and saline marsh).[53] One possible explanation for this finding

[53] This comment is somewhat speculative since there is little or no information on derived income by marsh type (or open water). Roberts et al. (2000) provide information that suggests revenues generated from intermediate marsh properties are higher than saline marsh but the authors provide no information on revenues

relates to the relatively large amount of intermediate marsh being offered for sale vis-à-vis other marsh types (see Table 3-3).

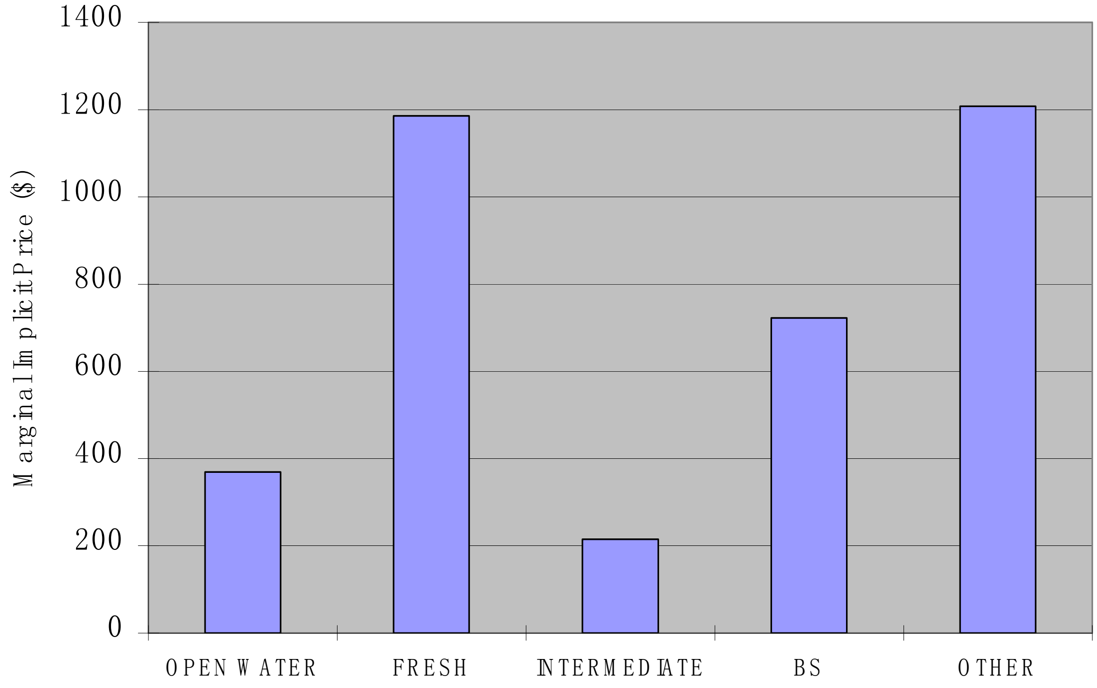

Figure 5-2 The Marginal Implicit Prices of Land and Water

Expressed on a percentage basis, the implicit price for properties with projected nominal land loss (DUMNOMLOSS) or moderate land loss (DUMMODLOSS) is less than those properties with no projected land loss. Specifically, properties with nominal projected land loss were estimated to be valued approximately 20% below those with no land loss while those with moderate projected land loss were estimated to be valued 35% less than those with no projected land loss, *ceteris paribus* (Table 5-4). Similarly, the property sales that have multiple non-contiguous tracts were estimated to be valued almost 20% less than single tract properties.

The time trend variable (YR) suggests that at its mean value, a one unit change (i.e., one

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associated with open water.

additional year) will result in \$8,169 increase in the property value, *ceteris paribus.* Based on the average property size (913 acres; Table 3-2), this translates to an increase of about \$9.00 per acre.[54]

5.2.2 MODEL 2

MODEL 2, as defined in Equation 4-5, considers sales price on a per acre basis (P2KPACRE). Maximum likelihood estimation of the Box-Cox transformation found the maximum likelihood for the log-likelihood function to be -664.8, with an associated lambda value equal to 0.00. The model performs adequately as judged by the adj-R^2 value of 0.45. The computed F-statistic, equal to 9.16, suggests that all exogenous variables, when considered jointly, have a statistically significant influence on the deflated price per acre (P2KPACRE) at the 99% confidence level (Table 5-5).

Table 5-5 Parameter Estimates Associated with MODEL 2

Variable	Parameter Estimate	Standard Error	t-Value	Pr>|t|
INTERCEPT	4.8236*	1.4400	3.35	0.0011
Ln(FRESH/OPENW)	0.0291*	0.0104	2.79	0.0062
Ln(INTER/OPENW)	-0.0393*	0.0121	-3.26	0.0015
Ln(BS/OPENW)	-0.0131	0.0108	-1.21	0.2272
LN(OTHER/OPENW)	0.0237*	0.0100	2.37	0.0198
LDROAD	-0.0338*	0.0187	-1.81	0.0728
LDCOAST	-0.1387	0.1196	-1.16	0.2489
LINTEREST	0.2020	0.1531	1.32	0.1899
LYR	1.2389*	0.2548	4.86	<.0001
DUMCOUNTY	0.4577*	0.2536	1.80	0.0740
DUMNOMLOSS	-0.3461*	0.1965	-1.76	0.0810
DUMMODLOSS	-0.9377*	0.3485	-2.69	0.0083
DUMSECT	-0.0943	0.1561	-0.60	0.5471

R^2: 0.5090, Adjusted R^2:0.4535, F-value: 9.16.
* Indicates significant at the 90% confidence level.
Parameter estimates and related statistics presented in this table are those associated with replacement of zero values (associated with wetland characteristics variables) by 0.01 using the modified Aitchison (1986) approach. See Equation 4-5 and related discussion for variable definitions.

Interpretation of the parameter estimates associated with the wetland characteristics

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[54] Given the large standard error relative to the estimated parameter on INTEREST, the estimate of marginal implicit price is likely to be misleading.

variables in MODEL 2 is not straightforward since the variables have been normalized. However, based on the analysis, one can conclude that as the ratio of fresh marsh (FRESH) to open water (OPENW) increases (decreases), the average price per acre increases (decreases) accordingly, *ceteris paribus*. This is also the finding with respect to the ratio of "other" acres to open water (Table 5-5).

Results also suggest that as the ratio of intermediate marsh (INTER) to open water (OPENW) increases, the average price per acre decreases. The estimated parameter associated with the ratio of brackish and saline marsh to open water, however, was not found to be statistically different from zero, suggesting that wetland owners value brackish and saline marsh (BS) the same as open water (OPENW). These results are graphically summarized in Figure 5-3.

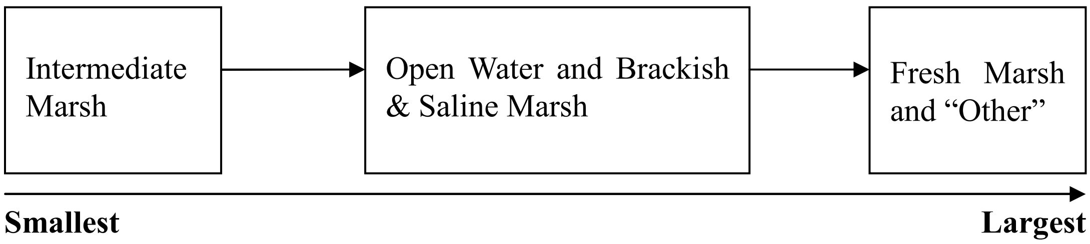

Figure 5-3 Impact of Wetland Characteristics on Property Price (MODEL 2)

The time trend variable (LYR) and distance to the nearest main road (LDROAD) were also found to significantly influence the average price per acre. The positive value associated with the time trend variable suggests that the average deflated price per acre has been increasing over time (possible reasons for this finding were presented in the discussion of the previous model). The statistically significant and negative parameter estimate associated with LDROAD implies that the average price per acre falls in relation to increased distance to the nearest primary road.

Finally, the two indicator variables for projected wetland loss (DUMNOMLOSS and DUMMODLOSS) were found to be statistically significant in influencing the average price per acre. The parameter estimates for both of these variables are negative, indicating that they exert a negative influence on price per acre and the relative magnitudes indicate that moderate projected land loss has a greater influence.

Parameter estimates associated with MODEL 2 tend to be somewhat sensitive to the zero replacement values (see Appendix for replacement method). Parameter estimates provided in Table 5-5 are those associated with a replacement value of 0.01. While the use of other values did not generally alter the relative importance of the different wetland characteristic variables, there were some moderate changes in the parameter estimates associated with the wetland characteristic variables (parameter estimates associated with other variables included in the model tended to be very stable, regardless of zero value replacement). When a replacement value of 0.1 is used (versus a value of 0.01 as used in Table 5-5), the parameter estimate associated with the ratio of fresh marsh to open water Ln(FRESH/OPENW) increased to 0.036 (s.d. equals 0.0127). Similarly, the parameter estimate associated with the ratio of "other" acres to open water Ln(OTHER/OPENW) increased to 0.030 (s.d. equals 0.012). The remaining two estimated parameters associated with the wetland characteristic variables were more stable.

5.2.3 Comparisons of Alternative Models

While many of the results associated with MODEL 1 and MODEL 2 are similar, there are some significant differences that need to be considered. One significant difference between the results associated with MODEL 1 and those of MODEL 2 relates to the relative contribution of brackish and saline acres (BS) to price (either in total or on a per acre basis). With respect to MODEL 1, the contribution of brackish and saline acres to total price was significantly higher than that of open water (OPENW). In MODEL 2, however, open water and brackish and saline marsh were found to be valued at roughly the same amount by the landowners. An explanation of this apparent difference is not entirely clear though the relatively large amount of multicollinearity associated with the wetland characteristic variables in MODEL 1 may be a contributing factor.

Second, both projected nominal wetland loss (DUMNOMLOSS) and projected moderate wetland loss (DUMMODLOSS) were found to negatively impact price (in total or on a per acre basis) with moderate loss exhibiting the greater influence. However, statistical significance of these variables was greater in MODEL 2 than MODEL 1.

Finally, the time trend (YR) was found to be statistically significant in MODEL 2 as was the discrete variable associated with parish where the property was located. These variables were found to be only marginally significant in MODEL 1. Differences here may also reflect a greater amount of multicollinearity across variables in MODEL 1.

5.3 Implications for the Use of Economic Incentives

Unlike in other states, where much of the wetland loss over time has been the result of conversion of wetland acreage to farming or development, wetlands in Louisiana are being lost primarily as a result of a natural erosion process. This feature, while presenting a challenge to policy makers attempting to develop a “master plan” to maintain/restore the state’s wetlands, makes Louisiana’s situation somewhat unique.

Approximately 75% of Louisiana’s wetlands are privately owned (McBride, 1992). While the public benefits are large, private benefits are relatively small. Divergence between public and private benefits, in no way unique to coastal wetlands, indicates that private benefits will be less than that considered socially optimal. Recognizing this to be the situation with privately owned forest property, for example, Romm et al. (1987) stated “[c]ost sharing subsidies are commonly used to promote public forestry objectives on land that is beyond public control.” These subsidies can take any number of forms including: (a) lump-sum allocations tied to technical assistance, (b) the reduction in taxes, or/and (c) the transfer of public rights or usufruct to private parties. As noted by the authors, “[i]n all cases, monetary benefits, actual and potential, are transferred to those who own or control land in exchange for their investment in some publicly desired forest regime."

In general, results of this study suggest that the values that wetland owners place on different wetland characteristic variables (i.e., FRESH, INTER, BS) differ significantly. This would indicate that any program's monetary benefits that "are transferred to those who own or control (wetlands) in exchange for their investment in some publicly desired (wetland) regime" will likely need to differ by wetland characteristic; premised on costs associated with maintenance/restoration being roughly equivalent across wetland types.

Without additional information, it is impossible to determine at this stage which of the three subsidy forms outlined by Romm et al. (1987) would be preferable in achieving any stated policy goal (e.g., a reduction in wetland degradation). Given the relatively limited property taxes imposed on classified wetland properties[55], reduction in property taxes may not provide sufficient incentive to achieve any stated policy goal.[56] If, however, the reduction in taxes can be tied to income tied to the property (both surface and subsurface), then taxes may be a more viable option.

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[55] While the property taxes are relatively small on an absolute basis, they may be relatively large in terms of income generated from wetland properties.

[56] A related issue, of course, is that some parishes receive a sizeable portion of property taxes from wetlands. Hence, any reduction in the assessed tax rate on wetlands would result in a significant decline in tax revenues needed to fund local public projects (e.g., schools).

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Wetlands, historically considered as worthless waste land, are among the most important resources. Louisiana's coastal wetlands, one of the largest deltaic systems in the world, represent a significant natural and economic resource for the state of Louisiana and the nation. Louisiana's coastal wetlands, accounting for about 30% of the U.S. total, and are termed "America's Wetlands". Unlike in most states, where coastal wetlands represent a relatively narrow transition boundary between solid land and water, wetlands in Louisiana are vast, often extending for many miles.

Despite a growing recognition of the contribution of wetlands to the welfare of society, loss of wetlands continues to be significant. Nearly 90 percent of all coastal wetland loss in the lower 48 states in recent years has occurred in Louisiana and the state, between 1932 and 2000, lost a total of 1,900 square miles. The current rate of wetland loss in the state is estimated to be from 25 square miles to 34 square miles per year

The Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) has, since 1990, become the primary funding source for addressing the state's wetland loss. Under CWPPRA, about 129 federal and state restoration projects are currently active. However, annual CWPPRA expenditures (about $50 million) are estimated to provide less than 10% of the funding necessary to adequately address the multitude of issues associated with wetland diminution.

Approximately 75% of Louisiana's coastal wetlands are privately owned. Because privately owned wetlands provide significant positive social and economic contributions, it is reasonable to devise and evaluate alternatives to more fully engage private coastal landowners in coastal restoration issues; particularly on individual tracts owned and maintained by these private investors. To properly craft incentives and mechanisms to encourage the socially optimal amount of investment by private owners, it is important to understand those factors that determine wetland valuation by the private sector. To this end, an hedonic price model that examined the influence of different wetland characteristics on the wetland market price was developed and estimated.

The focus of the research effort was the Chenier Plain (or Subprovince 4), which lies in southwest of Louisiana and north of the Gulf of Mexico. Overall, it includes three parishes - Cameron Parish, Calcasieu Parish, and Vermillion Parish. A total of 119 individual property transactions were identified and used in the hedonic price model.

Two alternative hedonic model specifications are considered in this study. In the first model, denoted as MODEL 1, deflated sales price of the property (PRICE2K) was used as the dependent variable and wetland characteristic variables (OPENW, FRESH, INTER, BS, and OTHER), their quadratic terms, and other relevant factors were used to explain the sales price. Results suggested that all parameter estimates associated with the wetland characteristics variables (both linear and quadratic terms) were found to be statistically significant though the quadratic terms, on an absolute value basis, were very small. The linear parameter estimates associated with fresh marsh (FRESH) and other property (OTHER) were found to be approximately equal and these two parameter estimates were significantly larger than the linear parameter estimates associated with the other three wetland characteristics variables. While the estimated parameter associated with brackish and saline marsh (BS) was also found to be higher than that found for open water (OPENW), it was less than those associated with fresh marsh (FRESH) or “other” acres. The parameter estimate associated with intermediate marsh (INTER) suggested that its influence on property price was lower than that of open water. The parameter estimates for projected nominal wetland loss (DUMNOMLOSS) for the 2000 to 2050 period and projected moderate wetland loss

(DUMMODLOSS) for the 2000-2050 period were found to be negative with the estimate associated with projected moderate loss exceeding that associated with nominal loss. This provides an indication that private values are discounted by landowners in conjunction with anticipated wetland degradation.

The estimated marginal implicit prices for fresh marsh (FRESH) and other property (OTHER) - nearly identical ($1,186 and $1,208, respectively) - were considerably higher than those found for the other wetland characteristics variables (OPEN, INTER, and BS). The marginal implicit price associated with open water ($369), while significantly less than that estimated for brackish and saline marsh ($723), was higher than that estimated for intermediate marsh ($215).

Properties with nominal projected land loss were estimated to be valued approximately 20% below those with no projected land loss. Those with moderate projected land loss were estimated to be valued 35% less than those with no projected land loss, *ceteris paribus.*

The second model specification, denoted MODEL 2, examined the influence of wetland characteristics and other variables on a price per acre basis. Results associated with MODEL 2 suggest that as the ratio of fresh marsh to open water (FRESH/OPENW) increases (decreases), the average price per acre increases (decreases) accordingly, *ceteris paribus.* Similarly, as the ratio of intermediate marsh to open water (INTER/OPENW) increases, the average price per acre decreases. However, the estimated price per acre was found not to be significantly influenced by the ratio of brackish and saline marsh to open water (BS/OPENW).

The deflated price per acre (P2KPACRE) was also found to be negatively related to the distance to the nearest main road (LDROAD) and positively related to the time trend variable (LYR). Finally, the two indicator variables for projected wetland loss (DUMNOMLOSS and DUMMODLOSS) were found to be statistically significant in influencing the average price per acre. The parameter estimates for both of these wetland loss variables were negative, indicating that they exert a negative influence on price per acre and the relative magnitudes indicate that moderate projected land loss has a greater influence.

6.2 Limitations and Further Research

Due to time and resource limitation, this research focused exclusively on southwest coastal Louisiana. This area of the state has experienced less wetland loss than either the central or eastern portion of the state and there is little or no projected "extreme" wetland loss in the study area. One natural extension of the current work would be to expand the analysis on a coastwide basis. This would allow one to examine (a) whether wetland property in Louisiana can be considered as a single market and (b) the influence of projected "extreme" wetland loss on property valuation by wetland owners.

A second useful area of research would be the use of spatial econometric techniques in the analysis of the hedonic price model. Given the limited number of observations available for the current study, use of such a technique proved to be infeasible. If such an analysis were to be conducted on a coastwide basis, however, the increased number of observations would likely lend itself to spatial econometric analysis.

Along the same econometric theme, use of semi-parametric and non-parametric techniques could be employed in the analysis. Results associated with these alternative modeling techniques could then be compared with the technique used in this study to determine the robustness of results to the technique chosen for analysis.

Finally, this study was conducted with only a minimal understanding of the wetland market itself. For example, there is little available information regarding the reason(s) why individuals/corporations purchase wetland tracts. Is it for the generation of income? While some properties are probably purchased for this reason, many (or most) are likely purchased only for recreational activities by those purchasing the property. Similarly, what are the principal reason(s) an individual or corporation sells wetland properties? Limited knowledge of the market suggests that any hedonic modeling results may be 'suspect' in nature. Results from a detailed survey eliciting information from wetland buyers and sellers as to the reasons for purchasing/selling wetland properties could be used to develop and estimate a more complete hedonic model of the wetlands market. This, potentially, could result in a more reliable estimated model and, hence, results that are more likely to be accepted and used by all interested parties.

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APPENDIX: ZERO VALUE REPLACEMENT

The variable ACRES is the total acreage of a property, which is consist of open water, fresh marsh, intermediate marsh, brackish and saline marshes, and others. If the five categories are divided by the total acreage ACRES, the proportions of all components or categories are produced. For every property all proportions always add up to a constant 1. These proportions are called compositional data, or closed array (Chayes, 1962; Pawlowsky-Glahn and Olea, 2004).

Compositional data analyses study relationships among proportions of components. Naturally the proportions of the whole are subject to a unit-sum constraint. Components or elements can be observed as zero. According to Aitchison (1986), there are rounded or trace zeros, and essential zeros. For the first zeros, they reflect imprecise observations for nonzero elements. In a real world, these elements may be very small, but greater than zero. If a more accurate measurement instrument is brought to observe these elements, their values should not be zeros. Zero values are measure “errors”, and stand for small number or trace values. For the second kind of zeros, the observations should be zeros, no matter how accurate measurement instruments are.

The natural log of zero is, of course, undefined. The techniques and the solutions of zero observations from statistical literature include amalgamation, zero (or trace) replacement, modified Box-Cox, and conditional modeling (Aitchison, 1986; Fry, et al., 2000). Here the modified Aitchison zero replacement technique (Fry, et al., 2000) is employed to address the zero logarithm issue.

The modified Aitchison technique assumes we can acquire a minimum unit λ for zero components. For example, a zero should be minimally replaced with 0.01 (one cent) in terms of property prices. One cent is the minimum sensible unit for the currency and the price. If we divide the value λ by the maximum value of the property price data sets, the minimum value for zero replacement τ_a is produced.

This research has to face the zero issue of marshes and open water when the double log functional form of the hedonic regressions is applied. For the research, the maximum value comes from all the total acreages (ACRES).

$$\tau_a = \frac{\lambda}{\max\{ACRES\}} \tag{A-1}$$

Assume that any composition has n nonnegative components, among which there are m zero and n-m nonzero. For a hedonic regression of this research, the value of n is fixed to 5 because we divide any property size into 5 categories in the data set: open water, fresh marsh, intermediate marsh, brackish and saline marshes, and others. The value of m lies between 0 and n-1, and it can be 0 or n-1, but cannot be n. If m equals to n, it means that all components of a composition are zeros and the composition or property should not be exist.

Then we can replace zero with the minimum zero replacement τ_a. We also can acquire the maximum rounding error δ and the reducing value τ_s as the following equations.

$$\delta = \frac{\tau_a \cdot n^2}{(m+1)\cdot(n-m)} \tag{A-2}$$

$$\tau_s = \frac{\delta \cdot m \cdot (m+1)}{n^2} \tag{A-3}$$

At the same time of replacing zero with τ_a, the modified Aitchison technique adjusts the nonzero values with the reducing value τ_s. Basically, we can have the new values for all components of a composition (ω):

$$\omega_i = \begin{cases} \tau_a \cdots\cdots\cdots\cdots\cdots\cdots \forall \omega_i = 0; \\ (1-\tau_s)\times\omega_i \cdots\cdots\cdots\cdots \forall \omega_i > 0. \end{cases} \tag{A-4}$$

Where i=1, 2 … n.

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VITA

The author was born in Jiangxi Province, People's Republic of China, on October 3rd, 1970. He obtained his high school education at Duchang High School and was graduated in July 1986. He received his Bachelor of Science degree in environmental planning and management from Wuhan University, China in July, 1991. He earned a Master of Science degree in environmental geosciences from East China Normal University, China in July 1994. He was employed by Central Research Institute of Building and Construction of former Minister of Metallurgical Industry, China, as environmental impact assessor and environmental engineer from August 1994 to July 2000. In December 2004, he obtained a Master of Science degree in environmental science from Louisiana State University. Since then, he entered the Graduate School of Louisiana State University and Agricultural and Mechanical College in Baton Rouge to earn the degree of Master of Science in agricultural economics.