ESSAYS ON THE IMPACT OF DEVELOPMENT ON AGRICULTURAL LAND AMENITIES AND VALUES IN TEXAS

A Dissertation

by

MEMORY MACHINGAMBI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2010

Major Subject: Agricultural Economics

ESSAYS ON THE IMPACT OF DEVELOPMENT ON AGRICULTURAL LAND AMENITIES AND VALUES IN TEXAS

A Dissertation

by

MEMORY MACHINGAMBI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Approved by:

Chair of Committee,	James W. Mjelde
Committee Members,	W. Douglass Shaw
	Frederick O. Boadu
	J. Richard Conner
	Urs P. Kreuter
Head of Department,	John P. Nichols

May 2010

Major Subject: Agricultural Economics

ABSTRACT

Essays on the Impact of Development on Agricultural Land Amenities and Values in Texas. (May 2010)

Memory Machingambi, B.Sc. Hons., University of Zimbabwe

Chair of Advisory Committee: Dr. James W. Mjelde

Market land prices ignore the non-market value of ecosystem goods and services; hence, too much agricultural land may be developed. Correct land valuation must include these non-market values. Values of ecosystem services provided by the Richland–Chambers constructed wetlands are assessed through meta-analysis to derive confidence intervals for the willingness-to-pay (WTP) for wetland services. Replacement costs are also used to estimate cost savings of creating wetlands to cleanse river water instead of constructing a conventional wastewater treatment facility. Benefit transfer is used to estimate WTP for non-market agricultural land amenities. Ecosystem services of runoff in the western and recharge in the eastern part of Comal County based on hydrological models are also calculated. Finally, seemingly unrelated regression is used to quantify the effects of growth on current agricultural land values in Texas.

Using two different meta-analysis transfer functions, mean WTP for the Richland-Chambers wetlands are $843 and $999 / acre / year. Estimated 95% confidence interval is $95 to $7,435 / acre / year. This confidence interval clearly indicates the uncertainty associated with valuing ecosystem goods and services. The

replacement cost of the Richland–Chambers constructed wetlands is estimated to be $1,688 / acre / year. Aggregate WTP to preserve farm and ranchland non-market amenities in Comal County is estimated to be $1,566 / acre. Using hydrologic models, the runoff is valued at $79 / acre, whereas, recharge value is $1,107 / acre. Development will cause a change in recharge, runoff, and pollution which will decrease societal welfare by $1,288 / acre. Seemingly unrelated regression results show that a percentage increase in population growth in the closest metropolitan statistical area (MSA) is associated with increases in land values of approximately $2 / acre. A one-mile increase in distance from the nearest MSA decreased land values by $4 / acre in 1997, $6 / acre in 2002, and $8 / acre in 2007. The diversity of studies illustrates that a cookbook type of methodology is not appropriate for valuing ecosystem goods and services. On the other hand, development contributes positively to land values through encroachment on agricultural lands.

DEDICATION

To Fari Nyashanu, my husband and best friend, thanks for all you endured so I could be here, I would not have made it without your support in every way!

ACKNOWLEDGEMENTS

First, I give all honor and praise to my savior, Jesus Christ, I would not have done it without your grace and love! I am deeply indebted to my committee chair, Dr. Mjelde, for his patience, encouragement and guidance, and my committee members, Drs. Shaw, Boadu, Conner, and Kreuter, for their support throughout the course of this research. Dr. Mjelde, thanks for the humor; it made the task easier when the going got tough. I am also very grateful to Dr. Richard Woodward for the meta-analysis program used for this research.

Thanks also go to the American Farmland Trust for funding and Dr. Neil Wilkins for the support of part of this research. I am also grateful to Mr. Darrel Andrews, Dr. Bill Batchelor, Dr. Jim Cathey, Mr. Jeff Gunnels, Dr. Edward Rister, Mr. Rufus Stephens, and Dr. Brad Wilcox, for their insights and advice during the course of this research.

Finally, thanks to my family for their love and encouragement, you are the best! To my beautiful babies, Liz and Ati, thanks for being such munchkins even though I played “absent mommy”, I love you!

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

CHAPTER I

INTRODUCTION

Ecosystems provide market goods such as timber, pharmaceuticals, and food, but also supply services not typically traded in markets, including water and air purification, soil stabilization, and climate regulation. The Millennium Ecosystem Assessment (2003, p. 53) broadly defines ecosystem goods and services, henceforth services, as "the benefits people obtain from ecosystems" which support or protect valuable economic services. Because many ecosystem services are supplied outside of commercial markets, their provision has little effect on policy decisions (Konarska, Sutton, and Castellon 2002; Sander 2009). Society, however, has long recognized the need to preserve ecosystems (Fausold and Lilieholm 1999; Daily et al. 2009), especially unique natural areas.

Population growth, increasing wealth, and changing preferences coupled with relatively low economic returns to agricultural enterprises are placing developmental pressures on rural lands. Further, increasing incomes and telecommunications advances are making it feasible for people to live and work in rural and semirural areas (exurban or rural residential growth[1], placing additional pressure on rural lands. These factors are leading the way to land use changes in the U.S. including Texas.

Wilkins et al. (2003) estimate that the top 10% of counties (ranked by loss of farm and ranchland) lost more than 580,000 acres of agricultural land mostly to urbanization between 1992 and 2001. Beattie (2001 p. 17), however, "…presents

---

This dissertation follows the style and format of the *American Journal of Agricultural Economics.*

[1] Growth in this study is used to represent urban, suburban, and exurban or rural residential growth.

evidence that agricultural land preservation for the purpose of ensuring future U.S. agricultural production capacity is not warranted. Loss of food and fiber capacity is a persistent myth that simply will not go away." Other reasons for preserving land may, however, be warranted. Urbanization land use changes are longer lasting than many other types of changes causing loss of ecosystem services (McKinney 2002). Hence, public investments in land stewardship on private farms, ranches, and forestlands are increasingly being considered as policy alternatives to slow or alter this growth. Such investments are often justified by the public non-market benefits of the open space which accrue to non-owners.

In Texas, agricultural land preservation may occur because of the passage of the Texas Farm and Ranch Lands Conservation Program (TFRLCP) in 2005. The program provides monetary compensation to landowners for not developing their land by selling of agricultural conservation easements to eligible entities. This program, however, is currently unfunded. Another response has been the call to obtain the "correct value" for land use through estimating the public value of non-market ecosystem goods and services provided by the land. The main emphasis with this correct valuation is not to place a price tag on a resource, but rather assess society's welfare changes caused by changes (Turner et al. 2003).

This dissertation explores how growth affects agricultural land values, as well as, the potential value of different ecosystem services provided by agricultural lands. Through interrelated studies, this dissertation illustrates the complexity of the matter, gives information that not only provides the rationale for preserving agricultural land but also informs policy makers on why ecosystem services should no longer be absent in land use decisions, along with several potential values for such services.

Objectives

The overall objective of the study is to assess the effect of growth on agricultural land values and ecosystem services amenities. To obtain this overall objective, specific subobjectives are:

1. To estimate, through meta-analyses functions and replacement cost methods, the value of constructed wetlands (CWs) for improving water quality;
2. To calculate the impact of population growth on water and land resources, hence, development's impact on ecosystem services from agricultural lands in Comal County; and
3. To quantify the effect of growth on agricultural land values.

To meet subojective one, meta-analyses functions from previous wetland studies are used to derive confidence intervals and point estimates for the value of the Richland-Chambers constructed wetlands. A replacement cost analysis of the CWs is also undertaken to provide additional evidence on the value that society derives from wetlands.

Subojective two is met through using unit benefit transfers to derive willingness-to-pay (WTP) for agricultural land amenities in Comal County. Hydrologic modeling is then used to quantify how growth impacts ecosystem services associated with runoff and recharge for Comal County. Ecosystem services values derived from Richland-

Chambers CWs are used along with estimates of the valued raw water to derive the effects growth has on resource demand for the growing city of New Braunfels in Comal County.

Finally, subobjective three is met through statistical analysis of the effect of population and income growth, along with distance to population centers on agricultural land values in Texas. Each of the subobjectives is explored in a self-contained study.

Organization of the Dissertation

The dissertation is organized as follows. An introduction to the problem is contained in Chapter I. Included in the introduction is the problem statement and objectives. General theoretical frameworks are presented in Chapter II including theories of the economics of public goods and externalities. These theories form the basis of the economic models used in the subsequent studies. Different methods of valuing ecosystem services are also briefly discussed. Contained in Chapter III is a literature review that provides background and perspective on how ecosystem services and agricultural land have been valued. Because each study is self-contained, specific valuation methodology and data collection methods are discussed in the respective chapters. A detailed analysis of the Richland-Chambers constructed wetlands for wastewater treatment is contained in Chapter IV. The impact of growth on runoff and recharge ecosystem services in Comal County is addressed in Chapter V. In Chapter VI, the effect of growth on agricultural land values is examined for Texas counties. Finally, unifying conclusions and recommendations are presented in Chapter VII. Further areas of research are also highlighted together with limitations of the current study.

CHAPTER II

RATIONALE FOR INVESTING PUBLIC FUNDS IN LAND STEWARDSHIP

The disappearance of open spaces, which maintain natural ecosystem habitats, has been observed in the U.S. including Texas (American Farmland Trust 2003). Open spaces have been lost to sprawling urban development because of the high returns landowners can realize from development (The Trust for Public Lands 2007). Land conversion impacts the provision of ecosystems' services, which humans value (Barbier 2007; The Trust for Public Lands 2007; Hellerstein et al. 2002). Not all the outputs from the land however are reflected in its market price, the "non-market outputs" which are mainly ecosystem services are not included in land prices. Hellerstein et al. (2002 p. 45) labels the exclusion of non-market ecosystem services in land prices "… a problem in the private provision of public goods."

Economic Theory

Non-market outputs of ecosystem services which include food security, scenic landscapes, wildlife habitats, agrarian cultural heritage, and recreational opportunities are reportedly missing in land prices (Hellerstein et al. 2002). Often in decision-making such goods and services are priced at zero, which effectively excludes their value from environmental management decision making (Heal 2000; Brander, Florax, and Vermaat 2006; Heal et al. 2005; The Trust for Public Lands 2007; Barbier 2007). Even though landowners have property rights to their land, the same rights do not apply to ecosystem goods and services, because landowners do not exclusively benefit from the natural systems on their land. No compensation for the production of rural amenities is provided to landowners, hence the incentives for landowners to preserve landscapes are lessened (Hellerstein et al. 2002). Natural systems which supply ecosystem goods and services often straddle properties owned by different landowners, further challenging the property rights structure. Hence, private land conversion decisions by landowners which reduce the supply of ecosystem goods and services to society do not account for all the costs and benefits. This reduced flow of ecosystem goods and services has created the current discussion of who should invest in ecosystem protection because “The private market is poorly supplying the public good” (Scott et al. 1998, p. 55).

Markets are where individuals come together in society to exchange resources,[2] as well as, rights to use the resources. Economic efficiency (henceforth efficiency) occurs in a market when the resources are allocated in a way that maximizes the net benefits to society (Tian 2009). In perfectly competitive markets with well defined property rights, markets provide society’s optimal resource allocations, this is also termed a Pareto optimum. Competitive markets (the ideal economic state) for private goods result in efficient allocations in such markets; efficiency occurs at the intersection of society’s supply (marginal opportunity costs) and demand (marginal benefit) curves. Perfectly competitive markets, however, are not the norm. Exchanges within markets are governed by the property rights structure. Property right structures that are not well-defined can lead to inefficient market allocations. Such inefficiencies are known as

[2] Resource is being used in here as a generic word referring to any resource, natural or manmade, that humans value. Given the subject matter of this dissertation, the discussion concentrates on natural resources goods and services, those derived from the environment and available in limited quantities.

market failures. Because property rights are critical in facilitating efficient markets, property rights are explored first before addressing consequences of their violations.

Property Rights

Property rights are a bundle of entitlements which define the owner's rights, privileges, and limitations for use of a resource. They are an instrument of society, deriving their significance from the fact they help people form expectations which they can reasonably hold in dealings with others (Demsetz 1967). For example, when buying an apple your expectation is that you can eat the apple. In a market transaction, a bundle of rights are exchanged. In buying the apple, money and its associated rights are exchanged for the rights to the apple. Without such rights and their exchange, markets would not exist. Property rights incorporate the social, cultural, legal, and institutional environment where the rights structure operates (Demsetz 1967).

Four characteristics of well-defined property rights are specificity (or universality), exclusivity, transferability, and enforceability (Hanley, Shogren, and White 1997). Entitlements should be completely specified so the owner knows what s/he can and cannot do with the resource. Exclusivity means all the benefits and costs of owning and using the resource should exclusively accumulate to only the owner. Transferability implies the owner is able to transfer all their rights in voluntary transactions. Finally, enforceability indicates that the owner can choose whatever form of control over his resource without fear of involuntary seizures. Efficient societal allocations result when property rights are well-defined. Any decline in resource value because of misuse by the owner results in a decrease in value to only the resource owner;

all costs and benefits are internalized (accrue to the owner). Property rights, therefore, act as a powerful incentive in guiding resource owners to maximize the net benefits from use of the resource (Demsetz 1967). If any of these characteristics is violated, inefficiency in the market may result; a market failure exists.

Market Failures

Market failures take many forms depending on the violated property right characteristic(s). A market failure implies the market system is not maximizing society's net benefits. Although market clearing (quantity demanded equals quantity supplied) may occur with a market failure, the inefficiency arises from the inability of market forces to maximize social net benefits. The market is not producing the correct price signals to induce consumers and producers to make choices that are socially efficient. A prime example of a market failure is pollution from automobiles. Because car owners do not incur all the costs associated with pollution from car exhaust (an externality exists because exclusivity is violated), people tend to drive more than society's optimal level of driving. Although market failures are attributed to factors such as market power, inappropriate government intervention, and the nature of resource, the factors most applicable to ecosystem services are public goods and externalities.

Public vs. Private Goods

Of particular interest to the problem of losing ecosystem services is market failures associated with what economists call public goods. In economics, public goods are not goods that are provided by a public entity, but rather goods that are non-excludable and non-rival in consumption (Samuelson 1954; Mishan 1969). Non-excludable means it is too costly to exclude non-owners from enjoying the benefits or incurring the costs from the use of a resource. Viewing a scenic open landscape from a public road is an example of a public good. The view is non-excludable because it would be too costly to try to exclude non-owners from viewing the landscape as they drive down the road. Non-rival means one person's consumption does not diminish another person's consumption. Landscape views are non-rival in consumption because one person's consumption of the view does not make less of the view available to other individuals. Because the landowner does not obtain all the benefits from the scenic landscape, economic theory suggests less landscape views will be provided or protected by the market than society's efficient level. Therefore, markets will not efficiently provide public goods (Scott et al. 1998).

Why markets under provide public goods, such as scenic landscapes, is illustrated in figures 1 and 2. For simplicity, in the following example, society consists of two individuals. There are two goods, a private (apples) and a public good (scenic landscape). Each individual's demand curve, D_i, for both the public and private goods are downward sloping to the right because of diminishing marginal utility. As additional goods are consumed, the marginal value or the utility gained from consumption declines.

A good with well-defined property rights is called a private good. Private goods in contrast to public goods, exhibit both excludability and rivalry in consumption. Once one person eats an apple, the other person cannot consume the same apple, it is rival in consumption. Further, an owner of an apple can exclude others from consuming the apple. With rivalry and excludability in consumption, society's or aggregate market demand (D_T) is obtained by the horizontal summation of the quantities that each consumer is willing and able to purchase at a given price. Horizontal summation of demand curves to obtain the market demand curve is illustrated in figure 1.

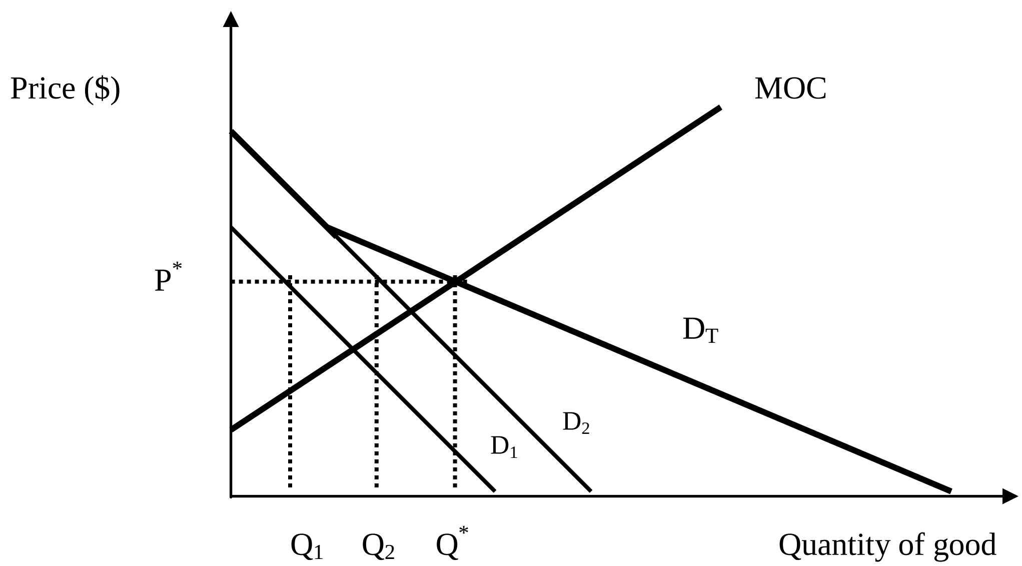

Figure 1. Horizontal summation of individual demand curves to obtain the aggregate market demand curve associated with private goods

Efficiency is given by the intersection of the aggregate demand (D_T) curve and the market marginal opportunity cost (MOC) curve, commonly known as the supply curve. This intersection is given by point P* Q* in figure 1. At this point, marginal benefits are equal to marginal opportunity costs. If less than Q* is provided, the marginal benefits are higher than the marginal costs, creating an incentive for producers to supply more apples. On the other hand, if more than Q* is available in the market, the marginal benefits are less than the marginal costs. Producers can only sell the product at a loss; therefore, they have an incentive to reduce production. At the efficient point, there is no incentive to produce more or less of the good; society's net welfare is maximized.

For a private good, the market efficiently supplies the good, because of the ability to exclude non-payers from enjoying the benefits of consumption. At price P^*, individual one demands the quantity Q_1 of the good (intersection of the price line and individual one's demand curve), whereas, individual two's quantity demanded is Q_2. Because of rivalry and excludability in consumption, individual one must buy and consume their own apples; they cannot consume apples bought by individual two. A similar situation holds for individual two. The sum of Q_1 and Q_2 equals Q* which is society's efficient point. With well-defined property rights, the market will supply society's efficient level of the good. The importance of this discussion will become apparent when discussing public goods.

The story is different for public goods (figure 2). Because of non-rivalry and non-excludability in consumption, simultaneous consumption of the good is possible;

therefore, aggregate demand is the vertical summation of the individual demand curves. For a given quantity of scenic landscape, aggregate demand is derived by summing the prices individuals are willing and able to pay for a given level of a public good, scenic landscape. As before, society's efficient point is given by the intersection of MOC and aggregate demand, D_T. This point is P* Q* in figure 2, but because of non-rivalry and non-excludability in consumption this point will not be obtained in the market as is the case with private goods.

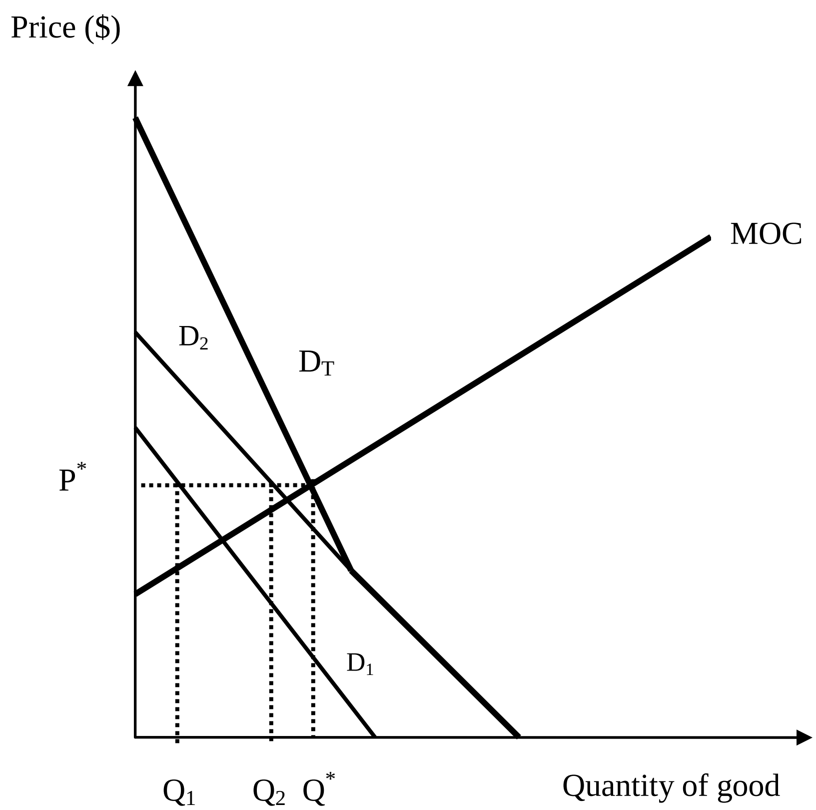

Figure 2. Vertical summation of individual demand curves to obtain the aggregate market demand curve associated with public goods

Quantities supplied of a public good by the market will be less than socially desirable level. At the socially efficient price, P*, individual two demands Q_2 of the good and individual one demands Q_1. To illustrate why less than optimal level of the good will be supplied, let individual two go first and buy the public good. S/he buys Q_2 units of scenic landscape. Individual one wants only Q_1 units which is less than the amount individual two buys at P*. Individual one, therefore, does not purchase any scenic landscape to reach his/her desired level. Because of non-rivalry and non-excludability in consumption, individual one consumes Q_1 units of the landscape provided by individual two. Individual one is "free riding" on individual's two purchase of the scenic landscape. Only Q_2 units of the landscape will be provided in the market and not the optimal Q^* units. Similarly, if individual one goes first and buys Q_1 units of the good, individual two will only purchase the difference Q_2-Q_1 to reach his/her preferred level of scenic landscapes. Again, only Q_2 units of the good are supplied. In this case, individual two is free riding on individual one's landscape purchases because of non-rivalry and non-excludability in consumption. One individual is benefitting from the other individual's quantity purchased. As a result, the market will only supply Q_2 units, which is less than society's efficient point, Q*. Public goods will be undersupplied by the market; hence inefficiency (market failure) is associated with the private provision of public goods.

The Public Goods Problem Mathematically[3]

Assume individual i with total income y_i produce a private good (c_i) with an implicit price of 1 and a public good (g_i) which is part of G (total quantity of the public good) with a price of p_G and G_{-i} is the contribution of all other individuals. The individual's utility maximization problem is:

$$\text{(1)}\qquad \begin{aligned} &\text{Max} \quad U(c_i, G) \\ &\text{subject to } c_i + p_G\, g_i = y_i \\ &G = \sum_{i=1}^{N} g_i = g_i + G_{-i}\,. \end{aligned}$$

It is assumed individual behavior is based on the idea of a Nash equilibrium[4]; further assume each individual assumes G_{-i} is fixed. Applying these assumptions to the utility maximization problem gives the marginal rate of substitution (MRS), which is the rate at which individual i must give up the private good to obtain one more unit of the public good.

$$\text{(2)}\qquad MRS_i = \frac{dU/dG}{dU/dc_i} = p_G$$

Each individual equates their value of an extra unit of public good (dU/dG) against the forgone consumption of the private good (dU/dc_i). The cost of producing the public good is measured in terms of less consumption of the private good. Because an increase in G simultaneously increases all individuals' utilities, the optimum occurs where

[3] For a more complete discussion, see Cornes and Sandler (1996).
[4] Nash equilibrium implies that all players simultaneously play best responses to each others' strategies.

$p_G = \sum_{n=1}^{N} MRS_n$ which is the "Samuelson Condition."[5] The maximum Pareto Optimum is based on the total sum of the individuals' valuations of an extra unit of the public good, which is higher than individual i's valuation. Hence, the public good will be undersupplied. Individuals will choose lower than optimum values of g_i, because they know that even if they do not produce any g_i, they will still be able to enjoy some level of the public good because other individuals will produce the good. The ability to free-ride makes intervention by the government or obtaining private incentives to increase production of the public good potentially necessary to correct the market failure.

The previous discussion is concerned with pure private and public goods which represents the extreme points. Rivalry and excludability is usually not as clear cut; a spectrum exists. Goods exhibit varying degree of rivalry and excludability, which furthers complicates the issue. Defining whether a certain commodity is a private or public good depends on the degree of rivalry and excludability. Many goods and services provided by ecosystems have a large degree of non-rival and non-excludability which leads to market failure.

Externalities

Besides public good issues, externalities also play a role in inefficient allocation of resources in the market. Externalities occur when exclusivity is violated. Such a violation implies the costs and benefits associated with use of a resource do not fully accrue to only the owner. External diseconomies (negative externalities) help explain

---

[5] Samuelson Condition implies that further substitution of public for private goods production (or vice versa) would result in a decrease in utility.

why resources are overexploited. In this case, the market price does not fully incorporate all costs; therefore, the price is too low and too much of the resource is used. Positive externalities (external economies) occur when not all the benefits associated with the resource accrue to the owner. Here, the market does not supply enough of the good.

Negative externalities, illustrated in figure 3, occur when the individual or private marginal opportunity cost curve (MOC_P) is less than society's marginal opportunity cost curve (MOC_S). A prime example is pollution. Social costs include all the costs of pollution on the environment, whereas, an individual's marginal cost curve includes only those costs that directly impact the individual.

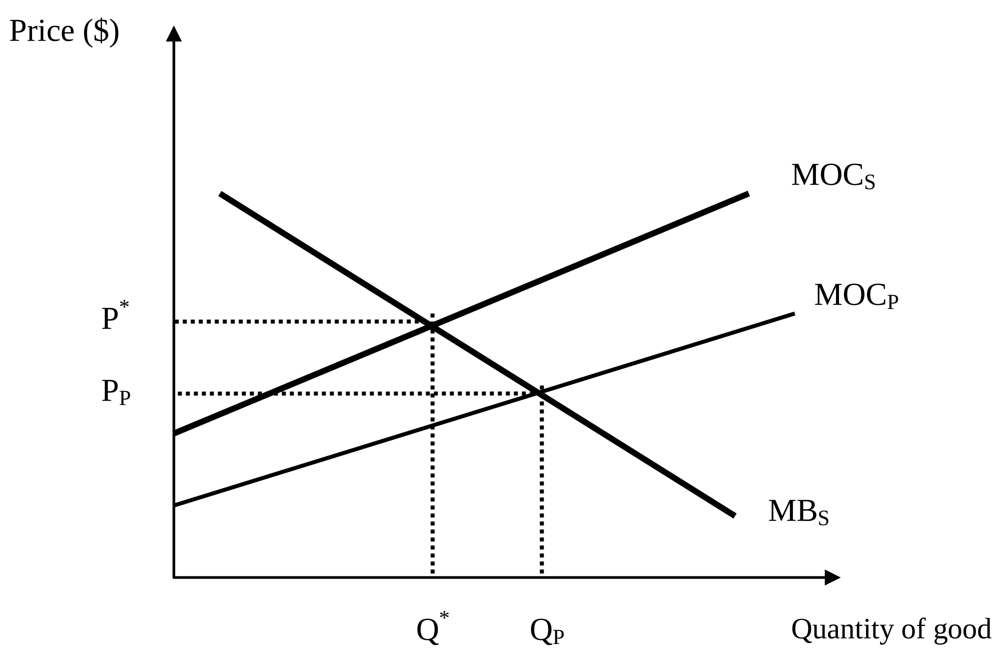

Figure 3. An external diseconomy caused by social and private marginal opportunity costs diverging

As before, society's efficient point is given by Q*P*. Because market participants are rational individuals, market participants consider their private marginal costs and not society's marginal costs when determining their consumption. The market will supply the good up to the point where private marginal costs are equal to private marginal benefits, point $Q_P P_P$. At this point, market price is too low ($P^* > P_P$), too much of the resource is consumed ($Q_P > Q^*$), and too much pollution associated with the use of the resource is generated. Not accounting for the pollution costs leads to overuse of resources by owners. The situation is reversed for positive externalities.

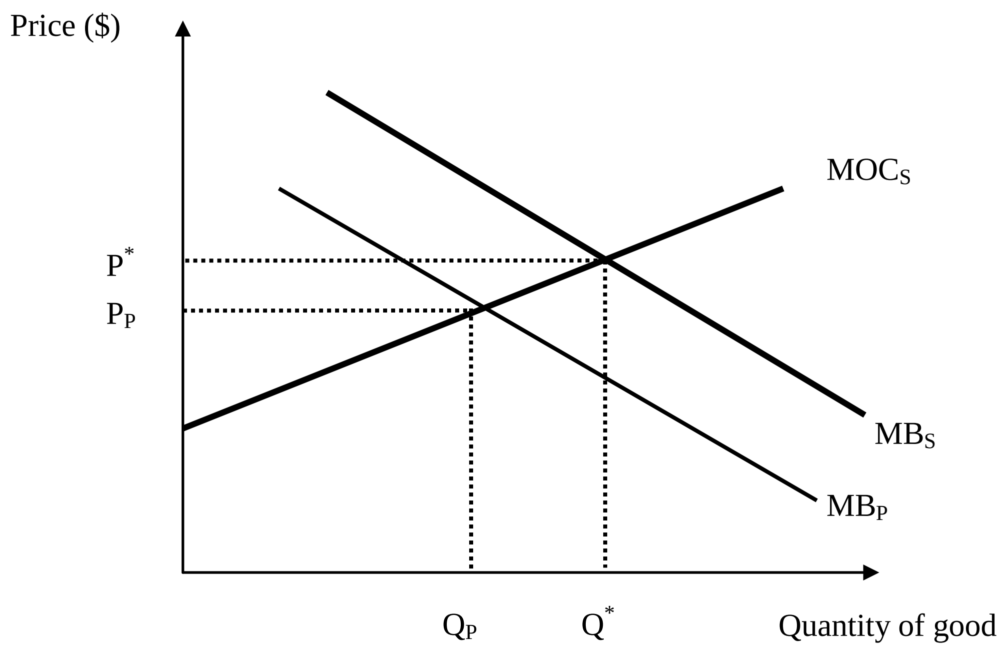

Figure 4. An external economy caused by social and private marginal benefits diverging

Positive externalities can occur when not all the benefits associated with the resource accrue to the owner. As an example, the private marginal benefits curve is not the same as society's marginal benefit curve (figure 4). The omission of some benefits results in a private marginal benefits (MB_P) curve that is less than society's curve. A prime example is a beautifully landscaped yard. The owner incurs all the costs, but everyone who enjoys the yard benefits. As before, society's efficient point is given by Q*P*. The private market, however, will only supply up to the point private marginal costs are equal to private marginal benefits, point $Q_P P_P$. With positive externalities, provision of the resource will be under provided ($Q_P < Q^*$) with a price that is too low ($P_P < P^*$). If landowners can not capture all the benefits associated with the provision of scenic landscapes, such landscapes will be underprovided.

Government Failures and Lobby Groups

Market failures are sometimes corrected by government intervention. It should be noted that the government should not attempt to correct all market failures. Government intervention is only warranted when the benefits of intervention outweigh the costs of the correction. Total cost and benefits must be considered when considering any correction mechanism (Coase 1960).

Government failure occurs when the government intervenes inappropriately in the market causing the market to fail to achieve allocative efficiency. Examples of government failure range from regulations restricting competition, such as price ceilings or floors, to no government intervention when such intervention is warranted. In our political / social system, lobbying groups[6] have evolved to help address and correct both market and government failures (Tietenberg 2006; Mjelde 2009). Lobbying, a very important function in our system, provides information and increases the amount of monetary resources available to monitor and correct market and government failures. Lobbying, however, is not without its potential drawbacks. If a lobbying group, for example, is successful in getting legislation passed which increases the groups' net welfare, there are no assurances this legislation will increase society's welfare. Passage of the legislation may create a larger decrease in the welfare of some other group. As another example, consider a resource worth $1 million dollars to two diverse groups. Both groups are willing to spend up to $1 million to obtain the resource. Because both sides are willing to pay up to $1 million dollars for the resource, up to $2 million may be spent on a resource worth $1 million. Because of these different failures, watch groups have arisen to monitor lobbying and government activities. These are just examples of checks and balances in our political / social system. Checks and balances partially arose in this case, however, because of market failures caused by improperly defined property rights. In recognition of the inefficiencies ill-defined property rights may place on society, government intervention and lobbying groups are necessary to ensure that public goods are provided to society at near the optimal level.

What are Ecosystem Goods and Services?

The Millennium Ecosystem Assessment (2003 p. 53) broadly defines ecosystem goods and services, as "the benefits people obtain from ecosystems" which support or protect

[6] Lobbying groups make concerted effort to influence elected government authorities.

valuable economic services. These benefits are classified into provisioning (food and water), regulating (flood and disease control), cultural (spiritual, recreation and cultural benefits), and supporting (nutrient cycling) services. Consequently, ecosystem services are necessary to support and maintain the environment and economic processes. Many of these services lack adequate substitutes, thereby, requiring careful stewardship of the ecosystems providing them. Processes, functions, and services of ecosystem services are listed in table 1.

Table 1. Goods and Services Provided by Ecosystems

Ecosystem functions	Ecosystem processes and components	Ecosystem goods and services (benefits)
Regulatory functions Maintenance of essential ecological processes and life support systems		
Gas regulation	Role of ecosystems in biogeochemical processes	Ultraviolet-B protection Maintenance of air quality Influence of climate
Climate regulation	Influence of land cover and biologically mediated processes	Maintenance of temperature, and precipitation
Disturbance prevention	Influence of system structure on dampening environmental disturbance	Storm protection Flood mitigation
Water regulation	Role of land cover in regulating run-off, river discharge and infiltration	Drainage and natural irrigation Flood mitigation Groundwater recharge
Soil retention	Role of vegetation root matrix and soil biota in soil structure	Maintenance of arable land Prevention of damage from erosion and siltation
Soil formation	Weathering of rock and organic matter accumulation	Maintenance of productivity on arable land
Nutrient regulation	Role of biota in storage and recycling nutrients	Maintenance of productive ecosystems
Waste treatment	Removal or breakdown of nutrients and compounds	Pollution control and detoxification

Table 1. Continued

Ecosystem functions	Ecosystem processes and components	Ecosystem goods and services (benefits)
	Habitat functions Providing habitat (suitable for living space) for wild plant and animal species	
Niche and refuge	Suitable living space for wild plants and animals	Maintenance of biodiversity Maintenance of beneficial species
Nursery and breeding	Suitable reproductive habitat and nursery grounds	Maintenance of biodiversity Maintenance of beneficial species
	Production functions Provision of natural resources	
Food	Conversion of solar energy into edible plants and animals	Building and manufacturing Fuel and energy Fodder and fertilizer
Raw materials	Conversion of solar energy into biomass for human construction and other uses	Improve crop resistance to pathogens and pests
Genetic resources	Genetic material and evolution in wild plants and animals	Biodiversity
Medicinal resources	Variety of (bio)chemical substances in, and other medicinal uses of, natural biota	Drugs and pharmaceuticals Chemical models and tools Test and assay organisms
Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion, handicraft worship, decoration, etc.
	Information functions Providing opportunities for cognitive development	
Aesthetic	Attractive landscape features	Enjoyment of scenery
Recreation	Variety in landscapes with (potential) recreational uses	Ecotourism
Cultural and artistic	Variety in natural features with cultural and artistic value	Inspiration for creative activities
Spiritual and historic	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes
Science and education	Variety in nature with scientific and educational value	Use of nature for education and research

Note: Adapted from Heal et al. (2005) and Barbier (2007).

There are numerous ecosystem services provided by any acre of land. Further, these services are not confined to political boundaries. Services are bundled with land

and other resources extracted from natural systems; isolating individual components is difficult. As noted earlier, non-rivalry in consumption present in most of these services creates very little, if any, incentives for landowners to invest optimally in ecosystem services. An example from table 1 would be habitat functions. If a landowner has trees on their land where a certain species of birds nest, their neighbor can cut down similar trees from their land, but still enjoy the birds because they nest in the neighbors' trees. In this case, both property owners' benefit, but only the landowner with trees incurs the cost of maintaining trees on their property.

What is Total Economic Value?

A generic stylized framework of total economic value (TEV) is presented in figure 5. This framework is extensive; it portrays most of the values humans place on natural resources (Mjelde 2009). Not all resources possess all the different components in figure 5. Further, there may be competitive and complementary relationships between the components; one must be careful to not double count values. The objective of the framework is to illustrate the various components that need to be considered when valuing ecosystems for policy and decision-making. Economic values are anthropocentric instrumental values based on utilitarian principles (Rolston 2000; Heal et al. 2005). Anthropocentric implies "human-centered" and assumes values arise because of the interest and preferences of humans (Rolston 2000). Values are further distinguished as being instrumental or intrinsic. Instrumental values of ecosystem services arise from the ecosystem usefulness in achieving a goal. Intrinsic values arise because the ecosystem has value in addition to its contribution to achieving a goal, that is, the ecosystem may have value beyond its instrumental value. Instrumental and intrinsic values can be either anthropocentric or biocentric. Biocentrism implies "non-human-centered; it does not exclusively center on humans (Rolston 2000).

One other classification is utilitarian and deontological values. Utilitarian values of an ecosystem arise because of its ability to increase human welfare. Because utilitarian values arise from the goal of increasing human welfare, utilitarian values are instrumental values (Heal et al. 2005). Under the deontological classification, ecosystems have a right of existence because they have intrinsic values. Economic values may undervalue a resource as they are not all-inclusive; they do not include biocentric values (Rolston 2000). The main emphasis in valuing an ecosystem is not to place "a price tag" on the resource, but rather to assess welfare changes caused by a policy change which affects the ecosystem (Turner et al. 2003). Concentration is on economic values associated with ecosystem goods and services; however, as noted other potential values exist.

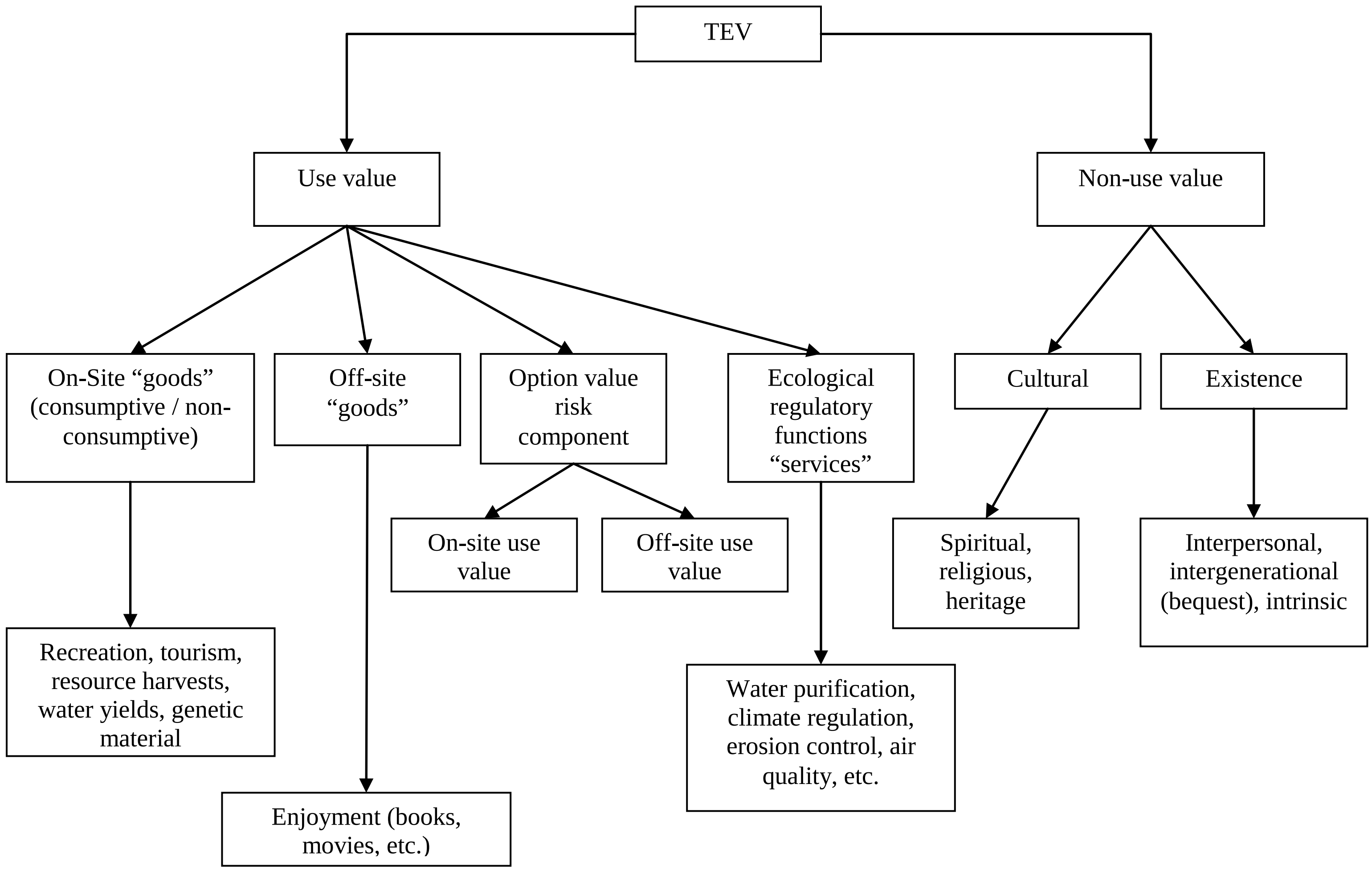

Figure 5. Components and relationships in the TEV framework associated with a stylized natural resource

TEV is divided into use and passive (nonuse) values. Use values arise from either direct or indirect interactions with the resource. Direct use of a resource is illustrated through both productive use within the economic system and on-site goods components. Productive use is when a resource is used as an input to produce a good that will be marketed in the economic system, for example, the use of rangeland for grazing cattle. The values of productive uses are usually reflected in the market price of the ecosystem, usually land. The remaining values are generally non-market in nature, although some of the components may have both market and non-market characteristics. On-site goods include activities undertaken at the resource. On-site goods can be consumptive (hunting) or non-consumptive (waterskiing on a lake). Both off-site goods and ecological service functions represent indirect use of a resource. Off-site goods are composed of activities undertaken away from the resource such as watching a documentary on a wetland. Ecological services perform a regulatory function essential for ecosystem balance which is indirectly beneficial to humans. An example of an ecosystem regulatory function is the protection of coastal lands from tropical storms provided by mangrove swamps. Option value allows an individual to postpone making an irreversible decision about a resource until they have more information about future costs and benefits.

Passive values are values not associated with the use of the resource. Both Turner et al. (2003) and Fausold and Lilieholm (1999) indicate there remains much debate surrounding the definition of passive values, especially given how they traverse the nonhuman criteria. Cultural beliefs may give intrinsic values to some resources. A prime example is the value given to ancient cave paintings by historians, anthropologists, and society. Interpersonal and intergenerational values arise from individual altruistic motivations, the warm glow or stewardship which one gets from ensuring the resource is available for others to use. Interpersonal values are concerned with providing the resource to the present generation; whereas, intergenerational (bequest) values are concerned with providing the resource for future generations. Intrinsic values arise when people feel that it is a human responsibility on behalf of nature to ensure resources are conserved (Turner et al. 2003). Saving endangered species is often considered an intrinsic value. As shown in figure 5, TEV is an aggregation of these different components. TEV, however, is not a simple summation of the different values.

Valuation Methodologies

To value natural resources, there must be a link between the structure, functions, and derived benefits of the natural systems (Heal et al. 2005). These linkages are complicated by the dynamic and complex nature of natural systems (Brander, Florax, and Vermaat 2006) and their interactions with the economic system. Because of the potential public good nature of services from land, most land has only part of its value reflected in its market price. For many ecosystem services, the lack of a competitive market makes it difficult to impossible to observe measurable values through prices (Heal et al. 2005; Brander, Florax, and Vermaat 2006; Straton 2006; Barbier 2007). In many policy contexts, some of the values for the various components are omitted; therefore, the economic values used in these contexts are lower bounds. If the resource values are totally omitted, then policy decisions implicitly place a zero value on the resource. Economic theory clearly shows the economic system will overuse a resource if a value of zero is placed on the resource. Placing a positive value on at least some of the components is generally better than placing a zero value on the resource.

Ideal General Methodology

A general methodological approach for valuing ecosystem services is presented in figure 6. One key point illustrated in this figure is information derived from various disciplines is necessary to value changes that occur in both quality and quantity of the resources. Valuation, therefore, requires a coalition of experts or output from the different disciplines. The United States Environment Protection Agency [U.S. EPA] (1995) refers to valuation as biophysical analyses linking biophysical processes with economic valuation. Another key issue is the "with and without" scenarios. What prompts valuation studies is society's desire to understand the effect of a new or a change in policy, for example, a policy on land conversion from agriculture to urban housing. In box 1, policy is used as a generic term to indicate any change be it a government policy, private initiative, or some other process. Policies can enhance or diminish the ecosystem's ability to generate welfare to society. Brush control policies in the Hill Country of Texas, for example, may enhance water yields; brush control, however, may diminish habitat for a species preferring brush over grassy areas.

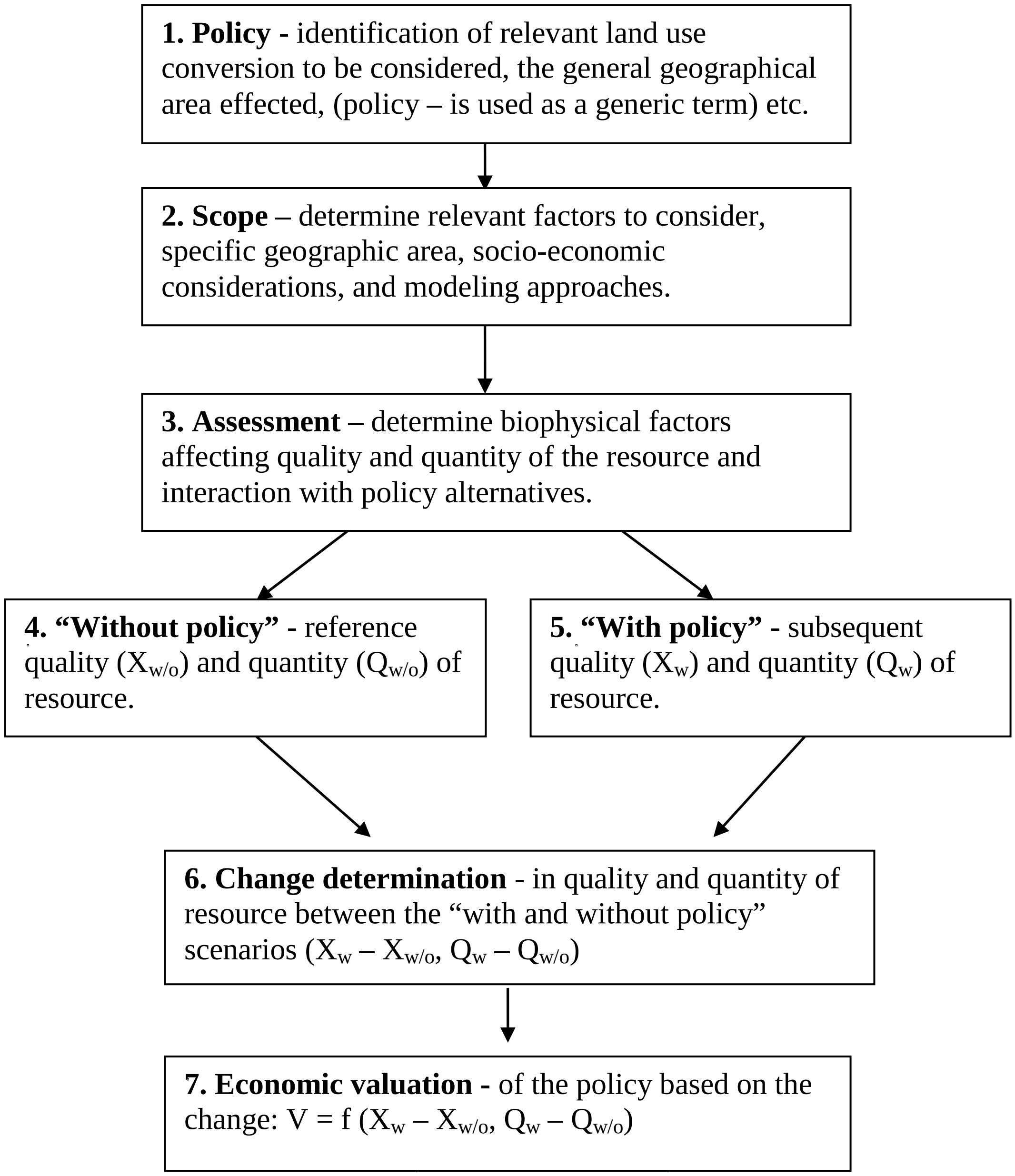

Figure 6. General methodology to determine the value of ecosystem goods and services from a natural resource considering both quality and quantity aspects
(Note: this figure does not include the cost side)

The scope (box 2) draws fences around the study. Much of this step is driven by how the policy affects the ecosystem, policy goals, institutional constraints, funding, available data, models, expertise, etc. Besides identifying an area, other factors affecting economic valuation must be determined. One such factor is the kind of services offered by the ecosystem (table 1). Further, attempting to value all services provided by a specific site individually would be time and modeling intensive, cumbersome, and may result in double counting. As such, some economic studies have estimated the total economic value directly instead of values for the different components (Lee and Mjelde 2007; Turner at al. 2003). A second approach has been to estimate a value for just one or a few of the ecosystem goods or services (Banzhaf et al. 2004).

To obtain the sum of the benefits, generally information on individual benefits is necessary along with a method of aggregating the benefits to the relevant population (Haab and McConnell 2002). “Willingness-to-pay” (WTP) is the concept most often used by economists to represent an individual’s value of a good. WTP refers to the value of a good or service; it is the maximum monetary amount that an individual would sacrifice to obtain a good or service. Individual’s WTP are then aggregated to obtain the sum of the benefits or aggregate WTP for a public action. Studies have suggested that the WTP increases for land with more ecosystem services than land with fewer services (Weicher and Zeibst 1973; Thibodeau and Ostro 1981; Ready and Abdalla 2005). Lack of a well-defined market, however, complicates estimating the value of ecosystem services.

Besides the services provided when valuing an ecosystem, it is also important to be sensitive to the geographical size of the area to be considered. Geographical size influences people's valuation of a change (Heal et al. 2005). The size of area where the policy will be implemented helps form the basis of the change. Valuing wetland services from 100 acres or 10,000 acres may lead to different per acre values (Heal et al. 2005). The policy, however, usually dictates the geographical region.

Socio-economic considerations must also be considered, including which economic values to consider (figure 5). At this point, determination of not only which factors to consider but also which economic values to include is necessary. Other issues affecting the ecosystem's value, such as population, substitutes, income, climate, etc., must also be considered at this time. The scope (e.g. area, factors, and values) along with available funding, data, models, and expertise dictates the modeling approach. As stated earlier, boxes 1 through 2 are highly interrelated; determination of one usually partially dictates the others.

Boxes 3 through 6, along with box 7, are much more disciplinary oriented and determined by boxes 1 through 2. Representative biophysical modeling approaches are presented in table 2. Box 7 involves economic models that build on the work of biophysical analyses (boxes 3 - 6). Concerning the linkages between biophysical and economics, U.S. EPA (1995 p. 7) states "It is difficult to overemphasize this important point." To illustrate the multitude of disciplinary models consider the following examples. First, if one chooses to value the ecosystem service of water yield from a given area of land, biophysical aspects must include hydrological modeling to determine how the policy will impact water quantity and quality. Economic modeling may include a supply (including treatment costs) and demand model for the city affected by the change in water quantity and quality. If a policy resulted in an increase in dust (with no health effects) from the ecosystem, cost of averting behavior, namely an increase in cleaning costs from market data may be the appropriate economic model, whereas, the biophysical model would track wind and dust. Another example of a nonmarket ecosystem service is the value of scenic views provided by open spaces. No real market data exists for this good; valuing scenic aspects is best accomplished by a stated preference approach.

Table 2. Examples of Biophysical Models Used in Valuing Ecosystem Services

Type of model	Factor(s) considered
Hydrology	Rate of recharge and discharge, quantity, quality
Oceanography	Wave pattern, wave damage, marine organisms
Climate	CO_2 regulation / sequestration
Biological	Fisheries
Vegetative	Crops / rangeland / trees
Count	Birds
Ecology	Species population

The key point from boxes 3 through 7 is that it is the change in the ecosystem resource brought about by the policy which affects societal welfare.

This change and subsequent value to society is the interaction of biophysical, political, economic, and other forces. Available funding, time, data, models, and other resources force valuation studies to deviate from the ideal presented in figure 6. Another key point is one size does not fit all. Until a specific policy, area, ecosystem service, etc. are defined, only a general approach can be stated. This nonspecific nature arises because of the non-market aspects of valuing ecosystem services and need for multi-disciplinary involvement.

Overview of Non-market Valuation Techniques

Given ecosystem services are generally not traded in the marketplace, non-market valuation techniques must be used. A brief overview of various techniques is presented. Economic techniques are better suited to valuing a change rather than providing an absolute value of an ecosystem. A graphic depiction of techniques commonly used by economists to value non-market goods and services is shown in figure 7.

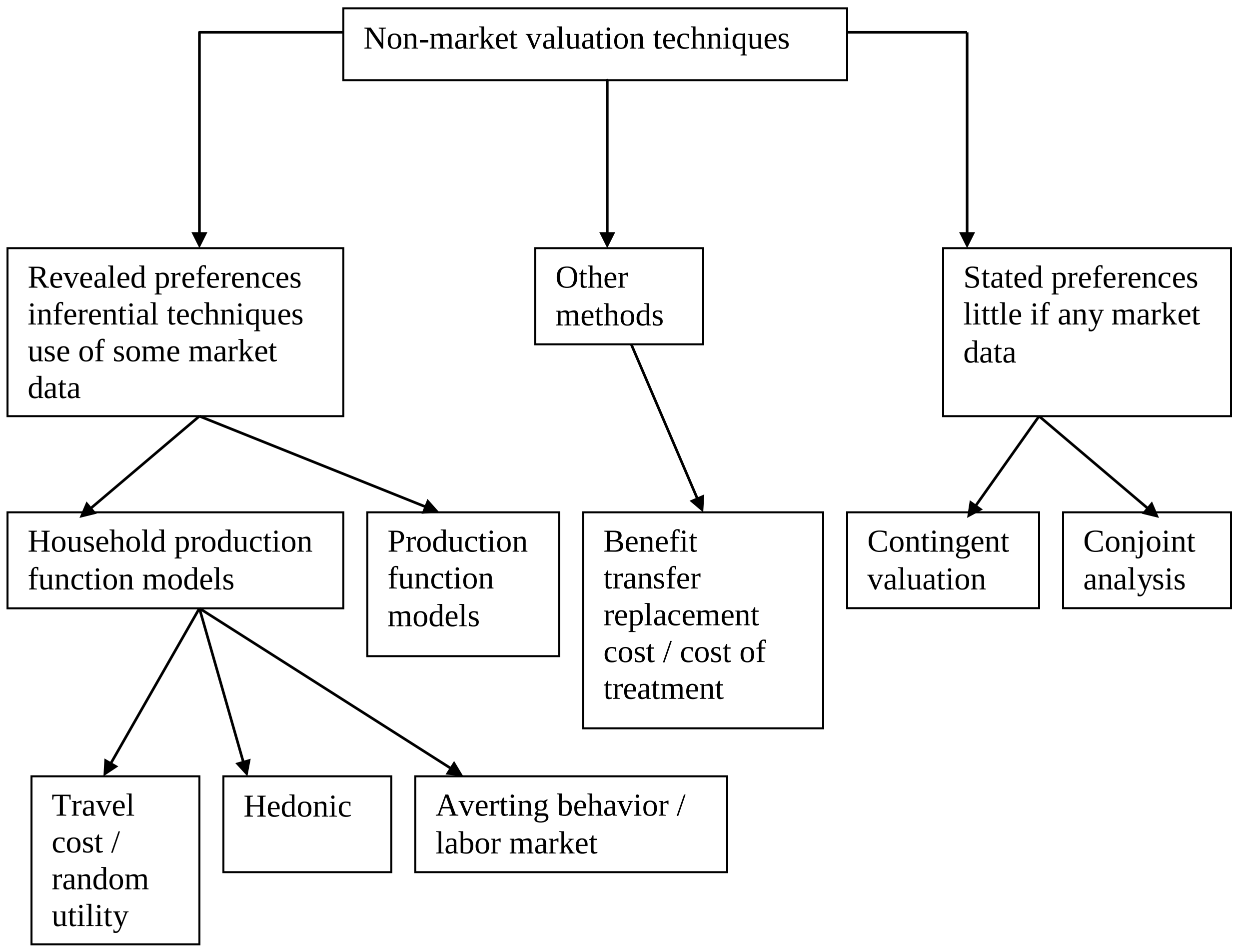

Figure 7. Relationship between non-market valuation techniques

Economic valuation approaches are given in table 3. Values from these non-market valuation approaches are obtained either directly or indirectly using the different methods.

Table 3. Classification of Valuation Approaches

	Revealed Preferences	Stated Preferences
Direct	Competitive market prices Simulated market prices	Contingent valuation, open-ended response format
Indirect	Household production function models Time allocation Random utility and travel cost Averting behavior Hedonics Production function models Referendum votes	Contingent valuation, discrete-choice and interval response formats Contingent behavior Conjoint analysis (attribute based)

Note: Adapted from Heal et al. (2005).

In table 4, what is involved in estimating non-market values for each method is briefly illustrated. Because a common metric is usually needed, quantified values are normally in dollar or WTP for the change.

Table 4. Different Valuation Approaches Used to Value Ecosystem Services

Valuation method	Types of values estimated	Common types of applications	Ecosystem services valued
Travel cost	Direct use	Recreation	Maintenance of beneficial species, productive ecosystems and biodiversity
Averting behavior	Direct use	Environmental impacts on human health	Pollution control and detoxification
Hedonic price	Direct and indirect use	Environmental impacts on residential property and human morbidity and mortality	Storm protection; flood mitigation; maintenance of air quality
Production function	Indirect use	Commercial and recreational fishing; agricultural systems; control of invasive species; watershed protection; damage costs avoided	Maintenance of beneficial species; maintenance of arable land and agricultural productivity; prevention of damage from erosion and siltation; groundwater recharge; drainage and natural irrigation; storm protection; flood mitigation
Replacement cost	Indirect use	Damage costs avoided; freshwater supply	Drainage and natural irrigation; storm protection; flood mitigation
Stated preference	Use and nonuse	Recreation; environmental impacts on human health and residential property; damage costs avoided; existence and bequest values of preserving ecosystems	All of the above

Note: Adapted from Barbier (2007).

Techniques commonly used by economists to value non-market goods and services include:

- *Revealed preference* – monetary values are estimated based on directly observed economic behavior or through some indirect data analysis method for which individual preferences can be inferred (Heal et al. 2005).

- *Stated preference* – monetary values are estimated based on stated behavior or survey responses that are used to reveal individuals' values (Heal et al. 2005).

- *Value transfer* – a value(s) from existing study (ies) is transferred to a new application different from the existing application in location and time (Boyle and Bergstrom 1992).

- *Replacement or avoided cost and cost of treatment* – benefits of a service are approximated by the cost of providing the service (Heal et al. 2005).

- *Production function* – the environmental good or service is treated as an input factor into the production of a market good or service. The availability of the ecosystem good or service influences the cost and supply of the market good. (Heal et al. 2005).

Because of time and budget constraints, the use of value or benefit transfer techniques have been increasingly used. These techniques involve taking the value(s) obtained from previous studies and transferring them to another location where time and budget constraints do not allow an original study (Rosenberger and Loomis 2003). Value transfers conditioned on attributes of ecological or economic choice setting are of two general forms:

- *Unit transfers* – this uses either a single point estimate such as the median or mean willingness-to-pay / accept (WTP/A), and transfers it to a new policy setting (Spash and Vatn 2006), and

- *Function transfers* –uses an estimated equation (supply, demand, or meta-analysis) to provide a customized value for a new policy application (Heal et al. 2005).

Cons of using non-market valuation techniques

For revealed preference methods, the key to obtaining values is whether an ecosystem service affects people's behavior, if it does not then applicability of the method becomes limited because behaviors cannot be observed (Heal et al. 2005). Even if market behaviors can be observed, Haab and McConnell (2002) argue that real values are typically not observable. Thus revealed preference methods are not as valid a benchmark against which other methods like stated preference methods can be measured against as market structures and institutions can influence market outcomes (Haab and McConnell 2002).

Stated preference methods have widely been criticized for their use of hypothetical questions to induce responses that can be used to infer preferences for or the value of changes in public goods (Haab and McConnell 2002). These responses however, are said to almost not reveal the precise economic value that economists wish to measure. Uncertainty and errors in estimation are highly likely since this is a two-step process, inferring the right behavioral function which is then estimated to get economic values can be complex (Haab and McConnell 2002). Besides, it is hard to ensure that respondents do not play games when questions are presented to them, how a certain situation is presented or affects their individual welfare highly influences how they respond. Use of combined stated and revealed preferences have been done as a way of cross-validating results from each approach and worked well only if the baseline level of the amenities are the same across the responses which in some cases does not apply.

The production function approach is limited in economic valuations because the underlying nonlinearities in ecological and economic relationships are not well understood (Haab and McConnell 2002). Until better understanding of the ecological, hydrological, and economic features as well as the physical effects on production of changes in the system is done, the production function approach becomes very limited in its applicability. Replacement costs methods also do not give economic values but the cost of replacing the service and does not include any benefit information. Most ecosystem services however do not have substitutes that provide the same services hence their limited applicability. Value transfers then make sense in such situations.

Value transfers may or may not work for all the components. It is difficult to obtain a representative sample of ecosystem values from previous studies because to transfer the value, the attributes of the locations must be similar. Because results for the new study depends on previous studies, errors committed in the original studies are carried over to the new study making benefit transfer depend on the accuracy of the original studies. There is also the problem of selection bias because the researcher selects which studies to include in the analysis (Hoehn 2006). Benefit transfer, however, has been gaining popularity as improvements in its use and estimation occur. Details about the methods used in this study are given in the appropriate chapters.

An Analogy

Out of sight, out of mind applies to ecosystem goods and services. Ecosystem goods and services are not purchased by consumers on a daily basis, as such consumers do not continually think about these services. A simple analogy between the automobile market and ecosystem services helps provide insights into the value of ecosystem goods and services.

Consider the price of a new automobile. Market price is determined by the interaction between supply (producers) and demand (consumers) conditions in the economy. To continue in business, producers can not (ignoring short-term promotions) sell automobiles below the cost of producing the car. Costs include management, parts, regulations, labor, capital, etc. A consumer will not purchase an automobile unless the benefits associated with ownership are greater than or equal to the purchase price. Ignoring externalities, price reflects society's marginal valuation of automobiles. The value of a new pristine automobile is greater than the value of the sum of its parts. Similarly, pristine ecosystems' values are derived from the many different use and nonuse values they provide. The value is greater than or equal to the sum of its parts.

As with all durable goods, the value of automobiles decline once purchased. Ecosystems' values also tend to decline from pristine undisturbed areas to areas that have been used by humans. *Ceteris paribus*, the value of ecosystem goods and services decline with increasing human use. In descending order in terms of the value of ecosystem goods and services, ecosystems can be generally ranked as follows: 1) pristine ecosystems; 2) lightly used ecosystems such as lightly grazed native pastures or forestland; 3) slightly altered ecosystems such as improved grazing land; 4) agricultural crop land and intense silviculture; and 5) sparsely developed land such as large tract subdivisions; and 6) intensely developed land such as towns and cities. Unfortunately, very little undisturbed pristine land remains in Texas, the United States, or the world.

Good land stewardship, just as with wise use and maintenance of an automobile, can maintain the value of the asset be it an ecosystem or an automobile. Improper use lowers the value of the asset possibly driving the value to zero or even negative.

Unlike new cars, the sum of the value of the parts of used cars does not provide a lower value for the car. That is, replacing many parts such as the tires, brakes, engine, etc. will cost more than the used automobile will be worth once the repairs have been completed. This fact has some implications for ecosystems. First, degrading the ecosystem and then restoration / revitalizing the ecosystem will not provide the same value for ecosystem goods and services than if the ecosystem was not degraded in the first place. Second, separately valuing the different components of ecosystem goods and services of non-pristine areas and summing the values may over estimate the value of the ecosystem. This helps explain why ecosystem valuation is not a simple aggregation of values of the different components making up the ecosystem. Unlike a car, separating the various components of the ecosystem is not easy; hence, the probability of double counting is high which could also be responsible for the inflated values derived from using the sum of parts approach.

Irrespective of the approach taken to value an automobile, it is generally accepted that as a car make and model becomes scarce, its value increases. Looking at the prices of vintage/classic cars illustrates this point. For example, a 1936 Mercedes 540K Special Cabriolet sold for $2,035,000 at the Scottsdale Classic Auction on Monday 21 January 2008, whilst the latest 2008 Mercedes-Benz SLR McLaren is selling for about a quarter of that price at $495,000 (Hamer and Hamer 2008). This shows that value is created from scarcity of a commodity. Even if the vintage car is used, its scarcity increases its value; this value could be higher than the original price if it is scarce enough. Although comparison of cars head-to-head is difficult because of different features, what is important is the illustration of increasing the value associated with increasing scarcity. This same analogy applies to ecosystems. Pristine ecosystems' values are high because of their scarcity. As society continues to lose ecosystems, increasing scarcity will increase the value of the remaining ecosystems. Less pristine ecosystems' values are also increasing as we lose more open spaces, just as some automobile values increase with increasing scarcity. World Heritage Sites maybe a case in point. Because of their uniqueness or realization of their importance to humans, these sites are highly valued and effort is being expanded to keep them in their almost pristine state. An example in the U.S. is the Olympic National Park in northwestern Washington State, which is highly valued for its diverse ecosystems. The same rationale also applies to endangered species; they qualify for such classification because they have a high risk of extinction.

CHAPTER III

LITERATURE REVIEW: PREVIOUS VALUATION STUDIES

A brief review of the literature provides background and perspective. This review is divided into four sections; ecosystem services, constructed wetlands, farmland amenities values, and agricultural land values. The first section provides further evidence of the economic value of ecosystems, whereas the other sections are particularly relevant to the related studies. Further, the review illustrates the wide range of values that have been obtained and the diversity of methodologies used. The review also illustrates the scarcity of studies valuing farmland amenities and ecosystem services in the U.S. and especially Texas. A discussion o the purchase of development rights to preserve agricultural lands concludes the necessary background for this dissertation.

Ecosystem Services

Various studies valuing different ecosystem services are summarized in table 5. As noted earlier, this summary illustrates the diversity of methods, areas, and services that have been valued. Several studies, for example, obtained willingness-to-pay (WTP) for changes in quality or level of ecosystem goods and services (Bulte et al. 2002; Beasley, Workman, and Williams 1986; Johnston et al. 2001). Other studies have valued recreational experiences (O’Rear Henry 1998), while other studies have explicitly valued ecological services (Loomis et al. 2000; Hagen, Vincent, and Wells 1992; Jenerette, Marussich, and Newell 2006; Kreuter et al. 2001).

Table 5. Overview of Ecosystem Goods and Services Values from Previous Studies

Location	Study	Amenities valued	Dollar value	Other
		Texas		
Houston, Texas	Khan (2005)	Effects of urban development on runoff	1984-1994, vegetation cover increased by 13%, decreased by 1% from 1994-2000 and 8% from 2000-2003	Concrete and asphalt increased by 21% (1984-1994), 39% (1994-2000) and 114% (2000-2003).
San Antonio, Texas	Kreuter et al. (2001)	Change in land use and ecosystem services due to urban sprawl	$5.58/ha/yr ($6.24 million) decline in ecosystem services value for 1976-1991 from rangeland to urbanized use $23.22/ha/yr decline in ecosystem value for change in land use from rangeland to woodland (1976-1991)	403% increase in woodland in the 1976-1991 period
Texas Rice Acreage	O'Rear Henry (1998)	Nonmarket values for wetland type services provided by rice acreage	Nonmarket value for rice production (-$157.11/acre) Nonmarket value for hunting $132.25 Market based hunting $7.24/acre Net fish harvest value $1.14/ acre	Consumer surplus $123.08 Producer surplus $1.93
Livingstone & Houston (Four Lakes Region), Texas	Turner (1991)	Recreational value of boating on freshwater	Average consumers' surplus using travel cost method (1985 US dollars): Control - $ 13.01 Livingstone - $102.09 Houston - $13.01	Average consumers' surplus using closed-ended contingent valuation method (1985 US dollars): Control - $39.38 Livingstone - $35.21 Houston - $13.81

Table 5. Continued

Location	Study	Amenities valued	Dollar value	Other
East and West Coasts of Florida (Virginia to Texas)	Bell (1997)	The marginal consumer surplus per acre of wetland (1984 U.S. Dollars)	WTP for a saltwater recreational fishing day: Florida East Coast - $53.25 Florida West Coast - $35.29 Capitalized value of wetland/acre: Florida East Coast- $6,471 Florida West Coast - $ 981	Average value of State Coastal Purchases/ Acre: Florida East Coast - $9,383 Florida West Coast - $2,000 Acres of saltwater marsh: Florida East Coast - 95,882 Florida West Coast – 431,266
Atchafalaya River Basin (Arkansas, Louisiana, Mississippi, and Texas (statewide)	Bell (1981)	Daily median WTP & net consumer surplus (CS) values for freshwater fishing, saltwater fishing and hunting by state (1975 US dollars)	Daily Median WTP in Texas for: Freshwater fishing - $5 Saltwater fishing - $33.33 Hunting by state - $14.29 Net consumer Surplus/recreational day for Texas: Freshwater fishing - $29.23 Saltwater fishing - $44.67 Hunting by state - $40.71	Daily Median WTP in all 4 states for fishing: freshwater - $6.16 saltwater - $20.08 hunting - $12.50 net CS/ recreational day for all 4 states in fishing: freshwater -$48.99 saltwater - $103.42 hunting by State - $63.33
The Aransas National Wildlife Refuge, Texas;	Bowker and Stoll (1988)	WTP to preserve the whooping crane (an endangered species) by both users and nonusers of the Aransas National Wildlife Refuge	Whooping crane annual estimates: mean WTP - $21-149 Median WTP – ($-62-67)	Both income and membership in wildlife organizations led to an increased probability of offer acceptance

Table 5. Continued

Location	Study	Amenities valued	Dollar value	Other
Texas Gulf Coast	Cameron (1988)	The value of access to the fishery in its existing state and with improved environmental quality (1987 US dollars)	Complete loss of access to the fishery - $3,037/angler Improvement of environmental conditions from one standard deviation below the mean index value to one standard deviation above - $1,400/angler/year	Increase in quality by one unit - $216 extra surplus for anglers
Colorado River Basin, Texas	Lansford, Jr. and Jones (1995)	Marginal price estimates for recreational and aesthetic values derived from Lake Austin	Mean values for residences within 2000 feet of Lake Austin -$151,253 Mean recreational / aesthetic price within 2000 feet of Lake Austin - $42,191	The study finds that the lake contributes $65,860,596 to the value of homes in the Lake Austin area
The Aransas National Wildlife Refuge, Texas;	Stoll and Johnson (1984)	Use, option price and existence values for the whooping crane resource (1983 U.S. dollars)	Mean use value of refuge visitors: with whooping cranes - $4.47 without whooping cranes - $3.07 Mean option price: Refuge visitors - $16.87 Texas residents - $10.67 Out-of-state residents - $13.24 Mean existence value: Refuge visitors - $9.33 Texas residents - $1.03 Out-of-state residents - $1.24	Total use value for the refuge - $213,000/ year Option price + existence value - $779,000/year Total annual value by users - $992,772 Texas, option price + existence value = $38.7 - $109 million U.S. option price + existence value = $573 - $1.58 billion
Fort Hood, Texas	Sutton, Stoll, and Ditton (2001)	WTP for increased license fees for different fishing quality scenarios; current, decrease by 25%, and increase by 25%	Fishing quality revenue from license sales would be maximized at license fee of: Current - $ 14.70/year Increased -$ 18.45/year Decreased - $ 12.90/year	WTP was related to fishing quality, license cost, and satisfaction with Fort Hood fishing

Table 5. Continued

Location	Study	Amenities valued	Dollar value	Other
Texas Coast	Oden, Butler, and Paterson (2003)	Various Coastal Erosion Projects	16-1 benefit-cost ratio over the economic life of the various projects	Varies by project – not necessarily ecosystem services but enhancement
Texas Coastal and Near Coastal Counties	Brody et al. (2007)	Effect of growth on flood damages	Single wetland permit translates into 2,188 in added property damage per flood	Naturally occurring wetlands important in mitigating flood damage
		U.S. Not Including Texas		
United States (121 cities)	Jenerette, Marussich, and Newell (2006)	Linking ecosystem valuation to ecological footprint analyses	Median monetary footprint value for water footprint area \$80,808/km^2/yr	
Washington State	Scott et al. (1998)	Cost to traffic	\$15-50/ac/yr	Opportunity costs grazing = 3.35, farming dry = 12.40, irrigation = 74.20 urban = 460.40
		Health – respiratory	\$0.45/ac/yr	
		Household Cleaning	\$48-169/ac/yr	
		Visibility Value	\$4-14/ac/yr	
		Cost of CRP	\$47/ac/yr	
		Cost of soil stabilization	\$6-21/ac/yr	
		Hunting	\$6-75/ac/yr	
		Species diversity	\$52-75/ac/yr	
Colorado	Rosenberger and Loomis (1999)	Ranch open space to tourist	\$1,132/group trip	Note – net value of the conversion of ranchland to resort uses is zero – gainers = losers
Columbus, Ohio	Weicher and Zeibst (1973)	Value of properties facing parks between 1965 & 1969	Properties facing parks sold for \$1130 more than similar properties (7-23% increase in value)	Facing intensively used recreational parks lessened property values by \$1150

Table 5. Continued

Location	Study	Amenities valued	Dollar value	Other
Philadelphia, Pennsylvania	Hammer, Coughlin, and Horn (1974)	Enhancement value	1 ha of parkland generated $6425/ha in enhancement value	
Chesapeake Bay, Maryland	Parsons (1992)	Land use restrictions impact on property values	14-27% increase in prices of houses 1000ft inland	4-11% increase in price of houses 3miles away from bay/major tributary
Charles River Basin, Massachusetts	Thibodeau and Ostro (1981)	Enhancement value of wetlands on surrounding properties	Abutting properties increase value by $480/acre	Properties adjacent wetlands increase value by $150/acre
Rhode Island	Kline and Wilchens (1996a)	Environmental Agrarian Aesthetic Anti-growth	Mean ratings for the public's preferences using VARIMAX: Protecting groundwater – 0.83 Wildlife habitat – 0.82 Preserving scenic quality – 0.26 Preserving rural character – 0.08 Providing local food – 0.15 Keeping farming as a way of life – 0.16 Slowing development – 0.13	People who grew up in rural and suburban areas prefer agrarian objectives while those who grew up in an urban setting preferred aesthetic objectives. College – educated respondents prefer environmental objectives more than non-college ones. Income across respondents was not a factor.
Alaska	Beasley, Workman, and Williams (1986)	Open space loss in agricultural amenities near population centers	Mean WTP to prevent moderate levels of housing development $76/household ($0-760) Mean WTP for prevention of high levels of housing development $144 ($5-1,000)	Annual amenity benefits from retaining farmlands in agriculture were $626,000 for moderate and $1,284,000/year for high level of housing development.

Table 5. Continued

Location	Study	Amenities valued	Dollar value	Other
Adirondacks Park, New York	Banzhaf et al. (2004)	TEV for improvements in ecological attributes following a reduction in pollution due to policy changes	Base case (stable current scenario, small ecosystem improvement) WTP range between $48 to 107 Scope case (larger ecosystem improvement) WTP range between $54 to 159/household/year	Discount rate was 5% for a 10 year lake and forest recovery scenario Total benefits for the state of New York range from $336 million - 1.1 billion
California, Oregon, Washington	Hagen, Vincent, and Wells (1992)	Benefits of a conservation policy for the Northern Spotted Owl and old growth forests	Average household benefit of preservation ranges from low to high at $3.39-13.56/household	Benefit/cost ratio range is 3.53-14.14
Suffolk County, New York	Johnston et al. (2001)	Nonmarket valuation of coastal farmland	WTP for the preservation of all natural land uses ranged from $0.035-0.143/household/acre/year Residents' WTP for nonmarket services provided by farmland was $1,199/acre/year	Land adjacent to open space had 12.83% increase in value Land adjacent to farmland has a 13.32% decrease in value
Rhode Island	Johnston et al. (2003)	Effects of the length of residency on rural amenities value	Marginal WTP for preserved open space adjacent to roads and developments ranged from $0.60 to $1.20 Marginal WTP to locate developments on main roads ranged from -$67 to -$10	Newer residents have WTP to prevent location of new developments in visible locations adjacent to main roads Newer residents have higher WTP for open space adjacent roads and developments than older residents

Table 5. Continued

Location	Study	Amenities valued	Dollar value	Other
Berks County, Pennsylvania	Ready and Abdalla (2005)	Farmland amenities and disamenities' effects on property values	Open space impact from a 1 acre change in land use on surrounding property values within 400 m (percentage changes per acre): Privately owned forest – 0.00276 Publicly owned forest – 0.00281 Eased privately owned grass, pasture & crops – 0.00162 Vacant privately owned: - 0.00091 Impact within 500m of neighboring property values: Animal production > -6.4% Mushroom -0.8% Airport -0.3% Landfill -12.4%	Land under easement had lower impacts on neighboring properties compared to land that was not under easement
South Platte River area (near Greeley), Colorado	Loomis et al. (2000)	WTP for increased ecosystem services that would result if 300,000 acres of conservation easements along the South Platte River were purchased from area farmers	WTP for improved ecosystem services $21/household/month or $252/annum (1998 U.S. Dollars)	Annual benefits for the region were estimated at $18.54 - 71.15 million which is greater than estimated project costs of $12.3 million

Table 5. Continued

Location	Study	Amenities valued	Dollar value	Other
		World Estimates and Locations Outside the U.S.		
The World's Wetlands	Brander, Florax, Vermaat (2006)	Wetland value	Mean $ 2,800/ha/yr Median $150/ha/yr	Average values derived from the different nonmarket valuation methods:
		Woodland	$1,000 – 10,000/ha/yr	
		Fresh water marsh	$1,000 – 10,000/ha/yr	CVM ~ $10,000
		Salt/brackish marsh	$1000 – 10,000/ha/yr	OC ~ $200
		Unvegetated sediment	$9000/ha/yr	MP ~ $800
		Mangrove	$400/ha/yr	PF ~ $600
		Biodiversity	$17,000/ha/yr	NFI ~ $550
		Amenity		RC ~ $9,000
		Fuelwood	$73/ha/yr	TCM ~ $600
		Materials	$300/ha/yr	HP ~ $10,000
		Recreational fishing		
		Recreational hunting		
		Habitat & nursery		
		Water quality		
		Flood		
Costa Rica	Bulte et al. (2002)	The optimum amount of land that should be set aside to achieve a balance between forest conservation and agricultural conversion based on certainty about trends in future ecological benefits and compensations by the international community.	International community WTP to increase conservation land amounts from the locally optimal level to the globally optimal level is $279 million	NPV (7% discount rate) of optimal land allocation amounts assuming set trend value of 0.05 and uncertainty level of 0.1 for Agriculture: $3.2 billion (local) and $2.9billion (global) Forestry: $825million (local) and $1.5billion (global)

Table 5. Continued

Location	Study	Amenities valued	Dollar value	Other
World Ecosystems	Costanza et al. (1997)	TEV of global ecosystem services for the 17 categories and 16 biomes	Ecosystems provide estimated $33 trillion in services annually (1994 U.S. dollars) TEV for marine biomes was $20,949 billion and for terrestrial biomes was $12,319 billion	TEV of ecosystem services ranged from $16 to $54 trillion Nutrient cycling ($17 trillion) Cultural resources ($3 trillion) Waste treatment ($2 trillion)

Note: CVM - Contingent Valuation Method, OC – Opportunity Cost, MP- Marginal Pricing, PF – Production Function, NFI – Net Factor Income, RC – Replacement Cost, TCM – Travel Cost Method, HP – Hedonic Price.
VARIMAX method is a way of analyzing the respondents' importance of ratings through matrices of correlations between rating variables and factors.

In one of the most cited and controversial studies, Constanza et al. (1997) estimates the economic value of global ecosystem services as $33 trillion (1994 U.S. dollars). For the San Antonio area, Kreuter et al. (2001) estimate that there is a decline in ecosystem value of about $23.22 / ha / yr for a change in land use from rangeland to woodland between 1976 and 1991 showing the impact of urban sprawl on ecosystems. O'Rear Henry (1998) estimates consumer surplus from wetland type services from a rice acre to be $123.08 / acre, whereas, producer surplus is only $1.93 / acre. Of their human induced variables, Brody et al. (2007) state wetland alternation has the strongest partial correlation to flood property damage. Increasing impervious surfaces also contributes to increasing flood damage. Dams appear to reduce flood damage to the same level wetlands alteration increases damage, but dams have other negative and positive environmental issues. Lansford and Jones (1995) found Lake Austin contributes approximately $65 million dollars to the value of homes in the Lake Austin area, by creating recreation opportunities and aesthetic views.

The various methods generally show higher WTP values for land with more ecosystem services than ones with fewer services (Weicher and Zeibst 1973; Thibodeau and Ostro 1981; Ready and Abdalla 2005). Farmland conversion to open space is more highly favored if the land is being converted to forestland rather than being deserted (Beasley, Workman, and Williams 1986). The kind of enterprise operated adjacent to a parcel of land has an impact on the value of the land (Johnston et al. 2003; Ready and Abdalla 2005; Thibodeau and Ostro 1981). Property prices increased by at least 4% if the adjacent land was open space or left undeveloped (Ready and Abdalla 2005).

Constructed Wetlands

Woodward and Wui (2001) and Brander, Florax, and Vermaat (2006) provide comprehensive reviews of studies valuating natural wetlands. To not repeat these reviews and the fact that one of the case studies is concerned with constructed wetlands (CWs), a brief review of value and services from constructed wetlands is provided. Wetlands' ecosystem benefits include nutrient removal from point and nonpoint source pollution, flood control, species habitat, erosion control, and recreation (U.S. EPA 2007). Besides efficiently removing pollutants, such as suspended solids and nutrients, wetlands have been documented as improving the quality of effluent discharge (Reuter, Djohan, and Goldman 1992; Knight 1997; Day et al. 2004; Bergstrom and Stoll 1993). The relatively low costs of developing CWs, along with the ecological and economic performance of wetlands has led to the growing interest in the creation of flexible artificial wetlands or CWs. Increasing development of wetlands is also occurring because of the passing of regulations and public policies influencing wetlands management (Wetlands Reserve Program 1999; Bergstrom and Stoll 1993).

CWs are generally designed to imitate natural wetlands in their form and functions (United Nations Environment Program [UNEP] 2008). Such wetlands have been designed in sizes from 200 m^2 to 4,000 ha or 0.049 to 9,980 acres (Knight 1997). Main reasons for constructing wetlands are to enhance wastewater treatment capacity, relieve pressure on existing wetlands, and as a mitigation effort to restore overused and lost wetlands. Most CWs are designed for multi-purposes including operating as secondary and tertiary wastewater treatment plants, providing wildlife habitat, providing on-site recreational facilities, and as accretion sources in coastal areas to offset subsidence (Day et al. 2004; Knight 1997; U.S. EPA 2007).

Two main types of constructed wetlands are subsurface systems common in Australia, Europe, and South Africa and the free-water-surface systems common in North America (U.S. EPA 1993; Brix 1999; UNEP 2008). As the names imply, subsurface systems have water flows below the ground; whereas, surface systems have above-ground flows (Rousseau et al. 2008). Although CWs take many forms, the basic components are a screening stage to separate solids by settling, wetland cells, aeration, and disinfection stages (UNEP 2008). CWs can be sited to take advantage of adjoining land and water structures; this technological ability has increased the use of CWs (Steer, Aseltyne, and Fraser 2003).

CWs for Wastewater Treatment

Compared to conventional (non-wetlands wastewater) treatment plants, CWs use relatively simple passive technology. This passive technology generally has lower costs in terms of capital investment, operation and maintenance, and labor costs relative to conventional treatment plants (Cronk 1996; Day et al. 2004; Steer, Aseltyne, and Fraser 2003). Constructed wetlands, however, generally require a much larger land footprint than conventional treatment facilities. Pollutants and nutrients are removed in wetlands through physical (settling and filtration), chemical (precipitation and adsorption), biological processes (denitrification, burial, and storage in vegetation), or a combination of these processes (Day et al. 2004). As a waste removal sink, CWs have been reported to be effective in lowering nitrogen, phosphorus, suspended solids, toxic elements, and bacteria from wastewater (UNEP 2008; Tarrant Regional Water District [TRWD] 2008).

CWs are a potential cost effective method of treating municipal, industrial, agricultural, and urban runoff wastewater (Knight 1997). Although CWs are generally thought to be mainly suitable for small communities (< 5,000 people), larger CWs have been successfully developed, for example, the Columbia Wetland (Knowlton, Cuvellier, and Jones 2002). The Columbia Wetland is a surface-flow constructed cattail wetland. It was created to treat primary and secondary effluent. The wetlands also provides constructed habitat for waterfowl in the Eagle Bluffs Conservation Area. Both the Eagle Bluffs Conservation Area and the Columbia Wetland are located in the Missouri River floodplain in Missouri. The Columbia Wetland has a design capacity of 67,000 m^3 (2, 366,082.67 cubic feet) per day of water flow; hence it is one of the largest constructed treatment wetlands (Knowlton, Cuvellier, and Jones 2002).

Most studies caution against comparing costs because the cost structures differ across projects (Rousseau et al. 2008; Knowlton, Cuvellier, and Jones 2002; Knight 1997; Steer, Aseltyne, and Fraser 2003). On a worldwide scale, Rousseau et al. (2008) concludes that CWs offer a cost-effective opportunity for creating high quality effluent that can be reused, as well as, opportunities for nutrient recycling, wildlife habitat, and recreational facilities. Accordingly, Knight (1997) argues that CWs should be treated as a vital component of the ecosystem, because they offer many of the functions that sustain ecosystems. Their design should take existing ecosystems into account.

In coastal lands, CWs are often specifically designed to efficiently improve nutrient uptake in wastewater, as well as, control erosion and curb subsidence problems (Day et al. 2004). Cost of treatment analyses conducted to evaluate the economic implications of using CWs instead of a conventional wastewater treatment plant at Breaux Bridge and Thibodaux in south Louisiana are summarized in Day et al. (2004). Cost savings over 30 years in 1992 dollars are estimated at $1.4 million for Breaux Bridge and $500,000 for Thibodaux (Day et al. 2004). The increased sediment load from CWs has nutritive value, which increases vegetation productivity resulting in sedimentation to enhance vertical accretion, therefore, helping elevate wetlands to offset sea level rise which is causing subsidence (Day et al. 2004).

In another southern Louisiana avoided cost study, Cardoch et al. (2000) estimate that if CWs were to be used in pre-treating wastewater from shrimp processing, the cost savings would be about $1.5 million (1995 dollars) over 25 years. Infrastructures of CWs have a normal functional life between 20 and 30 years. Avoided costs are affected by the discount rate and timeframe assumed. Feasibility studies show that CWs may help solve a number of problems in coastal wetlands including quality of wastewater dumped into open waters, erosion, subsidence, and vegetation growth (Cardoch et al. 2000; Knight, Clarke, and Bastian 2001; Knight 1997; U.S. EPA 2007; Rousseau et al. 2008).

In comparing a two-cell domestic wetland treatment with that of sand filter systems over 20 years in Ohio, Steer, Aseltyne, and Fraser (2003) estimate CWs had costs of $500 - 3,000 less than that of sand filter systems. Their ecological footprint, however, is larger than that of sand filter systems. Further, CWs release at least twice the number of pathogens (Steer, Aseltyne, and Fraser 2003). Steer, Aseltyne, and Fraser (2003) contend that for an alternative conventional wastewater treatment system to be at least as competitive as the wetland systems, its installation costs without annual expenses would have to be in the range $6,675 - 7,700 for a single-domicile treatment wetland. Steer, Aseltyne, and Fraser (2003) did not disclose total costs; therefore, comparison to other studies is difficult. The costs associated with the operation of conventional, mechanical-type wetland treatment systems have been calculated at between $0.011 to $0.057 / m^3 / day ($0.0000416 / gallon / day to $0.000214/ gallon / day) (UNEP 2008).

CWs as Recreational Sites

Increased focus on CWs as recreational sites has contributed to the multiuse design of CWs. Multiuse CWs are typically constructed to enhance the aesthetic appeal for recreation. This appeal also helps in the acceptance of recycled wastewater from the CWs (UNEP 2008). The recognized lack of acceptance for the recycling of wastewater for reuse in municipal uses is one of the major hindrances to citing CWs near municipalities (UNEP 2008; Gunnels 2008). Recognition of CWs' habitat role as an important ecosystem component (Knight 1997) will help with their cultural acceptance. Recreational activities associated with CWs increase their appeal to society. For example, in southern Sweden, biodiversity and walking facilities are the greatest welfare contributors of the CWs (Carlsson, Frykblom, and Liljenstolpe 2003).

Recreational activities that wetlands provide include public education, nature studies, exercise activities (nature walks, jogging, and hiking trails), recreational harvest (fishing and hunting), and recreational non-consumptive activities (birdwatching, picnicking, and camping) (U.S. EPA 1993). Examples of recreation use of CWs include the Arcata Marsh and Wildlife Sanctuary in California which in 1993 had an estimated 1,600 human use days (HUD) per hectare / year (HUD / ha / y), Show Low in Arizona (7 HUD / ha / y), and the Iron Bridge in Florida (4,800 HUD / ha / y) (U.S. EPA 1993).

Despite the beneficial uses associated with CWs, they have detrimental impacts associated with them. The most cited impact is the potential unpleasant odor because of anaerobic processes occurring. Constructed wetlands require land to be taken out of other use(s). The cost of this land conversion is the economic loss from the alternative activity, as well as, disturbing the soil and vegetation structures (U.S. EPA 2007). CWs may negatively affect the water quality and quantity of adjacent water bodies. Toxic levels of pollutants can be harmful to organisms that grow or come in contact with the CWs (U.S. EPA 2007). Human pathogens can be spread if humans come in contact with the wastewater or if mosquitoes breed in the CWs (U.S. EPA 2007). Studies have linked the denitrification processes with increases in greenhouse gas emissions (U.S. EPA 2007).

Farmland Amenities Values

Bergstrom and Ready (2006) review North American farmland amenity valuation studies over the past 20 years. They found only 30 studies. Of these 30 studies, 25 studies examined farmland east of the Mississippi River (including the state of

Minnesota and eastern Canada). Five studies are by the same authors. Only four studies valued farmland west of the Mississippi River in the 48 contiguous states (one study was in Alaska). Two of these studies were performed for the same county in Colorado. No study valued farmland in Texas. Bergstrom and Ready (2006) spent considerable effort (including obtaining additional data from several authors) to place each study's value in comparable terms (mean annual WTP per acre in 2007 dollars per household). As such, values presented by Bergstrom and Ready (2006) are briefly summarized here with references to the original studies.

Contingent valuation, conjoint analysis, and hedonic price methods are the main methodological approaches used in valuing farmland amenities. Generally, per acre estimates across studies are similar for contingent valuation and conjoint analysis. Similarly, estimates across studies using hedonic price methods are similar. Hedonic price estimates are larger than contingent valuation and conjoint analysis estimates. As expected a wide range of estimates are obtained. Most studies reported positive value for farmland amenities. Two studies (Geoghegan, Lynch, and Bucholtz 2003; Johnston et al. 2001) estimate the contributions of nearby farmland to residential property values are negative. Even within a state, there is a range of estimates. For example, Bergstrom and Ready (2006) report farmland protection values of $0.0468 / acre for the State of Delaware (Duke and Ilvento 2004), but a larger value of $0.2599 for Sussex County (Duke, Johnston, and Campson 2007). Three studies in Connecticut had a range of $0.0171 to $0.6879 / acre (Johnston, Campson, and Duke 2007a, b, c).

The western state studies are more relevant to Texas. In these studies, Bergstrom and Ready's (2006) estimates range from $0.0001 / acre / year / household for both Moffat County, Colorado (Bittner et al. 2006) and Sheridan County, Wyoming (McLeod et al. 2002) to $0.0405 / acre / year / household for Routt County, Colorado (Rosenberger and Loomis 1999), which includes Steamboat Springs. The fourth study, also for Routt County, had an estimate of $0.0161 / acre / year (Rosenberger and Walsh 1997). More highly populated states and areas have higher estimates than less populated states.

Agricultural Land Values

Agricultural land values consist of both agriculture and development components (Plantinga, Lubowski, and Stavins 2002); the potential uses for the land (Guiling, Brorsen, and Doye 2009). The agricultural component is a factor of agricultural rents, whereas, distance to population centers and changing interest rates influence the development component (Plantinga and Miller 2001). Development includes the rural-urban fringe - areas bordering central cities, surrounding close-in suburbs and noncontiguous nearby towns. This is where urbanization occurs through extension into the adjacent open countryside (Chicoine 1981). The main determinants of the size of urbanized areas are population, income, transportation costs, and agricultural land values with population growth possibly being the most influential factor (McGrath 2005). Urbanized areas impact farmland values.

The urban gravity / potential influence model (Reilly-index) is often used to measure the impact of urban centers on farmland prices (Shi, Phipps, and Colyer 1997). The urban influence model takes the form:

$$(3) \qquad U_i = {P_j}/{D^2_{ij}}$$

where U_i is the computed urban influence index number, P_j is the population of the metropolitan area j, and D_{ij}^2 is the square of the distance between the particular county and the relevant metropolitan area. The closest metropolitan areas are thought to influence a county and an increase in the numerical value of the urban influence index can be interpreted as the marginal contribution of a change in the relative distance while holding population constant (Shi, Phipps, and Colyer 1997). This urban influence variable captures the direction and magnitude of the relationship between distance and population. Urban influence increases with the size of the urban population causing an upward pressure on land prices in areas accessible to the urban centers (Shi, Phipps, and Colyer 1997). Land values tend to decrease with increasing distance from urban areas (Guiling, Brorsen, and Doye 2009). Lot sizes tend to increase and population densities decrease with increasing distance from urban areas, whereas, land rents tend to decline to offset the rising commuting costs (Capozza and Helsley 1989). Land rents, prices, and population densities, however, may also rise with commuting distance (Capozza and Helsley 1989). Inferences from previous studies are distance from urban areas may have mixed effects on land prices.

Plantinga, Lubowski, and Stavins (2002) report that accessibility to a county through improved highways (roads) leads to increases in the average value of agricultural land for development. Although counties close to rapidly growing urban centers face more pressure on their land values from urbanization, rural counties further away from urban centers are increasingly becoming attractive for homesites making them susceptible to development. Hence, all agricultural land faces some pressure from development irrespective of their proximity to urban centers.

Agricultural land is often undervalued and undersupplied because the external benefits the land provides are not efficiently accounted for in existing market transactions (Cotteleer, Stobbe, and van Kooten 2007). These externalities have led to the creation of option values / future development rents on land development. These values are capitalized into current farmland values because of the irreversibility of land conversion and uncertainty of future rents (Plantinga, Lubowski, and Stavins 2002). Option values are prices people place on land with the belief that in the future the land will be converted to development; they are speculative in nature (Cotteleer, Stobbe, and van Kooten 2007). Beattie (2001) contends that personal experience is paramount in forming notions about the disappearance of farmland.

Disappearance of farmland is heavily influenced by benefits realized from land use allocation decisions. Because development returns are increasingly greater than agricultural returns, the gap between the marginal private benefits of farmland preservation and development is widening. This increasing gap makes it difficult for landowners to forgo development in favor of land preservation unless compensation for preservation is provided; land will be allocated to the highest valued private use

(Plantinga, Lubowski, and Stavins 2002). This private optimal solution might not be socially efficient especially given that ecosystem services cross private land boundaries.

According to Hailu and Brown (2007) development, land prices, and stock of farmland in counties tends to spill over and influence land values in neighboring counties. Largely agricultural or rural counties tend to have more farmland which spreads out the effect of future development rents on the average value of agricultural land. Land development is too far into the future for development rents to have influence on current land values (Plantinga, Lubowski, and Stavins 2002). The situation is reverse for highly urbanized counties. Future development rents form a significant share of agricultural land values because of the pressure for land conversion and relatively a small amount of agricultural land within the county (Plantinga, Lubowski, and Stavins 2002). Although landowners make private decisions on land use, these decisions have implications for the neighboring farmland, highlighting the complexity of modeling agricultural land values.

The two most significant and consistent factors in explaining agricultural land values have been population and income (Guiling, Brorsen, and Doye 2009). An increase in either income or population increases the urban impact on agricultural land values. Income has the most impact on distance of the urban effect whilst population has the most impact on the size of the urban effect (Guiling, Brorsen, and Doye 2009). In modeling changes in agricultural land values, one has to consider all the aforementioned variables, as well as, the changing rural land markets (Richardson et al. 2009).

Purchase of Development Rights

Local, regional, state, and federal governments, along with non-government organizations are responding to loss of open spaces with a variety of policies (Bengston, Fletcher, and Nelson 2004). Broad policy categories include public ownership, regulations, and incentive based approaches. Public ownership of open spaces such as city, regional, state, and national parks and forest reflects society's decision on how these resources should be managed for the good of the general public. Such ownership is often justified by the public good nature of these areas (Bengston, Fletcher, and Nelson 2004). Often referred to as Smart Growth Codes (U.S. EPA 2008), regulations involve legal restrictions placed by a governmental agency on the use(s) of land. Coercion and / or the threat of sanctions back regulations (Bengston, Fletcher, and Nelson, 2004). The third general policy approach involves providing monetary incentives or disincentives to change / encourage certain voluntary landowner stewardship actions (Bengston, Fletcher, and Nelson 2004).

Incentive based approaches are gaining popularity from policy makers and researchers, because the programs are voluntary and reward participants for providing a public benefit that otherwise would not be rewarded or supplied. One such policy approach is the purchase of development rights through conservation easements. Such easements are designed to protect agricultural land open spaces by restricting how the land can be used. The land remains privately owned with the landowner retaining the rights to the use of the land and management responsibilities. Conservation easements, however, give rights to a third party to ensure that property is protected from development. Monetary compensation is provided to the landowner for selling the development rights. If the landowner sells the property, the conservation easement continues to limit development on the land. Of the three different policies, purchase of development rights is briefly further discussed here as an example of a successful program for conservation of agricultural land open spaces using public and non-governmental funding. The main Texas Law pertaining to purchase of development rights is also discussed.

Application of the Purchase of Development Rights

Market forces are placing increasing pressure on agricultural open spaces to be converted to developed uses. Because agricultural lands have both public good characteristics and externalities associated with them, the market is most likely not providing society's efficient level of open spaces. In response, governments are providing funds to slow / decrease open space conversion to developments. In Texas, for example, land conversion issues have led to the creation of the Farm and Ranch Lands Conservation Program (FRLCP) by the state legislature, for the purpose of purchasing development rights on private property (see FRLCP section for details).

Purchase of development rights (PDR) programs are spreading across the country after starting in the northeastern states (Crompton 2007) partially in response to inefficient market allocation of resources. Eleven thousand one hundred and seventeen easements / restrictions encompassing 1,894,565 acres of land had been protected at a cost of $4,471,499,799 in 23 states (California, Colorado, Connecticut, Delaware, Georgia, Kentucky, Maine, Maryland, Massachusetts, Michigan, Montana, New

Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Utah, Vermont, Virginia, and Washington) as of May 2009 (American Farmland Trust 2009). Of these funds, $2.8 million have been program funds with the remaining $1.6 million coming from the federal government, local governments, and private donations. PDR programs have been most active in the states of Pennsylvania, Maryland, Colorado, New Jersey, and Vermont. As of May 2009, these five states had protected a combined 1,431,614 acres (76% of protected acres) with Pennsylvania having protected the most acreage (407,647 acres) followed closely by Colorado (387,756) and Maryland (336,110). New Jersey and Vermont have protected 173,346 and 126,755 acres (American Farmland Trust 2009).

Montgomery County, Maryland is an example of taking development rights a step further to transferable development rights (Massachusetts Executive Office of Energy and Environmental Affairs 2008). In fact, a large percentage of U.S. agricultural land preserved through transferable development rights is located in Montgomery County (Montgomery County, Department of Economic Development 2006). Located next to Washington, D.C., the southern portion of the county experienced suburban growth in the 1960 and 70’s; whereas, the northern portion has large rural open spaces. In a nut shell,

> The program allows developers to increase residential density in designated receiving areas outside the Agricultural Reserve through the purchase of Transferable Development Rights from farmers. For every unit of density transferred (one TDR per five acres) into a designated receiving area, one development right is extinguished on a corresponding farm parcel. Developers purchasing TDRs provide income to the farmer that is often used for purchasing additional farmland, farm equipment, or

> estate planning (Montgomery County, Department of Economic Development 2006).

Montgomery County's transferable permits are private-sector investments in farmland conservation through a market-based program that allows for increased housing density in southern areas of the county. The price of the transferable permits increased from approximately $5,000 per permit (which represents five acres) in the mid 1980's to $10,000 in the mid 1990's, but decreased to approximately $7,500 in the early 2000's. Since 2003 the price has steadily increased to over $40,000 per transferable permit (Montgomery County, Department of Economic Development 2006).

The issue of public access as a component of preservation of agricultural land and open spaces has received limited attention in the literature (Bauer, Cyr, and Swallow 2004; Kline and Wichelns 1996a, b; McGonagle and Swallow 2005). Bauer, Cyr, and Swallow (2004) indicate people are more willing-to-pay for wetlands preservation if the preservation includes viewing towers and walkways to access the wetlands. Kline and Wichelns (1996a, b) found people generally desired greater access to lands that have rocky shoreline, ponds, and rivers, but access to other lands is sufficient. McGonagle and Swallow (2005 p. 492) conclude "PDRs may reduce expenditures relative to fee-simple purchase of land, but clearly PDRs without public access may limit taxpayer-voter support or charitable fundraising."

This discussion illustrates that across the U.S. the purchase of development rights is not only occurring, but can preserve open spaces while providing income to agricultural land owners. Being a voluntary program, landowners who participate perceive the benefits (monetary incentives in selling the rights) are greater than the costs to them (loss of development rights). Texas governments are behind many other state and local governments in purchasing development rights.

Current Texas Law on Conservation Easements and Development Rights

Texas is the second most populous state in the U.S. with a projected population growth rate of approximately 49 percent for the 50 year period between 2000 and 2050 (Texas State Data Center 2008). Increased demand for urban and commercial land use and decreasing benefits from agricultural uses is making land stewardship an increasingly critical issue. With average land values in Texas for nonagricultural use being about five times higher than agricultural use values (Jackson 2005b), many landowners are converting / selling their land for residential / commercial development. The state lost about 2.3 million acres of productive farmland to nonagricultural uses between 1982 and 1997 (Jackson 2005b). Also, Texas has the highest rural land loss in the U.S. from urbanization (Jackson 2005a). The Texas legislature has considered several options for addressing the multiple problems of rising land costs, drought and flooding weather, dwindling commodity costs, and development infringement (Jackson 2005b). One such option is the purchase of development rights (PDR), defined as, "The voluntary transactions between land owners and public or private entities in which the developmental rights to real property are sold in order to preserve the land in its natural state" (Jackson 2005b, p. 1).

On June 18, 2005, the Governor of Texas signed into law, Senate Bill 1273 (S.B. 1273), "*Relating to the Texas Land and Ranch Lands Conservation Program*." The law became effective on September 1, 2005. S.B. 1273 amends Sections of the Texas

Natural Resources Code Sections 183 *et. seq*. Under subsection 183.051, the purpose of S.B. 1273 is to create a grant making program to enable and facilitate the purchase and donation of agricultural conservation easements (Texas State Law 2007). Legislative history of the bill indicates the intent of S.B. 1273 is consistent with the broader concept of PDRs. There was considerable support for passing S.B. 1273; the only major change during passage was jurisdictional. Originally, the bill was introduced as an amendment to Title 4, Agriculture Code by adding Chapter 59A to create the Texas Farm and Ranch Lands Conservation Program (TFRLCP). The House committee proposed a substitute bill that amended Chapter 183 of the Natural Resources Code placing control of the program under the General Land Office instead of under the Texas Department of Agriculture.

Administration of the Program

Under S.B. 1273, the TFRLCP is created within Texas Department of Agriculture, but the program is controlled by the General Land Office. The program is administered by the General Land Commissioner (henceforth Commissioner) with the advice and assistance of the Texas Farm and Ranch Lands Conservation Council (henceforth Council). Council members' are appointed by the governor[7] to serve six year staggered terms, with two members' terms expiring February 1 of each odd-numbered year. The Council helps the Commissioner in administering the TFRLCP program and implements

[7] Council members consist of a family farmer / rancher, a designated representative of an agricultural bank or lending organization, a certified and experienced real estate appraiser, two designated representatives of statewide agricultural organizations, a representative of a statewide nonprofit organization representing land trusts operating in Texas, a natural resources expert, an experienced wildlife management representative from a higher education institution and two ex-officio designees (one from U.S. Department of Agriculture Natural Resource Conservation Service and one from Parks and Wildlife Commission).

rules adopted by the Commissioner. The Council is required to meet at least twice a year. They receive no compensation except travel expenses. Duties necessary to ensure proper evaluation and selection of applicants to receive grants is done by the Council through a scoring process.

Participation in the Program

Landowners' participation in the TFRLCP program is voluntary. The program provides monetary compensation to the landowner for not developing their land by the selling of agricultural conservation easements to eligible entities. Subsection 183.052, outlines the purposes that would justify the acquisition of agricultural conservation easements. Conservation purposes include: retaining or protecting natural, scenic, or open-space values of real property or assuring its availability for agricultural, forest, recreational, or open-space use; protecting natural resources; maintaining or enhancing air or water quality; or preserving the historical, architectural, archaeological, or cultural aspects or real property (Texas State Law 2007). Under the program, landowners retain the title to their land, participate in a market-based private land conservation program, which gives them autonomy in determining land operations, but they sell the rights to develop their land. Landowners can participate in TFRLCP programs, through selling their easements for a term of 30 years or perpetuity. At the end of a 30 year easement, the landowner can renew their term, but experience in other states has shown that because of limited funding, term easements are poorly financed (Crompton 2007). Third parties cannot implement conservation easements without the written approval of the landowner.

Easements, however, can be terminated if the landowner cannot fulfill conservation goals.

Transaction Mechanism

Under the TFRLCP, only qualified entities, such as nonprofit land trusts, public agencies (local or state government), or historic preservation organizations are authorized to transact with private landowners. Participating landowners are approved by the Council through evaluation by a scoring process. The scoring process considers factors such as:

a) maintenance of landscape and water integrity to conserve water and natural resources;
b) protection of highly productive agricultural lands;
c) protection of habitats for native plant and animal species, including habitats for endangered, threatened, rare or sensitive species;
d) susceptibility of the subject property to subdivision, fragmentation, or other development;
e) potential for leveraging state money allocated to the program with additional public or private money;
f) proximity of the subject property to other protected lands;
g) term of the proposed easement, whether perpetual or for 30 years; and
h) resource management plan agreed to by both parties and approved by the Council.

Purchase prices of easements are negotiated between landowners and entities based on the property's easement term and whether it is renewable, the payment terms (lump sum or annual), and if the landowner will keep some limited development rights. In PDR transactions, the value of the development rights for a property equals the current fair market value of the property (with its development rights intact) minus the estimated market price of property with a conservation easement in place (agricultural value). According to the Western Governors Association (2002), property values usually decrease by 40-75% when development rights are sold though PDR programs. Besides the obvious monetary benefit to the landowner, selling development rights reduces inheritance taxes because of the decrease in land value. In Texas, properties with conservation easements are eligible for agricultural valuation for tax assessment.

Financing the Program

The TFRLCP Fund is established in the General Land Office for buying easements. The Commissioner in consultation with the Council administers funds appropriated by the legislature and obtained through gifts, grants, donations, contributions, mitigation, and bond proceeds. Funds can be used to pay for agricultural conservation easements and transaction costs involved in the easement purchase. Further, the funds can also be used to coordinate and seek ways of leveraging the funds through community involvement such as establishing local funding mechanisms. Local funding mechanisms have been used in other states to attract matching private donors or federal easement funds like the Farmland Protection Program, the Conservation Reserve Enhancement Program, or the Forest Legacy Program (Western Governors Association 2002; Jackson 2005b). As expected given the TFRLCP is new and not funded, the program has received little concrete attention from landowners. As discussed below, the program generally does not allow properties to be acquired by eminent domain nor for the administrative costs to be over five percent of the amount in the TFRLCP Fund.

Funding was anticipated to come from federal agencies with the state of Texas matching a maximum of 50% of the funds. The major federal program funding for PDRs is the Farm Security and Investment Act (popularly known as the 2002 Farm Bill) which provided $600 million over six years (2002 – 2007) to federal agencies to help landowners and communities "…protect the land base for agriculture and forestry" (Western Governors Association 2002, p. 19). The other main federal agency operating programs providing grants for the purchase of conservation easements is the U.S. EPA. It was anticipated that the Council would apply for the grants on behalf of the State of Texas. Because no applications have been made to the Federal agencies by the Council, it is difficult to estimate the approximate size of the grants that would be available for the program. Further, the bill cannot be used as a legal basis for any appropriation of funds from relevant sources as there are no provisions in S.B. 1273 for appropriations.

Easement Termination

The Council establishes the criteria by which grants will be awarded and easements terminated. The only criterion mentioned for termination in the law is the landowner's inability to meet conservation goals. Termination is based on this vague criterion with the Council's decision to grant or deny easement termination based on the applicant's verifiable statement of impossibility. In the case of a termination of an easement, the landowner pays the fund the difference between the current appraised market value and the agricultural value of their property within 180 days of the appraisal. The easement holder is required to release the easement within 30 days of receiving repayment from the landowner. If the landowner is denied termination or fails to repurchase the easement within 180 days, they may not apply for another termination for five years.

Land that has an easement on it cannot be taken by eminent domain by any agency of the state, county, municipality, other political subdivision, or public utility except as a last resort for settlement. There is a requirement for a public hearing to determine the appropriateness of eminent domain before an agency can take landowners' property. Agencies must pay back to the TFRLCP fund the original amount granted for the easement and pay the landowner the difference between the fair market value and the original easement amount.

Expected Costs

According to a five-year fiscal impact analysis undertaken by the state legislative budget committee, the program was going to cost the state $150,000 / fiscal year for the first five years (2006-2010). This cost was based on the assumption that: "The agency anticipates that the Texas Farm and Ranch Lands Conservation program will fund 12 easement grants per year at a cost of $25,000 each for a total cost of $300,000. Given that the maximum state match for these grants is 50 percent, the state cost will be $150,000 a fiscal year" (O'Brien 2005, p. 2). Because the program has not yet started, it is difficult to make assessments of the program effects on the citizens of Texas, the State of Texas, and local governments, let alone potential costs. The above estimates maybe low if the program is to provide reasonable ecosystem services to the citizens of Texas. Using the estimates from previous PDR programs of $1,285 / acre, $300,000 / year provides only enough funds to purchase the rights on 233 acres / year.

CHAPTER IV

VALUATION OF RICHLAND - CHAMBERS CONSTRUCTED WETLANDS

Two valuations methodologies are used to estimate the value of constructed wetlands in the Trinity River Basin of Texas. First, using previous meta-analyses of natural wetlands valuations, estimates for the Richland - Chambers CWs are provided. These estimates assume that natural wetlands can be approximated by constructed wetlands. As discussed below, this assumption is reasonable for most wetlands amenities, but may not be appropriate for water quantity and quality. Second, replacement costs are used to estimate the value of the water quality aspects of the CWs. Replacement cost estimates of the value of wetlands tend to be larger than other methods (Woodward and Wui 2001; Brander, Florax, Vermaat 2006). As noted by Anderson and Rockel (1991), replacement cost methods are an upper bound on the true value. The discussion is not to be used to argue for or against constructed wetlands. Rather, the estimated values are illustrative of the values of constructed wetlands.

Richland - Chambers Constructed Wetlands

Expanding urbanization is increasing the demand for high quality water. Tarrant Regional Water District (TRWD) is not immune to this growth in demand for water. The District is one of the largest raw water suppliers in Texas, providing water to more than 1.6 million people in the north central Texas. Major wholesale customers are the cities of Fort Worth, Arlington, and Mansfield and the Trinity River Authority (TRWD 2008). The number of people served is expected to increase to over 4.3 million by 2060. The District's demand for water is expected to increase from 363,000 acre-feet / year in

2000 to 491,000 acre-feet per year in 2050 (Frossard et al. 2006). TRWD's 1990 Long Range Plan concluded that the District should pursue the option of diverting water from Trinity River into District reservoirs (Andrews 2008). The Trinity River is largely treated waste water flows with up to 90% of the base flows during parts of the year being wastewater flows (Frossard et al. 2006; Andrews 2008; Gunnels 2008). Water flows in the Trinity River have been increasing, especially in the summer, because of increasing population and development in the Dallas-Fort Worth Metroplex. Growth has lead to increased runoff (Gunnels 2008). After evaluating different treatment options, a wetlands treatment system was selected (Andrews 2008).

Wastewater recycling can effectively increase the supply of water to municipalities to meet increasing demand. One way of recycling water is the use of CWs, which have the added benefit of potentially improving the ecological footprint. Besides increasing water demand from the growing consumer base, another reason for developing the Richland - Chambers CWs is potential water quality issues in the Richland - Chambers Reservoir (Andrews 2008). This reservoir is one of several operated by TRWD to supply water to its customers. The Richland - Chambers CWs is a partnership between TRWD and the Texas Parks and Wildlife Department (TPWD). The Richland Creek Wildlife Management Area was created to compensate for habitat losses associated with the construction of Richland - Chambers Reservoir (TPWD 2008a). The Richland - Chambers CWs is part of this management area. Land for the wetlands was supplied by the TPWD (Frossard et al. 2006). TPWD's interest in the

CWs is in the creation of high quality ecological wetlands that can be used for recreational purposes.

The Richland - Chambers CWs is located approximately 60 miles south of the Dallas-Fort Worth Metroplex in Freestone and Navarro counties (Frossard et al. 2006) (figure 8). The wetlands were constructed here for several reasons: the proximity to both the Trinity River and Richland - Chambers Reservoir; a raw water pipeline already in place from the reservoir to Lake Arlington; availability of 2,000+ acres of floodplain land; and because of society's lack of acceptance of the use of recycled wastewater for municipal use (Andrews 2008; Gunnels 2008). Pilot-scale projects were conducted between 1992-2000, which processed 75,000 gallons of water / day. The pilot studies' wetlands outperformed many previous CWs in terms of nutrient and sediment removal (65% for phosphorus, 80% for nitrogen, and 95% of sediment) (Frossard et al. 2006; Andrews 2008). The CWs' current size is approximately 250 acres, but the CW is expected to expand to 2,000 acres over the next four years (Andrews 2008). Although there is no projected lifetime for these particular CWs, the TRWD acknowledges that it is currently facing challenges with phosphorus removal (Andrews 2008). Field-level studies are seeing similar sedimentation removal but nitrogen and phosphorous removal percentages have decreased.

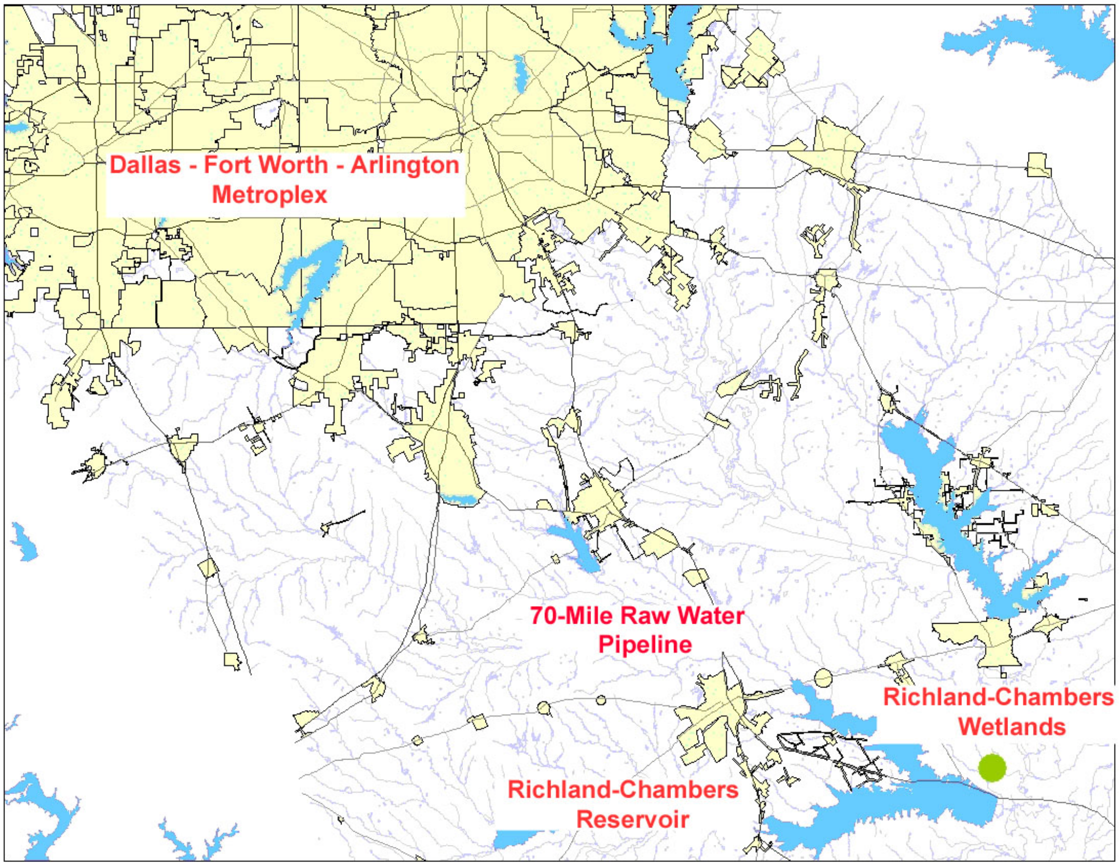

Figure 8. Location of the Richland - Chambers constructed wetlands
Source: Andrews (2008)

The objectives for developing the Richland - Chambers CWs are the production of high quality water and wetland habitat for wildlife through simulating natural wetlands functions (Locke et al. 2007). Benefits from these CWs are the improved water quality through the water recycling operation and recreation. The CWs are expected to provide opportunities for bird watching, water fowl hunting, and fishing (Gunnels 2008). Because development is still on-going, no significant numbers of visitors have used the CWs, but the TPWD expects a large increase in the number of visitors to the CWs once completed (Gunnels 2008). Visitors are required to purchase limited public use permits to access TPWD wildlife management sites (Gunnels 2008).

The Richland - Chambers CWs operates by pumping water from the Trinity River to a sedimentation basin and then through a series of wetland cells (figure 9). As water moves through these cells it is filtered by the vegetation before it is pumped into Richland - Chambers Reservoir (Alan Plummer Associates Inc. 2008). The sedimentation basin and cells lower the sediment load and nutrient level of the water, allowing higher quality water to be pumped into the reservoir (figure 9). As of fall 2008, no water has been pumped into the reservoir (Andrews 2008). Between and along the cells are gates and canals used to control the flow and depth of the water in the wetlands. Because water flows through the CWs are controlled, a consistent flow can be maintained; therefore, water in the CWs is not stagnant as is the case with many natural wetlands. Natural wetlands water flows are dependent on weather conditions with many wetlands going dry during part of the year. Further, because the CWs rely on water pumped from the Trinity River, the CWs can be drained for maintenance. Richland -

Chambers CWs differs from natural wetlands because of the high level of control of water flows and the consistency of flows.

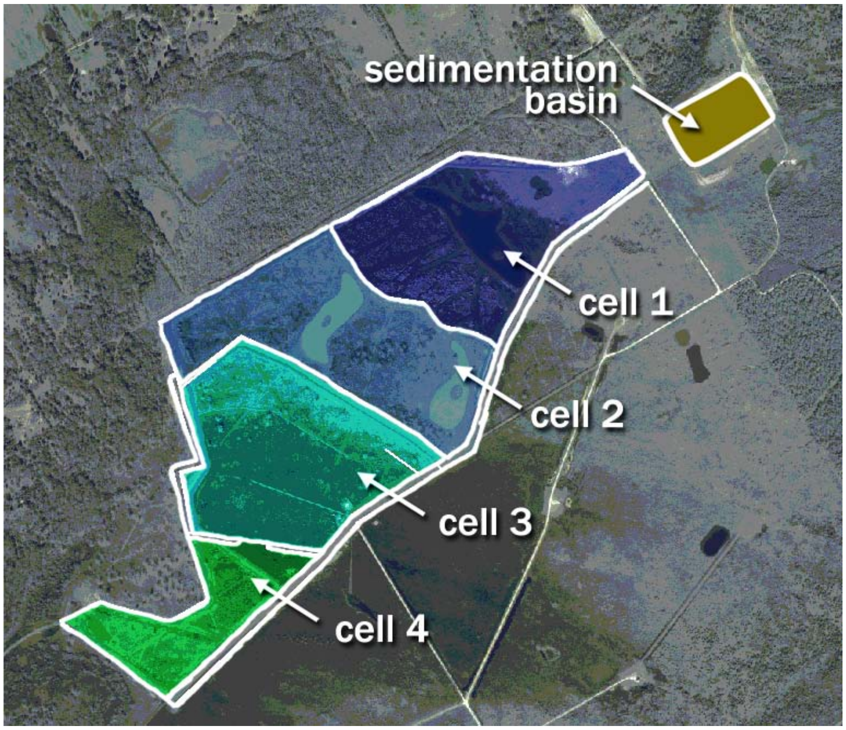

Figure 9. Richland – Chambers constructed wetlands cell layout
Source: Andrews (2008)

An additional challenge facing these CWs is that because the diversion point on the Trinity River is 60 miles downriver, the river picks up additional sediment from runoff and streams entering the river. This increased sediment increases the load of the water, above what it would have been if the CWs were located closer to Fort Worth.

Increased sediment results in an increased retention time in the CWs; water pumping costs back to Lake Arlington are also increased because of the distance from Fort Worth.

Wetlands Meta-Analysis

In this subsection, it is assumed the Richland - Chambers CWs are similar to natural wetlands. This assumption is valid for most amenities in the CWs, except water flow as previously noted. Here, a benefit transfer function approach is used to provide estimates of the value of the wetlands. A transfer function uses an estimated equation to predict a value for a new application. Functions from two previous meta-analysis studies on the value of natural wetlands are used (Woodward and Wui 2001; Brander, Florax, and Vermaat 2006). Both studies, which are briefly described, provide statistically-estimated wetland valuation functions using results from previous studies as the data. These studies are used to illustrate benefit transfer using meta-analysis. Both studies assume a wetland's value is influenced by the ecological and socio-economic environment within a given system. Studies used were selected on the basis of their apparent data quality, theoretical consistency of the methodology, econometric techniques, and statistical certainty. Each study estimated an equation relating wetlands value to characteristics of the wetlands and study parameters of the general form:

$$\ln(y) = f(x_a, x_s, x_m, x_o) + \mu \qquad (4)$$

where y is willingness-to-pay (WTP) for wetlands, x_a is the size of the wetland in acres, x_s is a matrix of services provided, x_m is a matrix of methodologies used, x_0 is a matrix of variables describing the study including year, socio-economic variables, location variables, and μ is the error term.

Meta-analysis, which can trace its beginnings to 1904, has become widely accepted as a systematic process to analyze results from a variety of studies. Results from previous studies are analyzed statistically to help explain variation across studies and to make generalizations. Within wetlands valuation, a wide range of values are reported. Heimlich et al. (1998) in reviewing 33 studies, for example, report values ranging from \$0.06 to \$22,050 / per acre. Rather than use a single value from an individual study, meta-analysis attempts to use many studies to explain some of this variation. Brander, Florax, and Vermaat (2006) suggest that transfer functions perform better than the transfer of a single value for at least three reasons: 1) information is taken for a large number of studies and not a single study; 2) methodological differences can be controlled; and 3) explanatory variables can be adjusted to represent the new site. Transfer functions can also result in a number of "transfer errors." Main errors deal with lack of representation of the explanatory variables characterizing the new site in the transfer function and crude characterization of sites.

Woodward and Wui (2001)

One objective of Woodward and Wui (2001) study is to assess the factors that determine a wetland's value through evaluating whether any systematic trends exist in the previous studies. Of the 46 studies they reviewed, 39 are used because they had common features which could be used as explanatory variables. From these 39 studies, 65 observations are derived. All studies used are from wetlands in the U.S.

Specifically, the equation they estimated is:

$$\ln(y) = a + b_a \ln(x_a) + b_s' x_s + b_m' x_m + b_0' x_0 + \mu \quad (5)$$

where y is the annual wetland value per acre in 1990 U.S. dollars, x_s is a matrix of services provided, x_m is a matrix of methodologies used, x_a is the size of the wetland in acres, x_0 is a matrix of variables describing the study including year and location variables, µ is the error term, and the a and b's are matrices of estimated coefficients. Estimated coefficients are provided in table 6. The estimated equation R^2 was 0.37 for their Model A; indicating 37% of the variability is explained by the regression.

Table 6. Meta-Analysis Coefficients and Independent Variable Values Used to Provide Estimates of the Richland - Chambers Constructed Wetlands

Variable	Woodward and Wui (2001)	Values used	Brander, Florax, and Vermaat (2006)	Values used
Intercept	7.872	1	-6.98	1
Year	0.016	14.908		
Coastal	-0.523	0		
Flood	-0.358	0		
Quality	1.494	1		
Recreational fishing	0.395	1		
Commercial fishing	0.669	0		
Birdhunting	-1.311	1		
Birdwatching	1.704	1		
Producer surplus	0.277	0		
Quantity	0.514	1	-0.95	1
Log acres (ha)	-0.168	9.281	-0.11	4.588
Amenity	-3.352	1	0.06	1
Habitat & nursery	0.577	1	-0.03	1
Storm	0.310	0	0.14	0
Publish	0.769	0	0	0
GDP per capita			1.16	9.547
Population density			0.47	7.074
Latitude			0.03	32.77
Latitude squared			-0.0007	1073.9
South America			0.23	0
Europe			0.84	0
Asia			2.01	0
Africa			3.51	0
Australasia			1.75	0
Urban			1.11	0

Table 6. Continued

Variable	Woodward & Wui (2001)	Value used	Brander, Florax, and Vermaat (2006)	Value used
Marginal			0.95	0
Mangrove			-0.56	0
Unvegetated sediment			0.22	0
Salt/brackish marsh			-0.31	0
Fresh marsh			-1.46	0
Woodland			0.86	1
Biodiversity			0.06	1
RAMSAR proportion			-1.32	0
Fuel wood			-1.24	0
Materials			-0.83	0
Recreational hunting			-1.1	1
Water quality			0.63	1
Hedonic pricing			-0.71	0
Net factor index			0.19	0
Replacement cost			0.63	1
Travel cost			0.01	0
Opportunity cost			-0.03	0
Market prices			-0.04	0
Production function			-1	0
Contingent valuation method			1.49	1

Note: No entry in a column indicates that independent variable is not used in that particular study.

Woodward and Wui (2001) stress the variability present not only in the primary data, but also in confidence intervals from their meta-analysis regression. They state "Cleary it would be highly speculative to use a single point from this distribution in a benefits transfer exercise" (Woodward and Wui 2001, p. 268). As such, their program and data were obtained from the authors to obtain both a point estimate and a confidence interval.

Brander, Florax, and Vermaat (2006)

Brander, Florax, and Vermaat (2006) also examined factors that affect wetland values by reviewing 191 studies conducted over the past 25 years. Eighty of the studies contained comparable information providing 215 observations. The studies represent 25 countries from all continents. Approximately half of the data set represents wetlands in North America. Brander, Florax, and Vermaat (2006)'s dependent variable is similar to that used by Woodward and Wui (2001), the value of wetlands in 1995 U.S. dollars per hectare per year in natural log form. Explanatory variables included matrices of study characteristics (x_s), wetland physical and geographical characteristics (x_p), and the socio-economic characteristics (x_e). Study characteristics included the valuation methods used. Wetland physical and geographical characteristics include wetland type, services, and area, continent, latitude, and RAMSAR[8] proportion. Socio-economic variables included population density within 50 kilometers and per capita income. Estimated coefficients are provided in table 6. Similar to Woodward and Wui (2001), variability in their data set is large.

Estimates for the Richland - Chambers Wetland Values

It must be stressed the meta-analyses are based on natural wetlands, but the Richland - Chambers is a constructed wetland. As noted earlier, it is assumed here the ecosystem services (therefore values) from constructed wetlands are similar to those from natural wetlands. Using the functions developed by Woodward and Wui (2001) and Brander,

[8] The Ramsar Convention on Wetlands is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. Some wetlands are Ramsar sites that are protected by this convention.

Florax, and Vermaat (2006), benefit transfer wetland values for the Richland - Chambers CWs are obtained. Besides the estimated coefficients from the meta-analysis, table 6 also contains the values for the explanatory variables used to represent the Richland – Chambers CWs.

Necessary values for the explanatory variables in the meta-analysis equations come from several sources. Based on communications with the TPWD and TRWD personnel, a value of 1 was assigned to the features the CWs contain (table 6). The size of the CWs is 243 acres (Frossard et al. 2006). Woodward and Wui (2001) transfer function requires the date of the study, the mean value of this independent variable from their study is used in valuing the CWs. Brander, Florax, and Vermaat (2006) requires some additional independent variables. Latitude of the CWs was obtained from PlaceNames.com (2008). Given the CWs lies near the border of Navarro and Freestone Counties, population density is taken as the simple average of the two county densities. Texas state level per capita income for 2006 is used (U.S. Department of Commerce, Bureau of the Census 2008a).

Inflation adjustment factors from the U.S. Department of Labor Bureau of Labor Statistics (2008) are used to inflate the values derived from the meta-analysis to 2007 U.S. dollars. For the Woodward and Wui (2001) model, a factor of 1.59 is used to convert from 1991 U.S. dollars, while a factor of 1.36 is used to convert Brander, Florax, and Vermaat (2006) 1995 U.S. dollar values to 2007 dollars. To make the results comparable, hectares are converted to acres using a factor of 0.4046 hectares / acre. Based on Weitzman (2001), the mean of 2,160 economists' social discount rate estimates is used of 3.96 percent as the best estimate. Sensitivity analysis is performed on the discount rate using two percent (approximately one-half of the base rate) and eight percent (an approximate doubling of the base rate) discount rates.

Using the Woodward and Wui (2001) model, a mean value of $843 / acre / year ($21,298 into perpetuity and $14,648 for a 30-year horizon assuming a 3.96% discount rate) is obtained for the Richland - Chambers wetlands. The 95% confidence interval is $95 to $7,435 / acre / year. Consistent with Woodward and Wui (2001)'s statements, this confidence interval is huge. Brander, Florax, and Vermaat (2006) function gives a mean value of $999 / acre / year ($25,235 into perpetuity and $17,358 for a 30-year horizon assuming a 3.96% discount rate). Unfortunately, confidence intervals can not be obtained from information in Brander, Florax, and Vermaat (2006). Estimates using Brander, Florax, and Vermaat (2006) fall within the 95% confidence interval suggested by Woodward and Wui's (2001) meta-analysis.

Using both Woodward and Wui (2001) and Brander, Florax, and Vermaat (2006) meta-analyses' functions, point estimates are generated. The confidence interval clearly supports Woodward and Wui's (2001) contention, that using point estimates from meta-analysis is suspect. Providing confidence intervals or sensitivity analysis is clearly warranted in valuing ecosystem services. Changes in independent variable values in some cases cause the point estimates to change dramatically. Care must be taken in using these meta-analysis studies, but they do provide evidence that CWs provide ecosystem services that people value.

Replacement Cost Analysis

A second approach to valuing the Richland - Chambers CWs is using a replacement cost methodology. Here, the services provided by the CWs are valued by the net cost of building a wastewater treatment facility which would provide similar cleaning of the Trinity River water. Public accessible data on the cost of building such treatment facilities is limited. In the 1970's, the U.S. EPA (1979, 1980, and 1984) collected and published wastewater treatment costs. This effort was an outgrowth of Federal government funding of treatment plants associated with the enactment of the Clean Water Act. Inflating such cost data by almost 30 decades to 2007 values would ignore any technological advances in treatment and construction. To overcome this limitation, an engineering cost estimation program, CapdetWorks, is used to provide cost estimates of a replacement treatment facility. Costs of developing the CWs are also necessary. Cost estimates of developing CWs are obtained from Frossard et al. (2006), Andrews (2008), and Rister (2008). An estimate of the replacement value of the CWs is then obtained by subtracting the annual costs of the wastewater treatment facility from the costs of constructing the wetlands.

Wastewater Treatment Facility

CapdetWorks Version 2.5 is state-of-the-art software for the design and preliminary cost estimates of wastewater treatment facilities (Hydromantis, Inc. 2008). Capdet model, originally developed by the U.S. Army Corps of Engineers for the U.S. EPA in 1973, has undergone extensive revisions and updates over the years to become CapdetWorks. Based on industry standard engineering equations, CapdetWorks uses a two-step procedure to obtain costs. First, CapdetWorks calculates the design of the facility based on user supplied unit processes in the facility and influent quality to the process. Second, the cost of the design is calculated. Costs categories include construction, operation, maintenance, material, chemical, and energy, along with legal and engineering costs. Cost estimates are based on a unit costing approach using inflation cost indices based on discussions with manufacturers, suppliers, and consultants (Hydronmantis, Inc. 2008). Default values are provided for all necessary inputs, both physical and economic. The user is able to override the defaults as necessary for their design. In calculating the replacement costs, default values are used except as noted. Replacement costs are based on the September 2007 U.S. average cost indices in CapdetWorks with the exception of land value. Land value is assumed to be $3,000 / acre based on current real estate land market values in the area around the Richland-Chambers reservoir.

The wastewater treatment facility used to obtain the replacement costs contains the following processes (this facility was designed with discussion with a civil engineer, Batchelor 2008):

influent pump station – used to pump the water from the Trinity River to the treatment facility;

screening device – used to remove large objects that may damage pumps and other equipment, obstruct pipelines, or interfere with the normal operations of the facility;

lagoons – two for sediment settling and nutrient removal because they require relatively unskilled operators and have low operating and maintenance costs, similar to CWs; and

pump station – use to pump the effluent from the treatment facility to the

Richland –Chambers Reservoir.

Influent Trinity River and effluent wetlands water parameters are set to average values provided by Alan Plummer and Associates, Inc. (2008). Maximum, average, and minimum flows from the Trinity River are set at a 15, 12.6, and 0 million gallons per day (MGD). Influent total suspended solids, total nitrogen, and total phosphorous are set at 206, 3.85, and 0.98 mg/L (Alan Plummer and Associates, Inc. 2008, Table IV-1). All other contaminates are set equal to zero as these are not the main contaminates of interest in constructing the wetlands. These assumptions provide a conservative cost estimate for the replacement costs.

CWs Costs

Frossard et al. (2006) provide cost estimates for constructing the Richland – Chambers CWs. These CWS cost estimates are much less detailed than those provided by CapdetWorks for replacement costs. Construction costs in Frossard et al. (2006) are inflated by a factor of 1.13 to obtain the costs in 2007 dollars. Operating costs (debt costs are not included as they are included in amortizing the construction costs) from Frossard et al. (2006) are also inflated by 1.13. Andrews (2008) noted the estimated project costs in Frossard et al. (2006) are low; further they do not contain land, legal, engineering, and a pump station costs. An additional $4 million plus land costs are added to the construction costs in Frossard et al. (2006) based on CapdetWorks estimate of $2.4 million in engineering costs for the treatment facility and conversations with Andrews (2008) and Rister (2008). The CWs costs provided in table 7 take this additional information into account. Land values are assumed to be $3,000 / acre. Total construction costs are approximately $1 million more than Rister (2008) calculated for CWs that are similar in size but with less pumping needs that may be located on the creeks that provide inflow to Richland – Chambers Reservoir.

Replacement Cost Valuation of the Services Provided by the CWs

Costs of constructing the wetlands and the treatment facility are summarized in table 7. CapdetWorks provides much more detail, but because much less detail is provided for the CWs costs, a similar level of detail is provided for both the CWs and the treatment facility. The treatment facility requires 32.7 acres compared to 250 for the CWs. Two eight acre lagoons are used in the treatment facility. Total project costs are approximately $5 million more for the treatment facility than for the CWs. Annual operating costs are slightly more than $100,000 for the treatment facility. Calculations from CapdetWorks indicate the treatment facility removes less nitrogen and sediment than the CWs are obtaining, but more phosphorus is being removed in the treatment facility. Such differences are expected.

Table 7. Costs for Constructing a Wastewater Treatment Facility and Richland - Chambers Constructed Wetlands in 2007 Dollars

Cost category	Treatment facility[a]	Richland – Chambers[b]
Total construction	18,401,900	11,2814,000
Land $3,000 / acre	98,100	750,000
Number of acres	32.7	250 for project 243 in wetlands
Total project	18,500,000	13,564,000
Amortized over 30 years @ 5%	1,203,452	882,358
Yearly operating cost / 1000 gallons	0.105645	0.082038
Total yearly operating @ 12.6 MGD 93% efficiency	451,850	350,882
Annual cost per gallon	0.000387	0.0002883
Total annual costs	1,655,302	1,233,240
Annual cost per acre based on 250 acres	6,621	4,933
Replacement cost = treatment costs – Richland Chambers costs / acre / year using 250 acres	$1,688	

Note: a) Calculated using CapdetWorks (Hydromantics, Inc. 2008).
b) Sources Frossard et al. (2006), Andrews (2008), and Rister (2008).

To make the costs comparable, the costs per acre are normalized based on the 250 acres necessary to provide the CWs. Annualized wastewater treatment costs are $6,621 / acre, whereas, the CWs annualized costs are $4,933 / acre. The replacement cost valuation of the services provided by the Richland - Chambers CWs is $1,688 / acre / year ($42,032 into perpetuity and $29,331 for a 30-year horizon assuming a 3.96%

discount rate). This replacement costs valuation of the wetlands services can be viewed as the cost savings of creating the CWs over a conventional wastewater treatment facility; the cleaning services provided by the wetlands. As noted earlier, the replacement cost method may provide an upper bound on the true value of the wetlands. Further, the value is associated with CWs that have the ability to control water flows, which is not the case with natural wetlands. Even with these limitations, the estimated value clearly indicates CWs are valuable in providing water cleansing functions (see figure 10).

Figure 10. Trinity River water before entering the constructed wetlands treatment and water at the end of treatment cell four
Source: Andrews (2008)

Discussion

As expected the replacement cost method provides a larger value for the Richland – Chambers CWs than either meta-analysis approach. The value estimate using Woodward and Wui (2001) meta-analysis is approximately one-half of that given by the replacement cost approach, whereas, the estimate using Brander, Florax, and Vermatt (2006) equation is approximately 40% of the replacement cost approach. These results are consistent with the previously noted contention that replacement cost approach provides an upper bound. Further, replacement costs maybe larger because in the CWs water flows are controlled and do not rely on precipitation for flows. The replacement cost estimate falls within the bounds provided by the confidence intervals given using Woodward and Wui's (2001) function. All estimates indicate wetlands may provide large ecosystem services values. Further, the large range of estimated values provides additional evidence of the large uncertainty associated with estimating ecosystem services.

CHAPTER V

RUNOFF AND RECHARGE VALUATION IN COMAL COUNTY

Different valuations of farm and ranchland amenities and associated ecosystem services are provided. First, willingness-to-pay (WTP) for conservation easements to protect farm and ranchland amenities for an average acre in Comal County is estimated using unit benefit transfer. Second, the value for an average acre in Western Comal County based on the value of runoff water to Canyon Lake is provided. Third, for an acre in the eastern part of the county, valuation of contribution to groundwater is provided. Per acre costs of growth in both parts of the county are estimated based on the runoff and recharge valuations. Finally, to illustrate the complexity of the loss of ecosystem services, projected growth for New Braunfels is used to determine the potential changes in recharge ecosystem services and the effect of urban growth. These two issues are interrelated, but are not the same issue. This discussion is not to be used to argue against urban growth. Rather, these are additional issues that must be considered when discussing farm and ranchlands' value to society. In the scenarios presented, best estimates are provided along with sensitivity analyses. The best estimates represent conservative estimates.

Overview of Comal County and the Edwards Aquifer

Comal County, which is comprised of 555 square miles, is located in south central Texas (Handbook of Texas Online 2008). The County contains all three zones of the Edwards Aquifer: the contributing zone (drainage area); the recharge zone; and the artesian zone (figure 11). Approximately the northwestern three-quarters of the county lies in the contributing zone, whereas, the eastern one-quarter of the county lies in the recharge zone. The southeastern end of the county is in the transition / artesian zone.

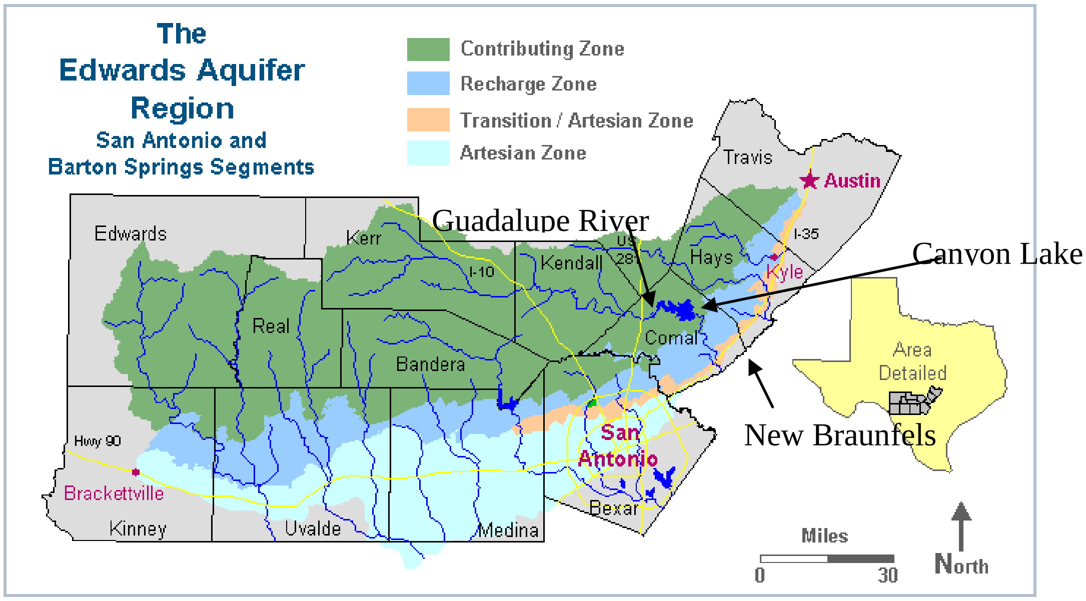

Figure 11. Zones within the Edwards Aquifer
Source: Edwards Aquifer District (2008)

Agriculture in the contributing zone is generally grazing operations consisting primarily of cattle, goats, and sheep (U.S. Department of Agriculture 2008). The western part of the county supports more timber-live oak, mesquite, and Ashe juniper, along with fewer grasses than the eastern part of the County.

The eastern quarter is pasture and cropland. The primary drainage for the county is the Guadalupe River which flows through Canyon Lake. Several streams located north and east of Canyon Lake drain into the Blanco River. Drainage for the southwestern part of the county is Cibolo Creek, which forms the county line between Bexar and Comal counties (Handbook of Texas Online 2008).

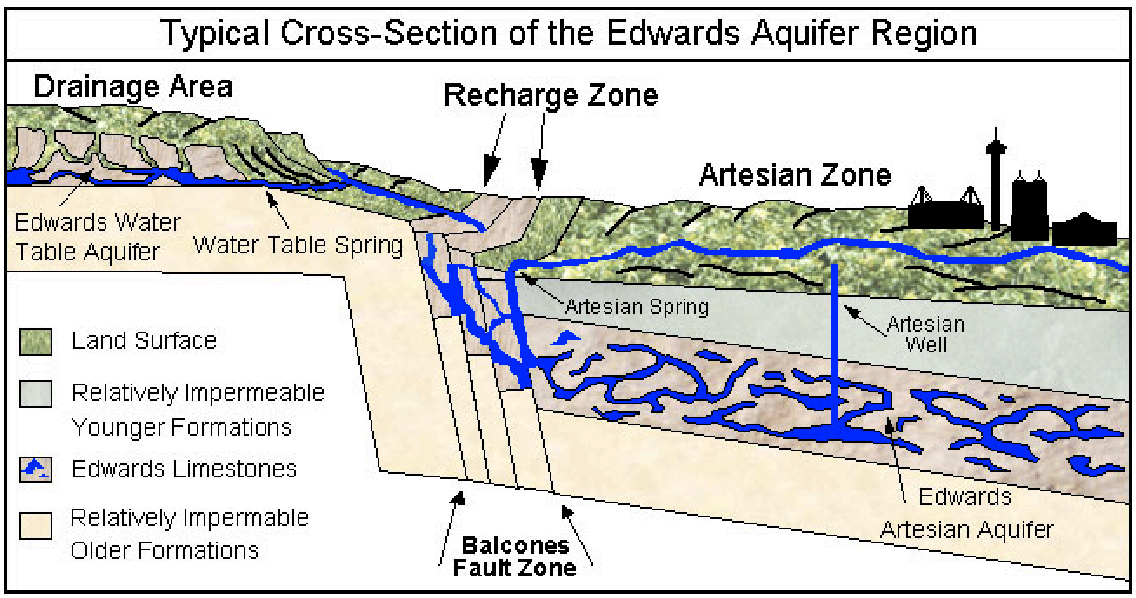

Figure 12. Typical cross-section of the Edwards Aquifer region
Source: Edwards Aquifer District (2008)

The importance and differences of the three zones for the Edwards Aquifer is illustrated in figure 12. In the contributing zone, water runs off into streams or infiltrates the water table or aquifer (Edwards Aquifer District 2008). Here, runoff and water table springs flow over relatively impermeable limestone until the water reaches the recharge zone. The contributing zone is approximately 5,400 square miles known as the Edwards Plateau, or Texas Hill Country (Edwards Aquifer District 2008). In the recharge zone, which is a 1,250 square mile area of highly fractured limestone formulations, recharge of the Edwards aquifer occurs when streams and rivers flow across the permeable formulation allowing water to flow into the aquifer. About 75-80% of recharge occurs in this zone. A small percentage of recharge occurs when precipitation falls directly on this zone. Medina Lake, which is partly built on the recharge zone, and the Trinity Aquifer also contributes to the recharge of the Edwards Aquifer. Average annual recharge is approximately 711,600 acre feet (Edwards Aquifer District 2008). Recharge is highly variable depending on yearly rainfall. Most recharge occurs in the western counties of Medina and Uvalde where the Edwards outcrop is very wide at the surface (Ockerman 2002). The transition zone is a thin strip of land south and southeast of the recharge zone from San Antonio to Austin. Some recharge occurs in this zone. Most of the flow of Cibolo Creek goes to recharging the aquifer. Water moves generally from southwest to northeast through the Aquifer.

Once recharge water reaches the artesian zone, the water is trapped between two relatively impermeable formations. The weight of the water entering the artesian zone puts enough pressure on existing water in the zone to force the water up through faults. Major natural discharge is at San Marcos and Comal Springs in the northwest. In years of relatively high recharge, San Antonio and San Pedro Springs in the southwest may flow. Water balance of the aquifer is generally understood, but there is a lack of knowledge of many details (Sharp and Banner 1997).

Comal County was the 56th fastest growing county in the U.S. between April 1, 2000 and July 1, 2006 (U.S. Department of Commerce, Bureau of the Census 2008a). During this time period, Comal County population increased by 23,160 or 29.7 percent. Two major population areas in the county are Canyon Lake and New Braunfels.

Creation of Canyon Lake Reservoir transferred the rural stretch of the Guadalupe River valley in northern Comal County into one of the largest rural population centers in central Texas (Handbook of Texas Online 2008). By 1984 more than eighty subdivisions had been built on the shores and in the hills surrounding the lake. The area is especially popular with retired people and as second homes. Canyon Lake area lies in the contributing zone with water from Canyon Lake providing the vast majority of potable water. The City of New Braunfels lies in the recharge area. New Braunfels lies along the Interstate 35 corridor between San Antonio and Austin. Tourism has also contributed to growth in Comal County. An estimated $500 million per year in economic benefits is brought into Comal County from recreational activities on Canyon Lake and Guadalupe River (Texas Center for Policy Studies 2002).

The Texas Water Development Board [TWDB] (2008) provides population estimates by water user group. Canyon Lake Water Supply Corporation is projected to grow from 9,741 users in 2000 to 32,010 users in 2020 and to over 90,000 by 2060. New Braunfels, the other major water user in the county, is projected to grow from 35,328 users to 56,982 in 2020 and to over 113,000 by 2060. Being in different areas and relying on different sources of water, the two areas provide an interesting contrast to value ecosystem services.

In western Comal County, the Guadalupe-Blanco River Authority (GBRA) has not made any groundwater purchases (Beutnagel 2008). Though a groundwater market exists, its value comes bundled with land prices because the land is purchased along with the associated groundwater rights. This makes it difficult to isolate the specific value that groundwater contributes to the overall ecosystem value. A look at how agricultural land amenities are valued by society will help explain the complexity associated with isolating specific ecosystem services.

WTP – Farm and Ranchland Amenities Values

In Bergstrom and Ready's (2006) review of studies measuring farmland amenity values; three studies, which valued amenities from western farm and ranchland are relevant (Bittner et al. 2006; McLeod et al. 2002; Rosenberger and Walsh 1997). All three studies used contingent valuation. McLeod et al. (2002) examined the value of farm and ranchland amenities in Sheridan County, Wyoming. They estimated WTP for implementing conservation easements in the county. The survey sample size was 2104 chosen randomly from landowner and non-landowner households in the county among whom some lived out of state. The mailed survey response rate was about 50% with the out-of-county responses being higher (56%) than within the county (47%). The mailed questionnaire was structured but it also had open-ended questions for the respondents to express their opinions about land use and land use planning in Sheridan County. Amenities were described as wildlife viewing, rural / western characteristics, solitude, scenic beauty, and air and water quality. Bittner et al. (2006) sought information on the public's perspective on private land management issues in Moffat County, Colorado. In assessing the public's commitment to preserving farm and ranchland, respondents' annual WTP donations for conservation easements were sought. Amenities considered include open space, wildlife habitat, rural lifestyle, solitude, access to public land, and water quality and quantity. Rosenberger and Walsh (1997) estimated the external benefits (non-market value) of the ranchland protection program in Routt County, Colorado, which includes the Steamboat Springs area. WTP for ranchland protection for open space, environmental, and cultural heritage was sought for different valleys. Estimated WTP from these studies are used to provide an estimate of the value of non-market amenities from farm and ranchland in Comal County, Texas.

Socio-economic characteristic of the four counties are presented in table 8. Agricultural operations are dominated by animal operations in the four counties. Comal County has the smallest area and largest per capita income. Characteristics presented in table 8 indicate Comal County is similar in some ways and differs in others to each of the three previously studied counties.

Table 8. Socio-Economic and Agricultural Characteristics for Comal County and the Counties Included in the Benefit Transfer

Characteristics	Colorado (Moffat)	Wyoming (Sheridan)	Colorado (Routt)	Texas (Comal)
	Socio – Economic[a]			
Population	13,680	27,673	21,580	101,181
Number of households	5,635	12,577	11,217	42,287
Average household size	2.58	2.31	2.68	2.72
Median income	54,000	33,000	54,940	66,907
Area (acres)	3,040,640	1,617,280	1,511,040	368,000
Median age	51	56	43.88	37.5
Population density (people / square mile)	2.8	10.5	8.3	139
Per capita county income	18,540	19,407	28,792	27,702
	Crops and Livestock[b]			
Wheat – all[c]	10,400	2,000	4,800	0
	(9,600)	(1,700)	(4,400)	
Corn – all	-	-	-	1,200
Oats	918	800		
	(633)	(600)	-	1,100
Cattle – all head	30,500	77,000	23,000	12,000
Sheep – all head	86,292	7,847	5,206	3,400
Goats – all head	359	0	54	8,000
Hay – all[d]	39,300	33,000	36,200	9,176
	Farms, Farmland, and Value[e]			
Farms number	443	561	593	832
Land in farms acres	1,017,612	1,638,163	450,239	203,291
Average size acres	2,297	2,920	759	239
Estimated value land and machinery per acre	$416	$456	$1,890	$2,102

Note: a) U.S. Department of Commerce, Bureau of the Census (2008a).
b) U.S. Department of Agriculture (2006).
c) Acres planted listed with acres harvested in parenthesis if it differs from planted acres.
d) Acres harvested.
e) Values for 2002 from U.S. Department of Agriculture (2006).

The methodology used to obtain the WTP for farm and ranchland amenities is as follows. First, a WTP per acre per year per household in the county is obtained from each study. Using the three WTP from the previous studies, a lower and an upper bound is obtained, along with a "best estimate." Aggregate WTPs / acre / year are obtained by multiplying the WTP / acre / year / household by the number of households in Comal County. These values are assumed to remain constant into perpetuity. As such, perpetuity values are calculated by dividing the WTP / acre / year by the discount rate to obtain WTP / acre for the amenities. Sensitivity analysis is performed on the assumed discount rate.

Bergstrom and Ready (2006) calculated WTP / acre / year / household in 2007 dollars. Their estimates from two of the studies, Wyoming (Sheridan County) and Colorado (Moffat County), are identical ($0.0001 / acre / year / household). Bergstrom and Ready (2006) used all values presented in the Rosenberger and Walsh (1997) study for Routt County, Colorado. These values include areas around Steamboat Springs, a large ski resort area. Obviously, this differs from Comal County; as such, the value Bergstrom and Ready (2006) calculated is not used. Rosenberger and Walsh (1997), however, split their study into the area around Steamboat Springs and the rest of Routt County. Using a procedure similar to Bergstrom and Ready (2006), WTP / acre / year / household is calculated for the rest of the Routt County ($0.0042 / acre / year / household). The lower bound is the WTP calculated for Sheridan and Moffat County, whereas, the upper bound is the value calculated for the Routt County. "Best estimate" is the mean value of the three studies.

Based on Weitzman (2001), a social discount rate of 3.96 percent is used as the best estimate. Sensitivity analysis is preformed on the discount rate using two percent (approximately one-half of the base rate) and eight percent (an approximate doubling of the base rate) discount rates.

Best estimate for the WTP to preserve farm and ranchland non-market amenities in Comal County is $1,566 / acre (table 9).

Table 9. Estimated Aggregate Willingness-to-Pay for Farmland Amenities in 2007 Dollars / Acre for an Average Acre in Western Comal County, Texas (Best Estimate in Bold)

	Lower bound	Mean	Upper bound
WTP / acre/ year / household	0.0001[a]	0.0015	0.0042[b]
Number of households[c]	42,287	42,287	42,287
WTP / acre / year	4.23	62.02	177.74
Value of farmland amenities into perpetuity in 2007 dollars			
WTP / acre @ 2%	211.44	3101.05	8887.14
WTP / acre @ 3.96%	106.79	**1566.19**	4488.46
WTP / acre @ 8%	52.86	775.26	2221.79
Value of farmland amenities over for a 30-year horizon in 2007 dollars			
WTP / acre @ 2%	94.71	1389.05	3980.81
WTP / acre @ 3.96%	73.48	1077.70	3088.52
Cont.			
WTP / acre @ 8%	47.61	698.22	2000.99

Note: a) Bergstrom and Ready (2006) estimates in 2007 dollars using Bittner et al. (2006) and McLeod et al. (2002).
b) Using a procedure similar to Bergstrom and Ready (2006), estimate is derived from Rosenberger and Walsh (1997) using rest of Routt County estimates in 2007 dollars.
c) Estimated 2007 number of households from U.S. Department of Commerce, Bureau of the Census (2008a) county estimates for 2006.

Sensitivity analysis shows WTP estimates are sensitive to the assumed discount rate. As expected, a higher discount rate results in lower WTP values. This occurs because at a higher discount rate, the future values of the farm and ranch lands are smaller in present value terms. The WTP to preserve farm and ranchland non-market amenities ranges from $53 / acre (highest discount rate using lower bound) to $8,887 / acre (lowest discount rate using upper bound) in 2007 dollars.

Value of Runoff in Western Comal County

The unit of analysis is an average acre in Western Comal County; hence, generalizations must be cautioned against as the valuation might not be representative of any specific acre. Information derived, however, is useful for general policy formulation. To estimate runoff rates in Western Comal County, the Soil Conservation Service (SCS) curve number method is used (Engel and Harbor 2001). This is a widely used simple and efficient method for determining the approximate amount of runoff from rainfall in a particular area. Though designed for a single storm event, the method can be scaled to find average annual runoff values (Harbor 1994; Engel and Harbor 2001). The method requires information on the rainfall amount and curve number, which is based on the area's hydrologic soil group, land use, and hydrologic conditions.

An accessible online tool to assess the water quantity and quality impacts of land use change called the Long-Term Hydrologic Impact Assessment (L-THIA) is used to generate average runoff values for Western Comal County. This model uses a variant of the SCS curve number method (Engel and Harbor 2001). L-THIA uses information on the location site (state and county), the soil type, rainfall, land use, and curve number to generate average runoff over 30 years.

According to Dugas, Hicks, and Wright (1998), 65% of rainfall is lost to evapo-transpiration, 30% infiltrates the ground, and 5% contributes to runoff in the Seco Creek region of the Hill Country. Others studies such as Owens and Knight (1992) and Thurow and Taylor (1995) also suggest low runoff percentages for the Hill County. By adjusting the curve numbers in L-THIA, the model is calibrated to generate a runoff of approximately 5% of rainfall. The importance of the use of L-THIA will become apparent in the growth section, where L-THIA is used to estimate changes in runoff as growth occurs in the western part of Comal County. L-THIA estimates runoff and not total water balance. As such, the focus in this section is runoff. Recall, recharge rates in this area of the Edwards aquifer are lower than in southern counties. For Comal County, mean annual precipitation is 35.08 inches for the years 1965 to 1997 (Engel and Harbor 2001). Five percent of this rainfall amount is 1.75 inches.

L-THIA, using curve numbers associated with soil hydrologic group class B and an average acre composed of 20% forest and 80% grassland/pasture, gives 1.74 inches of runoff. This runoff translates into a volume of 0.14 acre feet per average acre. Lemberg (2000) reports a five percent runoff loss because of transmissions and evaporations losses from subbasins to Choke Canyon Reservoir. HDR Engineering Inc., cited in Lemberg (2000), estimated transmission losses from Choke Canyon Dam to Corpus Christi, Texas to be approximately 50%. Summing these two losses gives a 55% loss of runoff water. The best estimate is only 45% of runoff provides water for human consumption in western Comal County. Sensitivity analysis is performed on this water loss estimate.

Two prices are used in valuing the runoff from Western Comal County. The first value is based on purchases by the Guadalupe-Blanco River Authority (GBRA) for senior water rights purchases in the Guadalupe River Basin. Recent purchase prices for surface water rights have been between $1,000 – 1,500 / acre foot for senior water rights (Schuerg 2008). A value of $1,250 is used as the best estimate. The second value is the annual shadow price from a large mathematical programming model of the Edwards Aquifer (McCarl 1999), which is approximately $100 / acre foot (McCarl 2008). Capitalizing this annual amount into perpetuity at the base discount rate of 3.96 percent (see WTP section) gives a value of $2,525 per acre foot. Because the model is of the Edwards Aquifer region, the model includes both agricultural and municipal aspects across the entire Edwards area. As such, the shadow price combines both of these aspects across the entire aquifer and not just the Canyon Lake area.

Ecosystem services values associated with runoff water from an average acre in western Comal County are presented in table 10 using different prices and losses. These values are calculated using the following formula (best estimate calculations provided),

$$V_{run} = P * \text{acre feet} / \text{acre} * E_1 \quad (6)$$

$$V_{run} = \$1,250 / \text{acre foot} * 0.14 \text{ acre feet} / \text{acre} * 0.45 = \$78.75$$

where V_{run} is the ecosystem service value of runoff in dollars per acre, P is the price in dollars per acre feet, and E_1 is the effective percentage of runoff that is available for water consumption.

Estimated ecosystem service values for raw water ranges from $53 to $212 / acre. The "best estimate" for ecosystem services value for runoff for human consumption is $79 / average acre in western Comal County. Sensitivity analysis shows that increasing the effective rainfall percentage by 50% and almost doubling the price leads to an increase of ecosystem services value of 168%, an increase of $133 / acre. Even under the highest effective percentage and price, the value of ecosystem service of runoff in western Comal County is low.

Value of Recharge in Eastern Comal County

In the eastern part of the county, groundwater is the main issue (Wilcox 2008). To estimate recharge, parameters needed are amount of rainfall, amount of rainfall that goes to ground infiltration, and the percentage of groundwater that provides recharge. Ockerman (2002) simulations for 1997-2000 suggest approximately 20% of rainfall falling on the recharge zone in Bexar County provides recharge. Dugas, Hicks, and Wright (1998) estimate that 30% of rainfall goes to ground infiltration, but not all of this groundwater provides recharge. Using Dugas, Hicks, and Wright (1998) estimate and a 55% water loss used in western Comal County minus the 5% evaporative losses for surface water from Lemberg (2000) gives a 50% water loss or 15% (0.5 *30%) of rainfall going to recharge. This value comprises the best estimate.

Table 10. Estimated Aggregate Values of Ecosystem Services for Raw Water in Comal County in 2007 Dollars / Acre for an Average Acre (Best Estimates in Bold)

	Raw water price		
Effective percentage[a]	$1250[b]	$2525[c]	$5250[d]
Runoff water in western Comal County into perpetuity in 2007 dollars			
30	52.50	106.05	NA
45	**78.75**	159.08	NA
60	105.00	212.10	NA
Recharge water in Eastern Comal County into perpetuity in 2007 dollars			
10	NA	738.14	1534.75
15	NA	**1107.21**	2302.13
20	NA	1476.28	3069.50
Runoff water in Western Comal county for 30 years in 2007 dollars[f]			
30	36.12	72.97	NA
45	54.19	109.46	NA
60	72.97	145.95	NA
Recharge water in Eastern Comal County for 30 years in 2007 dollars[f]			
10	NA	507.92	1056.07
15	NA	761.88	1584.10
20	NA	1015.83	2112.13

Note: a) See equations (6) and (7).
b) Guadalupe-Blanco River Authority 2007 average price on senior water rights (Schuerg 2008).
c) Shadow price from mathematical programming model of the Edwards Aquifer (McCarl 2008).
d) San Antonio Water System 2007 price paid for water rights (Thompson 2008).
e) NA means not applicable. San Antonio is a different water user not found in the western Comal County and Guadalupe-Blanco River Authority is not a typical groundwater user found in eastern Comal County.
f) Thirty year values calculated assuming the base discount rate of 0.0396 and water rights prices quoted are for perpetuity. Perpetuity values are changed into yearly values and then used for a 30 year horizon.

Estimates of the value of recharge water are provided in table 10 using two different prices for the water. The first price is the shadow price of $2,525 discussed earlier. The second price is based on purchases by the San Antonio Water System for water rights purchased into perpetuity. Purchase prices are approximately $5,250 (Thompson 2008). Higher prices are used in the calculations for eastern Comal County because of the higher population and industrialization in San Antonio makes the San Antonio Water System a high valued user. Further, there is a difference in the quality of water. Western Comal County is surface water, whereas, in eastern part of the county high quality aquifer water is valued. Ecosystem service value for groundwater from an average acre is calculated as

(7) V_{re} = P * rainfall inches / (12 inches / acre feet) * E_2

V_{re} = \$2,525 / acre foot * 35.08 inches / (12 inches /acre foot) * 0.15 = \$1,107.21

where V_{re} is the ecosystem service value in dollars per acre, P is the price in dollars per acre feet, rainfall is average annual rainfall in inches, and E_2 is the effective rainfall percentage. The best guess estimate is $1,107 / acre for ecosystem services of groundwater. Estimates of the value of the ecosystem services ranges from $738 to $3,070 / acre depending on price and assumption on the percentage of rainfall that provides recharge (table 10).

Comparison of the Values

In calculating the value of ecosystem services, several important assumptions are made that should be explicitly stated. First, because of lack of data the unit of analysis is an average acre. This acre is considered too small of an effect on total water supply or demand to have any meaningful market price effect. For the WTP for non-market amenities, the scenario is payment to preserve farm and ranchland. The land use change scenario considered for runoff or recharge is from nothing to an average acre for the county. The assumption of a base of nothing is changed below in the growth section. Care must be used in comparing the values because of the different methodologies used in deriving the estimates of ecosystem services values.

With the above cautions, the value of the farm and ranchland ecosystem services is surprisingly consistent with expectations. The value of an average acre providing recharge water is $1,107 / acre compares reasonably well to the ecosystem services value of $1,566 / acre derived from WTP estimates for Comal County. The latter value includes other ecosystem services in addition to water. To avoid double counting, however, these values cannot be summed. This is because the WTP estimates of ecosystem services values can not be broken down into the various components included in the general survey questions. Recall, the components included water quality and quantity. The lower value of water in western part of the county reflects the difference in surface versus high quality aquifer water, population differences, along with higher value industrial users in San Antonio. This lower water price coupled with low runoff volumes is reflected in the lower value for ecosystem services associated with an acre for runoff in the western part of the county compared to the value for recharge in the eastern part.

Land Use Conversion – Canyon Lake Area

As previously noted, the Canyon Lake area and western Comal County are experiencing rapid growth. Unfortunately, data to provide a detailed analysis of this growth are not available. Changes associated with an average acre are provided. Using L-THIA as previously calibrated for an average acre in western Comal County, runoff changes for land use change from 20% forest and 80% grassland to 100% low-density urban housing are estimated. Newburn and Berck (2006) also contend that open spaces will be converted to low-density urban residential housing beyond the urban fringe. This change represents the housing growth occurring in many areas in this part of the county.

An increase of 0.14 acre-feet / average acre in runoff is predicted by L-THIA. This increase results in a total runoff of 0.28 acre-feet / acre after development. Barrett and Charbeneau (1996) simulations of the Barton Springs area of the Edwards Aquifer also show development increasing runoff. Increase in runoff occurs because of an increase in imperviousness associated with roads, roofs, driveways, etc. (Brabec, Schulte, and Richards 2002). This land use change implies a positive ecosystem benefit associated with an acre of land for Canyon Lake in terms of increased surface water supply. Using the best estimate, this two-fold increase in runoff implies an increase in ecosystem services value from $79 / acre to $158 / acre. This increase in water supply, however, is misleading, because increasing growth results in additional water use. The Texas Water Development Board (2008), for example, projects Canyon Lake Water Supply Corporation water use to increase from 1,495 acre feet in 2000 to over 6,838 acre feet in 2030. This increase in water use cannot be used in valuing ecosystem services, but rather is a result of population growth and development. The net water balance per acre developed is expected to be zero to negative for growth in western Comal County.

With increased runoff from development also comes increased pollution. Numerous previous studies (Brabec, Schulte, and Richards 2002; Barrett and Charbeneau 1996; Carle, Halpin, and Stow 2005; Charbeneau and Barrett 1998; Gobel, Dierkes, and Coldewey 2007; Tang et al. 2005) have shown that development will result in an increase in pollution associated with runoff. Results from modeling the land use change in L-THIA indicate increases in the following non-point pollutants: nitrogen, phosphorus, suspended solids, lead, copper, zinc, cadmium, nickel, oxygen demand, oil and grease, fecal coliform, and fecal strep. A small decrease in chromium is estimated. Nitrogen runoff, for example, is predicted to increase from 0.276 lbs / acre to 1 lb / acre, a four-fold increase. These estimated increases and previous studies indicate the importance of non-point pollution associated with growth and development. Increased pollutants cause water quality to decrease which has potential human health consequences or increased water purification costs.

Brabec, Schulte, and Richards (2002) in reviewing the literature on impervious surfaces and water quality, indicate low density housing will have imperviousness percentages ranging from 15% (0.5-1.0 acre lots) to 40% (< 0.25 acre lots). Further, their review provides percentage impervious thresholds for degradation of different environmental measures. Depending on the parameter, the thresholds vary from approximately 10% to 50% imperviousness. Fish diversity, benthic invertebrates, habitat quality, and oxygen thresholds are around 10%. On the other extreme; metals, chemical water quality, sediment, and base flow thresholds for degradation are around 40%. These changes are a function of development and growth and not ecosystem services values. They, however, must be considered as costs in evaluating growth. The most important issue in the Edwards Aquifer concerning growth may not be the change in runoff but rather the quality change in the runoff (Wilcox 2008).

Increased pollution leads to increased costs to treat the water for human consumption and / or increased sedimentation of the Canyon Reservoir. The cost associated with development is to bring the water quality to predevelopment levels and not to human consumption quality levels. One potential cost effective method is constructed wetlands. Cost estimates associated with the Richland - Chambers constructed wetlands (see Richland - Chambers Constructed Wetlands CWs Replacement Costs section, table 7) are $0.0002883 / gallon / year to construct and operate the wetlands. Using this per gallon cost estimate and cleaning up all runoff (note all runoff and not just the additional runoff is dirtier than before development), a cost of $26.31 / year to clean the runoff (0.28 acre feet * 325,900 gallons / acre feet * $0.0002883 / gallon / year) is obtained. Costs into perpetuity are $664 ($26.31 / 0.0396). Best estimate of the cost of development on western Comal County on surface water only is $585 / acre ($79 - $664).

Land Use Conversion - New Braunfels

The case study on New Braunfels sheds additional light on the complicated issues surrounding development in the Edwards Aquifer recharge zone. In this case study, projected urban growth is used to determine the potential change in ecosystem services.

Population in New Braunfels is expected to more than double by 2040 (Texas State Data Center 2008). The Texas Water Development Board (2008) estimates that the City of New Braunfels' water requirements will also double by 2040. Assuming that the household size stays constant, additional land area will be needed to accommodate the population growth, resulting in the conversion of surrounding farm and ranchland to urban areas. Projected increase in land area, population density, imperviousness, and recharge are determined.

Population Density and Projected Land Area Changes

Data for Texas cities with more than 500 and less than 350,000 people (U.S. Department of Commerce, Bureau of the Census 2008a) are used to estimate an equation that relates total population to population density. Only cities with these populations are used because there is a large variability in the smaller cities and 350,000 is a reasonable upper limit. This assumption decreased the effects caused by variables not included in the model.

Estimated population density as a function of total population is:

$$\text{(8)} \qquad \underset{}{\text{Density}} = \underset{(5.90)}{1158.7} + \underset{(6.77)}{6.215}\ \text{Population} - \underset{(-4.84)}{0.00293}\ \text{Population}^2 + \mu$$

where density is people per square mile, population is total population in thousands, μ is the error term, and t-statistics are given in the parentheses. The number of observations is 1,151. Population and population squared are both statistically significant at p-values of 0.05 or less. Population densities, in the relevant range, increase at a decreasing rate as population increases, given the signs on both coefficients (figure 13).

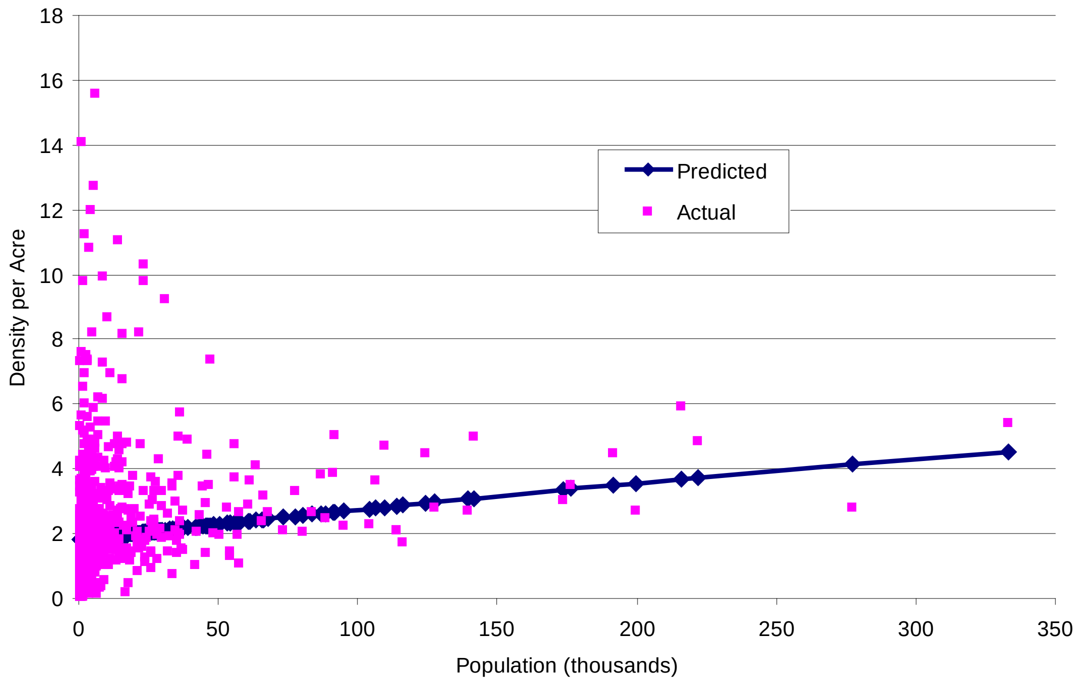

Figure 13. Population densities for different Texas cities

The R^2 associated with this simple model is 0.04 which is low, but the data is cross sectional. Equations estimated using cross sectional data tend to have lower R^2. Because of variation in cities with lower populations, the model provides a relatively poorer fit for low population cities relative to higher population cities. As shown in figure 13, as population increases, the error between actual and predicted values becomes smaller. To convert population / acres to population / square-miles, the predicted density is divided by 640 (number of acres in a square mile). The model predicts New Braunfels' population density for the year 2000 to be 2.148 people / acre, which is similar to the U.S. Bureau of the Census' 2000 estimate of 2.155 people / acre.

Equation (8) is used to predict population density for New Braunfels for each of the population projections for the period 2006 – 2040 (Texas Water Development Board 2008). The projected land area needed to accommodate the new population for each decade is derived by dividing the projected population by the population density. Additional land area required to accommodate population growth are given in table 11. By 2040, New Braunfels is predicted to increase by approximately 18 square miles. Growth by decades is presented in table 11.

Table 11. Resources Required to Accommodate Population Growth

	Year			
Parameter	2006	2020	2030	2040
Projected levels				
Population[a]	49,969	60,186	75,239	90,002
Density[b] (per acre)	2.148	2.349	2.475	2.597
Land area[b] (square-miles)	36.348	40.034	47.499	54.150
Water use[a] (acre-feet)	8,339	13,213	16,350	19,457
% Imperviousness[b]	31.867	32.714	33.241	33.746
Changes from 2006				
Population		10,217	25,270	40,033
Density (per acre)		0.201	0.327	0.449
Land area (square-miles)		3.686	11.151	17.802
Water use (acre-feet)		4,874	8,011	11,118
% Imperviousness		0.848	1.374	1.879
Estimated economic losses in 2007 dollars from 2006				
Recharge water (Total)		-522,386	-1,580,352	-2,522,951
Qualitative economic losses (-) or gains (+)				
Runoff		+	+	+
Endangered species		?	?	?
Pollution		-	-	-
Open space		-	-	-
Others		?	?	?

Note: a) From Texas Water Development Board (2008).
b) Calculated, see text.

Imperviousness

City expansion results in increased imperviousness which leads to decreased groundwater recharge and increased runoff (Brabec, Schulte, and Richards 2002). Using a function developed by Graham, Costello, and Mallon (1974), the percentage of imperviousness area is calculated

$$\text{(9)} \qquad I = 91.32 - 69.34\,(0.9309)^{PD}$$

where I is the percentage imperviousness and PD is the population density (population / acre).

Expected changes in population density lead to different imperviousness percentages. Predicted imperviousness percentages using equation (9) increase from 31% to 33% (table 11). With increased imperviousness comes increased runoff and reduced recharge (Barrett and Charbeneau 1996; U.S. EPA 2006). Because of the small changes in imperviousness percentages, changes in imperviousness are not considered in the following analysis. They are presented to show that imperviousness percentages are in the range associated with environmental degradation as discussed for western Comal County.

Recharge

Increases in imperviousness of approximately 10-30% associated with growth are assumed to decrease the amount of recharge by approximately 20% of rainfall infiltration (Barrett and Charbeneau 1996; U.S. EPA 2006). Consequently, only 80% of the infiltration becomes effective for human consumption resulting in a loss of ecosystem services associated with growth in New Braunfels.

For groundwater, the base recharge in equation (7) is multiplied by 80% to get the adjusted recharge. With this adjustment, equation (7) is used to provide the ecosystem services associated with recharge after development as

(10) V_{re}^{D} = P * rainfall inches / (12 inches / acre feet) * 0.80 * E_2.

Using the best estimates, a value of $885.77 / acre is obtained for recharge after development. Subtracting this value after development from the best estimate value of $1,107.21 / acre before development gives a loss in ecosystem services of $221.44 / acre (in 2007 dollars) for recharge associated with growth.

Using the estimates of population growth and associated increase in size of New Braunfels, aggregate loss in ecosystem services associated with recharge can be obtained (tables 11 and 12). Population estimates are given by decade; therefore, the analysis follows this path. For the 14 years (2006 – 2020), New Braunfels is predicted to increase by 3.686 square miles. Aggregate loss in ecosystem services in 2007 dollars is

(11) $V^{*} = (V_{re} - V_{re}^{D})$ * change in square-miles * (640 acres /square-mile)

V^{*} = ($1,107.21- $885.77) / acre * 3.686 square-miles * (640 acres / square-mile) = $522,385.82.

The best estimate is that an aggregate loss in ecosystem services associated with recharge of $522,385 (2007 dollars) will be incurred as New Braunfels grows. This aggregate loss in ecosystem services is approximately $37,313 per year. Predicted losses for other time periods are presented in tables 11 and 12. These losses are only for recharge losses because of development, other factors associated with development are discussed qualitatively. Because of a predicted slowing in growth and a slight increase in population density, losses decrease between 2030 and 2040 compared to the period 2020 - 2030.

Other Issues

Besides changes in runoff and recharge, additional growth results in other changes in the environment. As with the western Comal County example, some of these changes are qualitatively discussed. Loss of recharge associated with increased use of water from the aquifer from development may affect endangered species within the Edwards Aquifer. Comal and San Marcos Springs support habitat for endangered species (McCarl 1999). A minimum flow is required by law to maintain endangered species habitat. Reduced recharge and increased water use imply habitat for these endangered species' maybe threatened. The level of impact based on growth in New Braunfels is unknown. Because New Braunfels is located near the end of the recharge zone, most additional runoff caused by growth will not provide recharge for the Edwards aquifer but rather increase flows in the Guadalupe River downstream from New Braunfels.

Increased runoff may be a benefit to the Guadalupe River as increases in flow may occur. Changes in the Guadalupe River flow may have benefits to another endangered species, the whooping crane whose winter habitat is in the Aransas National Wildlife Refuge in the Gulf of Mexico (Canadian Wildlife Service and U.S. Fish and Wildlife Service 2007).

Table 12. Changes in Amenity and Water Recharge Values in New Braunfels across Decades

	Year			
Parameter	2006	2020	2030	2040
Projected levels				
Population[a]	49,969	60,186	75,239	90,002
Density[b] (per acre)	2.148	2.349	2.475	2.597
Land Area[b] (square-miles)	36.348	40.034	47.499	54.150
Water Use[a] (acre-feet)	8,339	13,213	16,350	19,457
% Imperviousness	31.867	32.714	33.241	33.746
Changes from previous period				
Population		10,217	15,053	14,763
Density (per acre)		0.201	0.126	0.122
Land area (square-miles)		3.686	7.465	6.651
Water use (acre-feet)		4,874	3,137	3,107
% Imperviousness		0.848	0.526	0.505
Estimated economic losses in 2007 dollars from previous period				
Recharge water		-522,391	-1,057,961	-942,599
Qualitative economic losses or gains				
Runoff		+	+	+
Endangered species		?	?	?
Pollution		-	-	-
Open space		-	-	-
Others		?	?	?

Note: a) From Texas Water Development Board (2008).
b) Calculated, see text.

Increased water flow from the Guadalupe River may be beneficial to the cranes. Fresh water inflows from the Guadalupe are necessary to maintain an ecologically healthy Guadalupe Estuary, the cranes wintering site. More inflows into the estuary may increase the productivity of the estuary and provide fresh drinking water for the cranes (Texas Parks and Wildlife 1998; Canadian Wildlife Service and U.S. Fish and Wildlife Service 2007). Also chances of predation may be lessened as more inflows may allow whooping cranes a chance to build their nests totally surrounded by water.

Further, increases in-stream flow and may benefit other downstream users. Potential negative consequences of increased runoff are increases in flooding and pollution. Increases in pollution were previously discussed concerning growth in western Comal County. As previously noted, changes in water quality is one of the major issues the Edwards Aquifer region currently faces. Changes in water quality are a concern for both surface and ground water. Decreased water quality may have a detrimental effect on the Guadalupe estuary. Another effect is the loss of open space associated with growth, in addition to changes in water quality and quantity. It appears open space value may be relatively high in the aggregate; however, on a per household basis it is small.

Illustration of Scope

The previous estimates of the cost of development are based on limited scopes. For western Comal County the scope is runoff, whereas for eastern Comal County the scope is the change in groundwater. These two scopes are the main concerns of residents in the respective parts of the county. Residents of the State of Texas, however, would be interested in both runoff and recharge. Although the Edwards and related aquifers are some of the most studied in the U.S. still much is unknown about these aquifers. As with the previous estimates, assumptions based on previous studies are made to overcome this lack of knowledge.

For western Comal County, development increased runoff by 100% from 5 to 10% of rainfall. This change in runoff affects the amount of evaporation and recharge. For example, the U.S. EPA (2006) suggests as development increases runoff, approximately 75-80% of the increase in runoff comes from a decrease in groundwater with the remaining 20-25% coming from a decrease in evaporation. A conservative assumption is that groundwater is decreased by 3.75% (75% of the change in runoff coming from groundwater x 5% increase in runoff). Using the previous assumption that only 50% of groundwater provides recharge and the best estimate of $2,525 / acre foot as the value of groundwater, the loss of groundwater is estimated to be $138 / acre into perpetuity (0.5 x 0.0375 x 35.08 inches of rainfall x $2,525 / acre feet of groundwater / 12 inches / foot). This loss in recharge water is larger than the gain of $79 associated with runoff even though the amount of loss in recharge water is less than the amount of increase in runoff. The difference is because of the higher valued aquifer water. Development does not change the amount of rainfall, but redistributes the water between evaporation, ground infiltration, and runoff. Adding the loss in recharge water to the previous estimate of the costs of development, the total cost of development is $723 / acre into perpetuity ($79 – $664 – $138). As expected, expanding the scope increases the costs of development.

For eastern Comal County, expanding the scope to include runoff increases the costs of development to $963 / acre into perpetuity. This estimate is obtained as follows. The 20% decrease in groundwater assumed earlier translates into an increase in runoff of 8% using the previous assumption of 75% of the increase in runoff comes from a decrease in groundwater [(30% groundwater before development x 20% loss)/75% = 8%]. Eight percent increase in runoff has a value of $160 / acre (0.08 x 35.08 inches rainfall / 12 inches / foot x $1,250 /acre foot of surface water x 0.55 effective groundwater percent from before). Similar to western Comal County, the gain in runoff value ($160) is less than the loss in recharge ($221). Because of higher density development, the higher runoff and lower recharge values are expected for eastern Comal County compared to the western part of the county. Finally, to obtain the cost of development, the cost of cleaning the runoff must be added to the estimates. Using the procedure developed for western Comal County, the annual cost of cleaning runoff (note as before all runoff is cleaned) is $35.71 /acre / year (0.13 runoff percent x 35.08 inches of rainfall x 325,900 gallons / acre foot x $0.0002883 / gallon / year / 12 inches / foot) or $902 /acre into perpetuity ($35.71 / 0.0396 discount rate).

Because of the higher density development in eastern part of the county, the costs of development / acre associated with water are higher. In both parts of the county, the main cost of development is pollution and not the loss of water. Two final notes about the estimated costs of development are: 1) the costs assume all of the runoff is cleansed using the wetlands, and 2) there is no cost to cleaning recharge. Reality is somewhere in between these assumptions, but as noted earlier, much more detailed hydrological and pollution modeling is necessary to provide the break down. The reason it is not clear as to what amount of runoff to use in assigning a cost to pollution is that the environment can assimilate some of the increased pollution at no cost to humans or the environment. Such detailed modeling would require considerable financial and expertise resources. A lower bound would be to include costs only associated with the increase in runoff. The lower bounds for western and eastern Comal County for the costs of development are $391 and $615 / acre into perpetuity.

The estimated change in ecosystem services is lower than values suggested by Constanza et al. (1997). Constanza et al. (1997) placed the following per hectare values per year on ecosystems services: woodlands temperate/boreal $302; rangeland grass/rangeland $232; bare soil cropland $92; and residential, commercial, and transportation $0. Placing these values into dollars per acre gives the values of (perpetuity values in parenthesis using the base discount rate) woodlands $122 /ac ($3,086/ acre), rangeland $93 / acre ($2,370 /acre), and cropland $37 /acre ($940 / acre). Because Constanza et al. (1997) gives no value to acres in residential growth these values are the loss of ecosystem services. This assumption of no value, however, is a very strong assumption. Kreuter et al. (2001) using Constanza et al. (1997) values provide a total loss of ecosystem services for changes in the percentage of woodland, grassland, and residential areas to be $5.58 / hectare / year or $57 into perpetuity for Bexar County. They note

> One explanation for the apparent small net effect of land use conversion on the value of ecosystem services in the study area is that the loss of ecosystem services on land being developed was offset by the apparent conversion of ecologically ‘less’ valuable bare soil (cropland) and rangelands to ecologically ‘more’ valuable woodlands” (Kreuter et al. 2001 p. 341).

These values are presented to show a wide discrepancy in ecosystem services values.

Biodiversity Changes in Comal County with Development

The impacts of conversion from agricultural land to exurban development on ecological implications on native species are not well understood (McKinney 2002; Maestas, Knight, and Gilgert 2001; McCleery et al. 2008). Complicating the issue for Comal County is a lack of before and after development data on species diversification

(Stephens 2008). Further complications include less data on species counts in counties mainly because of a change in species counts by the Texas Parks and Wildlife Department to resource management units encompassing several counties and less frequent counts (Stephens 2008). Presented here is a qualitative assessment of development on native animal populations based on expert opinion and backed by studies from other areas. Although tremendously important, endangered species are not considered because of the entire different set of regulations governing them.

Comal County is currently undergoing a shift from large land holdings of over 10 acres to holdings of less than 10 acres. This shift has created a rural-urban interface. The developed smaller land holdings areas tend to have high deer densities compared to the larger rural land holdings (Stephens 2008). Canyon Lake area, one of the fastest growing areas of smaller holdings, has higher deer densities compared to other parts of the county (Stephens 2008). This increase in deer populations coupled with increasing human populations may lead to increased wildlife-human conflicts. Although no scientific explanation has been put forward, the smaller landholdings make deer more visible than larger land holdings and occasional feeding from people also attracts deer to developed areas as they have easier access to food than in less developed areas. West and Parkhurst (2002), in a survey of Virginia's landowners likely to experience deer damage, found that agricultural producers experienced more damage than rural homeowners. In Comal County, landowners with land holdings smaller than 10 acres are not allowed to harvest deer on their land, possibly contributing to the higher densities on smaller land holdings (Stephens 2008). Land use conversion may eventually impact deer hunting recreational activities.

As expected, species besides deer that are able to adapt to human changes in the environment have been increasing more in population densities in developed areas than those that cannot adapt. McKinney (2002) and Maestas, Knight, and Gilgert (2001) discuss urban biotas avoiders, adapters, and exploiters. Maestas, Knight, and Gilgert (2001) found higher densities of black-billed magpie, Brewer's blackbird, house wren, European Starling, American Goldfinch, broad-tailed hummingbird and Bullock's oriole on exurban land than on either ranch or protected land. Spotted and green-tailed towhees, Brewer's sparrow, Lazuli bunting, Vesper sparrow, and coyote had higher densities on ranch and protected lands. No difference in density of bobcats between the three land types was found. Nonnative plant species were higher on exurban and protected lands than on ranchland.

Larger wildlife populations in developed areas are thought to affect ecosystems and their functions (Stephens 2008). Increased deer populations can lead to decreases in vegetation deer prefer, which can have a significant impact on the ecosystem. This change may be especially prevalent on smaller land holdings. Urban birds can also alter habitats as they normally increase with development because of increased access to food and shelter. Many urban birds become nuisance birds; examples include the white tailed dove, roosting drakehalls, and blue jays. Besides altering the habitat, increased wildlife populations may lead to other wildlife-human conflicts, such as animal-vehicle collisions and transmission of diseases (Hernandez et al. 2006; McCleery et al. 2008; Beringer et al. 2002; Bradley, Gibbs, and Altizer 2008).

Discussion

Even though urban growth is normally associated with negative consequences on ecosystem services, in this case, an increase in runoff may be a beneficial ecosystem service to surface water users. The increased flow from the runoff can have positive impacts on downstream water users, both flora and fauna although the quality of water is normally compromised. The cost of the change in water quality appears to be greater than the increase in value of the increased runoff. Groundwater recharge was shown to decrease which is a negative ecosystem service impact. In both cases, open space losses occurred. More detailed hydrological modeling coupled with economic valuation techniques directed specifically towards valuing the change in ecosystem services is necessary for this region.

Further, although not completely comparable, WTP for open spaces appears to be higher than for ecological services associated with water. Besides the obvious open space comprising more than a single service, ecosystem services from water are unique. Development does not change (ignoring any microclimates) the amount of water falling on an acre. Rather, development impacts the water quality and the water balance between groundwater infiltration, surface water runoff, and evapo-transpiration. At some level, these water ecosystem services exist. Changes in pollution level, cannot necessarily be counted as an ecosystem service, but most definitely is an effect of development.

CHAPTER VI

TEXAS AGRICULTURAL LAND VALUES

Similar to most states in the U.S., development in Texas is rapidly occurring on lands adjacent to metropolitan areas and areas offering recreational experiences. According to the U.S. Department of Commerce, Bureau of the Census (2008b), of the 10 counties in the U.S. with the highest numerical growth from 1 July 2006 – 1 July 2007, five are in Texas (Harris, Tarrant, Bexar, Collin, and Travis). These five counties gained 214,839 people. This growth in population has been linked to economic growth resulting in increased personal income (U.S. Department of Commerce, Bureau of Economic Analysis 2008). Plantinga and Miller (2001) find that population influx into a county forces urban expansion into surrounding agricultural lands driving up development rents, therefore, land values. Currently, many land buyers in Texas do not plan to farm when they acquire land, but rather use the land to provide recreational opportunities, as well as, for investment purposes (Richardson et al. 2009). Growth in non-farm personal income increases land values (Richardson et al. 2009). Recreational opportunities also lead to increases in land values (Kline and Wilchens 1996b; Lansford and Jones 1995) especially in areas with open spaces (Irwin and Bockstael 2001; Irwin 2002).

Texas' increasing population especially in metropolitan and surrounding areas are causing a conversion of farmland to developed areas, changing the level and types of ecosystem services provided by the land. In addition, development in Texas is linked to recreational opportunities and aesthetic values (Pope 1985). Pope (1985, p.81) in an evaluation of the factors affecting rural land values in Texas concludes:

> "Population density, proximity to major metropolitan centers, quality of deer hunting, and aesthetic differences across the state explain the majority of the differences in rural land values. On average, only about 22 percent of the total market value of rural land in Texas can be statistically explained by its productive value."

This chapter addresses the third subobjective of quantifying the effect of growth on agricultural land values in Texas. To accomplish this objective, a model of agricultural land values over three time periods is estimated using county level data.

Modeling Time Effects on Agricultural Land Values

As presented in the literature review chapter, numerous studies have examined various factors that influence agricultural land values. Based on these previous studies and data availability, the following equation for agricultural land values in Texas is estimated:

(12)
$$\begin{aligned} LV_{it} = {} & f(REG_i, MSA1PPI_{it}, MSA2PPI_{it}, ACR_{it}, NR_{it}, \\ & MSA1P_{it}, MSA2P_{it}, MSA1D_i, MSA2D_i, DRES_i) + \varepsilon_{it} \end{aligned}$$

where

LV_{it} is the average per-acre value of agricultural land in county i at time t,

REG_i is the ecological region in which county i is located,

ACR_{it} is the percentage acreage in farmland,

NR_{it} is average annual per-acre net returns from agricultural land,

$MSA1P_{it}$ is the change in population of the closest MSA,

$MSA2P_{it}$ is the change in population of the second nearest MSA,

$MSA1PPI_{it}$ is the percentage change in per capita personal income for MSA1,

$MSA2PPI_{it}$ is the percentage change in per capita personal income for MSA2,

$MSA1D_i$ is the distance from geographic center of county i to the center of MSA1,

$MSA2D_i$ is the distance from geographic center of county i to the center of MSA2,

$DRES_i$ is the distance from geographic center of county i to the nearest reservoir,

and ε_{it} is the random error.

The Estimator

Cross-section time series data on Texas counties for three years (1997, 2002, and 2007) are used. Separate equations for each year are specified. Each equation represents an agriculture census year with cross sectional units being individual counties. Such a design creates a balanced panel data set; hence, using ordinary least squares estimation is non-optimal. Further, the issue of omitted variables may arise when the effect of unknown (omitted) variable(s) that have been omitted from the regression. Three approaches have been used to handle omitted variables problem; constant coefficients, random, or fixed effects regressions (Greene 2003). Constant coefficients model is not used because it imposes numerous restrictions on the model, namely, county and temporal effects are lost because the data for the three years is pooled to estimate a single equation. A Hausman specification test to help determine if the fixed effects model (assumes omitted variables differ between counties but remain fixed over time) which gives consistent but not efficient estimates, is better model than the random effects model (assumes omitted variables vary by county and time), which gives efficient but sometimes inconsistent results, is conducted (Greene 2003). The tests chi-squared are negative indicating the model failed to meet the asymptotic assumptions of the Hausman test. Therefore, it may be more appropriate to use seemingly unrelated estimation.

Seemingly unrelated regression (SUR) is used to estimate the model (Zellner 1962). Such an estimator accounts for the multiple equations (across time) with similar independent variables and errors that may be correlated across equations (Greene 2003). SUR uses generalized least squares estimation and allows for the joint estimation of a system of equations with correlated errors, thereby, improving efficiency compared to using Ordinary Least Squares. Only the linear functional form of equation (7) is presented here. A modified quadratic form was estimated but based on the Akaike Information Criterion (AIC) and the Bayesian Information Criteria (BIC) the linear model fit the data better than the quadratic. Further, logarithmic forms could not be estimated because some of the variables are negative.

Data

As noted, data included is for the agricultural census years of 1997, 2002, and 2007, the last three agricultural census years. Although there are 254 counties in Texas, only 237 have complete data. Missing data are caused by unreported county level data on land values, government payments, or the market value of land by the National Agricultural Statistics Services. Usually values are not reported because the values may identify individual land owners.

Data comes from a number of sources: U.S. Department of Agriculture's National Agricultural Statistics Service; U.S. Department of Commerce's Bureau of the Census; U.S. Department of Commerce's Bureau of Economic Analysis; and U.S. Department of Labor's Bureau of Labor Statistics. Agricultural land values (LV_{it}) are derived from the U.S. Department of Agriculture (2008) census of agriculture selfreported estimates by farm operators on the value of their land and buildings. These estimates represent current market rates for land and buildings. Nominal values are converted to constant 2007 dollars using the appropriate Consumer Price Index (CPI) from the U.S. Department of Labor, Bureau of Labor Statistics (2008). LV_{it} variable is expressed as real dollars per-acre.

In Texas different climatological regions have been shown to influence land values (Pope 1985), hence regional differences are included in the model. REG_i is the ecological region county i is located. The nine ecological regions included are shown in figure 14 (TPWD 2009). Classification of the ecological regions follows vegetation and soil type, as well as, rainfall patterns. Regions are qualitative variables with region three being the base (omitted from the regression to avoid perfect collinearity).

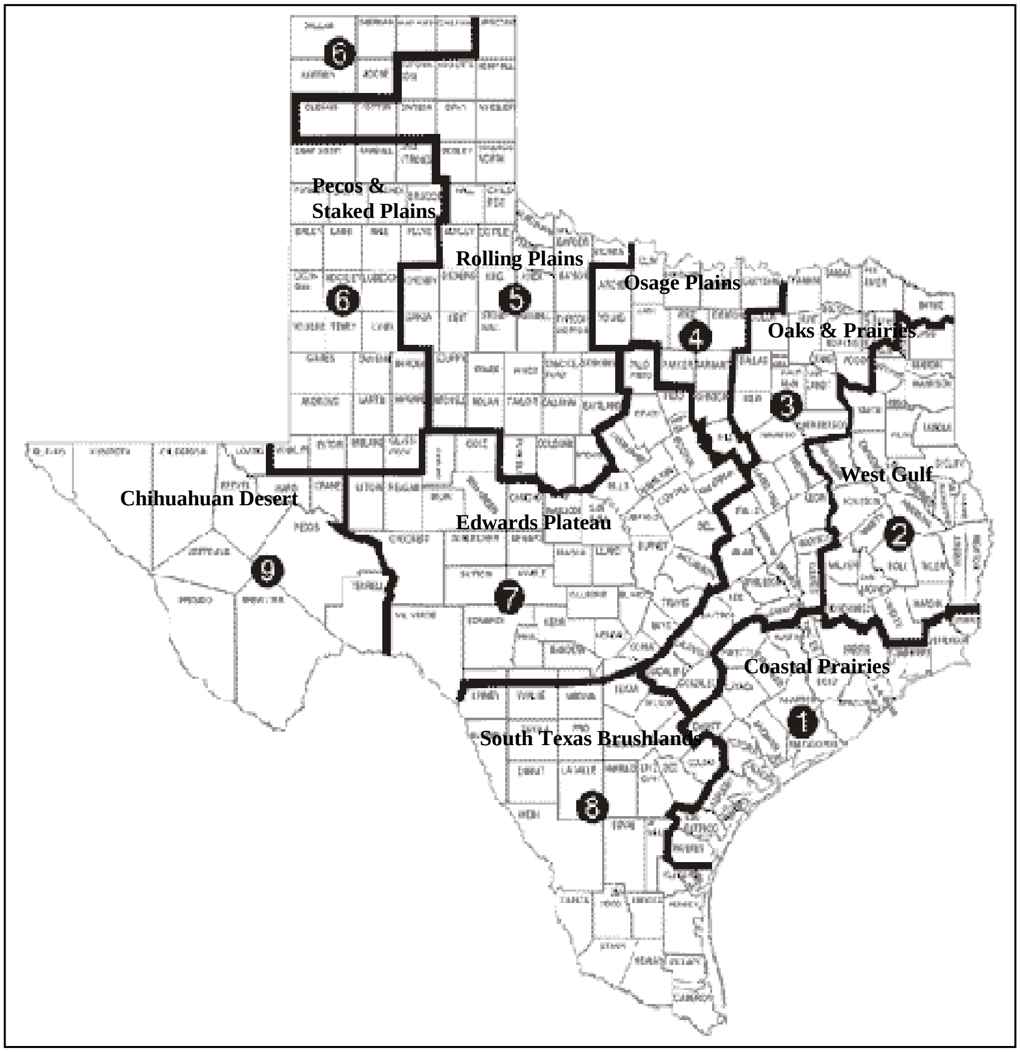

Figure 14. Map of the nine ecological regions of Texas
Source: Texas Parks and Wildlife Department (2009)

The variable ACR_{it} is the percentage of acreage that is in farmland within county as reported in the U.S. Department of Agriculture (2008) Census of Agriculture. Per capita personal incomes, $MSA1PPI_{it}$ and $MSA2PPI_{it}$, are the percentage changes in per capita personal income in the MSAs from the U.S. Department of Commerce, Bureau of Economic Analysis (2008). Personal income is income received by all persons from all sources before deduction of personal income taxes and other taxes. The closest two MSAs to each county center are included.

Population changes (in thousands of persons) in both MSAs ($MSA1P_{it}$ and $MSA2P_{it}$) are derived from the Population Estimates Program, Population Division of the U.S. Department of Commerce, Bureau of the Census (2008a). Travel distances in miles from the geographic center of each county to the MSAs and nearest reservoir ($MSA1D_{it}$, $MSA2D_{it}$, and $DRES_{it}$) are calculated using Google Map. Reservoirs in this dissertation refer to the Texas reservoirs and major bays as classified by the TPWD (2008b) used for recreational opportunities. Theses reservoirs are defined by the TWDB as containing 5,000 acre-feet or more of water (TWDB 2007). Distance to the nearest MSAs is used instead of travel time because the distance variable produced more robust estimates than travel time. Both time and distance variables could not be included because they are highly correlated (correlation coefficient of 0.940). Agricultural net returns (NR_{it}) are measured as the per-acre net return to agricultural uses calculated as the market value of products sold (crops or livestock) plus government payments minus total farm production expenses. Data for calculating net returns are from the Census of Agriculture of the U.S. Department of Agriculture (2008). Net returns are expressed as real 2007 dollars per acre.

Using county level data, regions in the east (regions 1- 4, and 8) have larger population densities than regions in the west (5, 6, 7, and 9) as shown in table 13.

Table 13. Average Values for the Texas Ecological Regions

Ecological Region	Farmland (acres)	Population	Per capita income ($)	Distance to nearest MSA (miles)	Distance to nearest reservoir (miles)
Coastal Prairies	445,150	300,234	33,533	38	26
West Gulf Coastal Plain	194,410	61,220	28,400	55	25
Oaks and Prairies	366,514	132,516	29,068	43	25
Osage Plains	466,800	222,761	33,083	36	21
Rolling Plains	507,840	16,481	29,660	69	47
Pecos and Staked Plains	574,624	25,565	31,054	58	65
Edwards Plateau	589,148	70,406	30,606	62	41
South Texas Brushlands	617,149	125,606	23,016	60	55
Chihuahuan Desert	1,433,240	87,261	24,750	115	248

Note: Counties making up a region had their data compiled to derive means for the different variables. Sources of the data are as explained in the text.

Population densities of the eastern regions ranged from 0.20 to 0.67 people / acre compared to 0.03 to 0.11 people / acre for the western regions. Eastern regions (1, 2, 3, and 4) had lower average distances to reservoirs ranging from 21 to 26 miles than western regions (5, 6, 7, and 9) where average distances to reservoirs ranged from 41 to 248 miles. Per capita personal incomes are slightly higher in the eastern regions than western regions. Drier western counties are larger in terms of farmland acres than the eastern counties (all counties in the western regions have at least 500,000 acres in farmland, while all counties in the eastern regions have less than 500,000 farmland acres). Summary statistics of the data and the units used are as shown in table 14.

Table 14. Descriptive Statistics for Agricultural Land Value Model

Variable	Variable Description	Units	Mean	Std. Dev.	Min.	Max.
LV97	Agricultural land value 1997	$1,000 / acre	1.043	0.697	0.137	3.225
ACR97	County farmland 1997	%	0.787	0.203	0.096	1.222
MSA1PPI97	MSA 1 income 1997	%	0.054	0.019	0.022	0.13
MSA2PPI97	MSA2 income 1997	%	0.057	0.023	0.022	0.13
MSA1D	Distance to nearest MSA	miles	57.37	31.97	1.4	187
MSA2D	Distance to second closest MSA	miles	100.48	43.74	29.8	277
DRES	Distance to nearest reservoir	miles	48.73	52.94	0	403
NR97	Agricultural net returns 1997	$1,000 / acre	0.025	0.043	-0.032	0.333
MSA1P97	Population in nearest MSA 1997	thousands	55.411	105.523	0.491	377.434
MSA2P97	Population in second closest MSA 1997	thousands	51.749	100.283	0.491	377.434
LV02	Agricultural land value 2002	$1,000 / acre	1.145	0.813	0.096	4.292
ACR02	County farmland 2002	%	0.775	0.198	0.116	1.038
MSA1PPI02	MSA1 income 2002	%	0.032	0.0129	0.006	0.056
MSA2PPI02	MSA2 income 2002	%	0.032	0.0132	0.006	0.056
NR02	Agricultural net returns 2002	$1,000 / acre	0.0107	0.0467	-0.082	0.467
MSA1P02	Population in nearest MSA 2002	thousands	60.368	123.413	-4.086	417.023
MSA2P02	Population in second closest MSA 2002	thousands	56.821	117.187	-4.086	417.023
LV07	Agricultural land values 2007	$1,000 / acre	1.687	1.497	0.162	18.862
ACR07	County farmland 2007	%	0.783	0.205	0.099	0.997
MSA1PPI07	MSA1 income 2007	%	0.064	0.002	0.06	0.068
MSA2PPI07	MSA2 income 2007	%	0.064	0.002	0.06	0.068
NR07	Agricultural net returns 2007	$1,000 / acre	0.027	0.082	-0.063	0.788
MSA1P07	Population in nearest MSA 2007	thousands	73.24	141.432	-3.894	462.45
MSA2P07	Population in second closest MSA 2007	thousands	68.81	134.136	-3.894	462.45

Note: Number of observations is 237 counties per year.

Results

STATA 9 statistical package is used for all estimation. Multicollinearity appears not to be an issue because most variance inflation factors are below three. Parameter estimates are presented in table 15. The R^2's for the three equations are reasonable for cross section data ranging from 0.47-0.75.

Table 15. Estimation Results for Agricultural Land Value Model

Variable	Estimate	p-values	Variable	Estimate	p-values
Constant, 1997	1.97	0.000	Coastal Prairies 97	-0.256	0.008
Constant, 2002	2.57	0.000	Coastal Prairies 02	-0.307	0.021
Constant, 2007	3.79	0.403	Coastal Prairies 07	-0.4	0.263
NR97	1.085	0.025	West Gulf 97	-0.011	0.914
NR02	0.389	0.477	West Gulf 02	-0.049	0.751
NR07	7.264	0.000	West Gulf 07	-0.058	0.883
ACR97	-0.779	0.000	Osage Plains 97	-0.049	0.672
ACR02	-0.763	0.000	Osage Plains 02	-0.019	0.900
ACR07	-1.79	0.001	Osage Plains 07	-0.22	0.570
MSA1P97	0.002	0.000	Rolling Plains 97	-0.673	0.000
MSA1P02	0.002	0.000	Rolling Plains 02	-0.688	0.000
MSA1P07	0.002	0.003	Rolling Plains 07	-0.83	0.005
MSA2P97	0.001	0.643	Pecos & Staked Plains 97	-0.589	0.000
MSA2P02	0.0002	0.464	Pecos & Staked Plains 02	-0.7	0.000
MSA2P07	0.0008	0.189	Pecos & Staked Plains 07	-1.35	0.000
MSA1D97	-0.004	0.000	Edwards Plateau 97	-0.29	0.001
MSA1D02	-0.006	0.000	Edwards Plateau 02	-0.14	0.205
MSA1D07	-0.008	0.004	Edwards Plateau 07	-0.3	0.267
MSA2D97	-0.0006	0.371	South Texas Brushlands 97	-0.52	0.000
MSA2D02	-0.001	0.180	South Texas Brushlands 02	-0.49	0.000
MSA2D07	-0.0005	0.827	South Texas Brushlands 07	-0.694	0.025
DRES97	-0.0009	0.197	Chihuahuan Desert 97	-0.506	0.013
DRES02	0.0007	0.486	Chihuahuan Desert 02	-0.67	0.016
DRES07	0.003	0.207	Chihuahuan Desert 07	-1.24	0.070

Table 15. Continued

Variable	Estimate	p-values	Variable	Estimate	p-values
MSA1PPI97	1.766	0.106	MSA2PPI97	2.03	0.023
MSA1PPI02	-4.096	0.149	MSA2PPI02	-2.353	0.401
MSA1PPI07	-9.66	0.845	MSA2PPI07	5.37	0.897
R^2, 1997	0.75		AIC	1,058.17	
R^2, 2002	0.67		BIC	1,245.44	
R^2, 2007	0.47				

Note: The dependent variable is agricultural land values (LV_{it}). See table 14 for variable description.

Significant variables include percentage acreage in farmland, agricultural net returns, nearest MSA population change, distance to the nearest MSA, percentage per capita income change in the nearest and second nearest MSA, and regional differences. Net returns, population change, and income change seem to be driving land values upwards, whereas, farmland percentage, distance to the nearest MSA, and regional differences seem to be driving land values downwards.

Larger percentages of farmland acreage are associated with decreased land values in a county. For a one percent increase in farmland acreage, land values decreased by 0.8% in 1997, 0.8% in 2002, and 1.8% in 2007. The acreage coefficient increases over time, more than doubling between 1997 and 2007. Net returns from farming are associated with increased land values in 1997 and 2007, however, net returns is not significant in the 2002 model. A dollar / acre increase in net returns resulted in a $1.09 / acre increase in land value in 1997 and a $7.26 / acre increase in land value in 2007. Positive effect of net returns on land values is similar to results in previous studies (Shi, Phipps, and Colyer 1997; Guiling, Brorsen, and Doye 2009; Livanis et al. 2006).

An increase in population growth in the nearest MSA is associated with an increase in land values. The effect of population growth is uniform across the three years. A percentage increase in population growth increases land values by approximately $2 / acre (units are in thousands of people in table 14). Population growth in the second nearest MSA, is not statistically significant.

Distance to the nearest MSA is inversely related to land values. This result is supported by earlier studies that found that as distance increased from the center of the MSA, land values decrease to compensate for commuting and other costs (Capozza and Helsely 1989; Guiling, Brorsen, and Doye 2009). The coefficient associated with distance from the nearest metropolitan area increases over time. A one-mile increase in distance from the nearest MSA decreases land values by $4 / acre in 1997, $6 / acre in 2002, and $8 / acre in 2007. Distance to the second nearest metropolitan area (MSA2D) is not significant across the three years as is distance to the nearest reservoir.

Although many studies (Capozza and Helsley 1989; Plantinga, Lubowski, and Stavins 2002; Guiling, Brorsen, and Doye 2009; Richardson et al. 2009) identified income as an important factor in determining land values, per capita incomes in the nearest two MSAs are only significant in the 1997 model. A percent increase in nearest MSA income is associated with increases in land values of $1.8 / acre and $2.03 in second nearest MSA in 1997. This positive influence is most likely because as the spending ability within a metropolitan area increases the ability to purchase land in the surrounding countryside increases (Chicoine 1981). Unexpectantly in 2002 and 2007, the per capita incomes are not significant. The percent change in per capita income in MSAs had the smallest variability (its coefficient of variation is 0.034) among all variables across the three years. In 2007, for example, the percentage change in income range from 0.060-0.068.

For the ecological regions, region 3 which is the Oaks and Prairies, is the base. Chi-squared tests showed that the regions are not jointly equal to zero and neither are they equal to each other, indicating regional differences. Regions 2, 4, and 7 with the some of the largest population growths, do not show any significant differences in land values compared to region 3. Regions 1, 5, 6, 8, and 9 have significantly lower land values compared to region 3. Statistical tests indicate that the coefficients associated with regions 1 and 7, 2 and 4, and 6 and 9 are not statistically different from each other. These regions show similarities in their population growth patterns. Regions 5, 6, and 9 which are to the west of region 3, have land values that are lower than regions east (1and 2), south (7 and 8), and north-west (4) of region 3. This pattern also coincides with the population densities of the regions, the less populated western regions have lower densities compared to the eastern and southern regions. These results might also be showing the importance of aesthetic appeal and other regional subjective differences on land values.

Table 16. Elasticities at the Means of Agricultural Land Value Model

Variable	Elasticity	Variable	Elasticity
MSA1PPI97	0.092*	MSA2P97	0.006
MSA1PPI02	-0.116	MSA2P02	0.014
MSA1PPI07	-0.365	MSA2P07	0.034
MSA2PPI97	0.11*	DRES97	-0.045
MSA2PPI02	-0.065	DRES02	0.031
MSA2PPI07	0.203	DRES07	0.09
MSA1D97	-0.228*	ACR97	-0.588*
MSA1D02	-0.311*	ACR02	-0.517*
MSA1D07	-0.287*	ACR07	-0.832*
MSA2D97	-0.059	NR97	0.026*
MSA2D02	-0.113	NR02	0.004
MSA2D07	0.030	NR07	0.115*
MSA1P97	0.124*		
MSA1P02	0.122*		
MSA1P07	0.083*		

Note: Asterisk (*) represent statistical significance. See table 14 for variable description.

The effect of the independent variables are placed in comparable terms by computing elasticities at the mean (table 16). All elasticities significance levels are the same as their respective coefficients (expected in a linear model). Farmland percentage acreage influences land values more than any other variable across the three years. A one-percent increase in farmland acreage would decrease land values by 0.58%, 0.51%, and 0.83% in 1997, 2002, and 2007. Net returns in 2002 had the least influence on land values. Land values are shown to be inelastic with respect to all the variables.

Discussion

A county with a larger percentage of farmland tends to have smaller agricultural land values, most likely because of less pressure for land conversion compared to urban counties with smaller percentages of farmland. This result is similar to Plantinga, Lubowski, and Stavins (2002)'s findings that development is far into the future for rural counties, hence the net effect from development on average land values is small. Decreasing acreage effect over time may be partially explained by the changing demography of farmland buyers (Dunford, Marti, and Mittelhammer 1985; Richardson et al. 2009). The increase in nonfarm (non-traditional) land buyers increases the demand for smaller land holdings for nonfarm recreation or investment portfolios which may drive up land values. Counties with larger farmland acreage percentages have smaller land values than counties with smaller farmland acreage percentage because of land supply (Richardson et al. 2009). Herdt and Cochrane (1966) suggest that land supply should be considered a market function because it portrays the landowners' reaction to the quantity offered for sale and not the total land quantity. Hence, the rate of return on land becomes critical because this determines whether non-traditional landowners will place land on the market and move to alternative investments that offer better returns (Herdt and Cochrane 1966). Elasticity results suggest the supply of agricultural land may have a larger influence on land values than demand aspects, although it is shown both supply and demand factors are relevant. The relative importance is, however, changing overtime.

The large magnitude of the coefficient associated with net returns in 2007 may be partially explained by the more enterprising nature of landowners and increasing profitability of alternative operations. Livanis et al. (2006) shows that in the continental U.S., agricultural landowners on urban fringes are surviving urbanization pressure through increased production of high-valued crops such as fruits, vegetables, nursery, and greenhouse crops. Further, ethanol as a bio-fuel has improved farm profitability.

Henderson and Gloy (2009) show that ethanol plants positively affect nearby land values. Shi, Phipps, and Colyer (1997) argue that increasing farm incomes increase the price of agricultural land.

Wilkins et al. (2003) argue that many landowners in Texas want to keep their lands in agriculture, as this constitutes part of being a Texan. Plantinga, Lubowski, and Stavins (2002) report that only six percent of the 1997 agricultural land values in Texas are from the development component, the rest is agricultural, providing further reasons for Texans keeping their land rural. The passage of the Texas Farm and Ranch Lands Conservation Program (TFRLCP) into law on 1 September 2005 (see PDRs section in Chapter III) might have informed more landowners about the situation of land fragmentation situation in Texas possibly making them more unwilling to fragment their land. However, in Pennsylvania, Maryland, and West Virginia, Hailu and Brown (2007) show that farmland protection policies are not a significant factor in decreasing agricultural land development.

An increase in population growth in the nearest MSA led to an increase in land values in the county. This is in line with Shi, Phipps, and Colyer (1997)'s "urban influence" argument that the nearest metropolitan area's population drives up land values. Guiling, Brorsen, and Doye (2009) and McGrath (2005) also cite population growth as the most important factor in influencing agricultural land values. Although regional differences impact land values in Texas, population growth in those regions seems to be a key main factor. Regions 1, 2, 3, 4, 7, and 8 contain Houston-Sugarland-Baytown, Dallas-Fort Worth-Arlington, Austin-Round Rock, and San Antonio MSAs with five of the fastest population growth counties (Harris, Tarrant, Bexar, Collin, and Travis) in the nation (U.S. Department of Commerce, Bureau of the Census 2008b). These regions are not significantly different from region 3 in terms of land values. Land in the Texas highlands, brushlands, and desert in the western regions have lower population growth, as well as, land values.

Distance to the nearest MSA is significant factor whilst distance to the second nearest MSA is not a significant factor in land values. Significance and insignificance of the distance variables may indicate that beyond a certain distance, development becomes less attractive because of commuting and other costs. Capozza and Helsely (1989), however, highlight the fact that land values, rents, and population densities might also increase with distance from metropolitan areas. Distance to a metropolitan area may have a mixed effect on land values.

Distance to the nearest reservoir is not significant. It appears this variable is not picking up information on the aesthetic and recreational opportunities of reservoirs on land values that was hoped. One reason is that interest in recreational opportunities within the reservoir often involves boating, with the majority of boats commuting to a reservoir for recreation, as long as, there is public access. Hence, this variable maybe picking up some of the distance effect to recreational opportunities to a limited extent.

Percent non-farm per capita personal income growth is an important factor driving agricultural land prices for 1997 which is in line with Richardson et al. (2009). Income is one factor driving nonfarm buyers to acquire agricultural land (Plantinga, Lubowski, and Stavins 2002). Factors such as interest or inflation rates (Plantinga and

Miller 2001; Dunford, Marti, and Mittelhammer 1985) could be important as nonfarm buyers acquired land in their investment portfolios (Richardson et al. 2009). Including these variables at the county level is not possible because of lack of data and possible collinearity problems. Spatial modeling techniques would be more useful especially in generating distance data as they may be more precise than Google map.

CHAPTER VII

CONCLUSIONS, LIMITATIONS, AND RECOMMENDATIONS

Taken in their entirety, results from this dissertation and previous studies indicate ecosystems provide goods and services beyond those traded in the marketplace. Further, economic theory clearly indicates market participants will not fully value these goods and services in market transactions because of externalities and public good aspects. Texas local, regional, and state governments (not considering endangered species) are behind many other areas of the U.S. in maintaining open spaces to provide these public goods and services.

Although not 100% comparable, results indicate wetlands are more valuable than pasture / croplands. This result is expected for several reasons. There is less acreage in wetlands than in agricultural lands in Texas and the U.S. Economic theory suggests that as the supply of a commodity decreases the resulting increase in scarcity manifests itself in a higher price or value. Further, wetlands by their physical and biological nature are generally more productive than pasture / croplands.

The diversity of the studies and their different valuations clearly show that a cookbook type methodology is not appropriate for valuing ecosystem goods and services. Cookbook approaches may be highly relevant for market-based issues such as the cost of community services. Only a general methodology can be provided for the value of ecosystem goods and services. The main reason for this difference is the fact that ecosystem services are not traded in the marketplace. In essence when valuing ecosystem goods and services, the analyst creates a proxy for the marketplace.

Purchase of development rights on private lands to provide the goods and services associated with the ecosystems may reduce public expenditures relative to purchasing the land outright. Public support for purchases of development rights on private land may be increased if the purchases include increased public access to open spaces (Cameron 1988; Carlsson, Frykblom, and Liljenstolpe 2003). Within Texas, the law pertaining to the purchase of development rights is written such that it does not provide incentives to individuals to purchase development rights. As written, the law requires purchase by “approved” entities; individuals can not purchase development rights. Further, by not funding the law, little more than window dressing has been accomplished. Dissemination of the passage of the law and its use has been poor.

This dissertation only scratches the surface of the issues associated with agricultural lands, ecosystem goods and services, their values, and who should provide these goods and services. To illustrate the complexity, consider the Comal County study. The relevant population (or scope) is different households in Comal County. Increased runoff from development may increase flows in the Guadalupe River. Increasing the scope is shown to include additional costs and benefits. Changes in flows in the Guadalupe River will affect the Aransas Wildlife Refuge habitat, the wintering site for whooping and sandhill cranes. Revenues for businesses on the Platte River in Nebraska are associated with tourists visiting the Platte River area during the migration of sandhill and whooping cranes. Business owners in this area may be willing-to-pay to have higher quality and / or larger inflows into the Aransas Wildlife Refuge. The value of these inflows to these businesses is unknown. Because of economic, physical, and biological linkages, at least part, of their livelihood is dependent on changes in the Guadalupe River Basin. Political boundaries also play a role. Why would any one in the Guadalupe Basin be willing-to-pay for a policy change that does not benefit them directly but benefits businesses along the Platte River? Further, why would businesses along the Platte River pay for changes in the Guadalupe Basin if Comal County or the State of Texas is picking up the bill. Further, because of jurisdictional issues collection of funds may be prohibitively costly. This is just one of many complicating issues not covered in this study.

The agricultural land value model developed in this dissertation shows similar results to previous studies, namely population growth, proximity to metropolitan areas, and amount of farmland acreage in a county affect agricultural land values with regional differences (Chicoine 1981; Pope 1985; Capozza and Helsley 1989; Plantinga, Lubowski, and Stavins 2002; Guiling, Brorsen, and Doyle 2009; Sander 2009). Urban development is inevitable given Texas' large population growth rates. Development rents will drive up land values especially in counties in the Coastal Prairies, West Gulf, Osage Plains, Oaks and Prairies, Edwards Plateau, and South Texas Brushlands regions, where the majority of population growth is occurring. These areas also have aesthetic appeal that attracts land buyers. The distance variables indicate that beyond a certain distance, development becomes less attractive because of commuting and other costs.

Policy Context

To be comparable with land prices, the economic values of ecosystem goods and services have generally been placed into perpetuity values. For at least two reasons it is informative to view the economic values over a 30 year horizon. First, the Texas Farm and Ranch Lands Conservation Program allow landholders to sell their easements for a term of 30 years or perpetuity. This is the main program in Texas for purchase of development rights. Second, the Texas 2007 State Water Plan uses 2040 as one of their benchmark years, which happens to be 30 years from the date of this dissertation. The estimated WTP for farmland amenities and raw water values for Comal County, along with the WTP for the Richland-Chambers reservoir and replacement cost estimates are also presented estimates based on a 30 year horizon. Loss of ecosystem services estimates associated with growth in western Comal County and New Braunfels area are not calculated for a 30 year horizon. The reason is once developed; land is very rarely converted back to agricultural land. Development tends to be permanent. These losses are, however, projected for various years including 2040. For some policy implications examining the 30 year horizon may be more relevant than the perpetuity values. For example, for the years 2006 – 2020 it is estimated 2,359 acres will be converted from agricultural to city development, the estimated aggregate loss in ecosystem services is $522,386 in total or $37,314 per year (2007 U.S. $). Predicted total losses in water recharge for the periods 2020 – 2030 and 2030 – 2040 are an additional $1,057,961 and $942,599. These figures may be used to inform policy makers and help in water and land planning issues associated with growth.

Estimated economic values of ecosystem goods and services in this dissertation are specific to each area. This qualification is relevant to all research and is not only specific to the areas presented here. Results presented here, however, maybe applicable to other areas. This is especially important in the policy arena where decisions must be made, but time and funding constraints limit the amount of studies. Because of the similarity of counties within the Edward's Plateau to Comal County, the ecosystem goods and services values presented maybe generally applicable to these other counties. Although specific values will differ, the magnitude of the values will be similar to those presented in the Comal County scenarios. For the Richland – Chambers constructed wetlands, the ecosystem service value estimates of water cleansing are expected to be higher than for natural wetlands. The main reason is that by its nature, a constructed wetland's water flows and other management options can be regulated to a much higher degree than in natural wetlands. Comparing the meta-analysis estimates to the replacement costs estimates supports this contention. Even with this qualification, the Richland – Chambers case study is illustrative of the value of wetlands across East Texas.

Estimated agricultural land value functions provide insight and values which can be used for planning purposes by policy makers. Given the high population growth rates in Texas, urban encroachment onto surrounding agricultural lands is inevitable. Knowing factors that cause land values to change is useful in land use planning.

Regional differences affect land values in Texas, this shows the complexity of trying to model land values for a state as expansive as Texas. Getting an average agricultural land value to use for comparison with a study like the Comal County may be misleading as more localized modeling would be required. The studies can, however, be linked in other ways. Applying the New Braunfels study results to agricultural land values, it shows that increased demand for resources will occur to accommodate the increased population and this has varied consequences on ecosystem services. Demand for water and land area will increase which increases impervious surfaces associated with less recharge and increased runoff that might lead to flooding and reduced water quality because of increased pollution. Other impacts not quantified include development effects on endangered species, rates of disease transmission, urban heat island effects, air quality, access to recreational areas, and scenic quality. Omission of ecosystem services valuation in policy making compromises natural systems upon which economic development depends.

Overall, this dissertation increased our understanding of how land use change decisions impact our ecosystem services. Having a dollar value for different ecosystem services helps create a market proxy which policy makers can use to make informed decisions about land use changes or development. Results are suggestive of the values the public could pay to landowners to manage their private lands in ways that protect ecosystem services.

Limitations

There are several limitations of the study. First, applicability of the of the agricultural land values study results to computation of future development rights values is limited in this case because the TFRP is not yet operating in Texas. Hence, there is no point of reference or current prices to use for computation. Personal per capita income change was not significant, however, most studies found this to be an important factor in determining land values. Further investigation into why income is not significant is warranted. Because county data is used, interest rates can not be included because rates do not differ enough across cross sectional units / counties (Dunford, Marti, and Mittelhammer 1985) resulting in collinearity problems. Although Dunford, Marti, and Mittelhammer (1985) argue that using inflation rates is a viable option, the most reliable inflation figures are annually computed national statistics. Using these rates would still have the problem of collinearity.

Distance to the nearest reservoir was not significant in this study which warrants a different approach to modeling recreational opportunities. Additional studies that model agricultural land values in Texas on the regional level are warranted. Spatial mapping techniques such as Geographical Information Systems (GIS) may provide more precise data on distances between counties and MSAs. Further, GIS can be used to create various visual land use change and impact scenarios. Ability to interview people about their views on land use change will also help inform policy makers about how differently people value open spaces.

The use of benefit transfers in both the Richland-Chambers CWs and Comal County has the main drawback that errors committed in the original studies are carried over into our results. Also, the confidence interval calculated for the Richland-Chambers using the Woodward and Wui meta-analysis program is large, showing the limitations of using benefit transfers as it can give very imprecise results. For Comal County, unit benefit transfer was mainly used and confidence intervals could not be calculated. Application of the Richland-Chambers results is limited by the fact that these CWs are only in the experimental phase and just currently being expanded to full phase, efficiency in the larger project may differ. The large land footprint of the CWs is partly justified by the use of the CWs as recreational sites; attractiveness of the CWs is questionable given their lack of social acceptance as they may produce unpleasant odors because of anaerobic processes. Although Texas is the fastest growing state in the U.S., Comal County is in the Edwards Plateau region which is among some of the fastest growing counties in Texas; may not be representative of the population growth rate in other areas of Texas, limiting applicability of the results. Use of the Edwards Aquifer region water rights prices also makes it difficult to compare results as this is a unique aquifer with jurisdictional issues surrounding its governance.

More real-world applications of valuation techniques on ecosystem services to policy contexts in Texas are required to provide additional information. Very few studies have been done on the economics of land-use change and development's implications on ecosystem services in Texas even though Texas is the fastest growing state in the nation. This dissertation, therefore, makes a contribution towards informing the public about the values that ecosystems provide.

REFERENCES

Alan Plummer Associates, Inc. 2008. "Tarrant Regional Water District Field-Scale Constructed Wetland Phase 1 Operations June 3, 2003 –Jan. 9, 2007." Final Report, Tarrant Regional Water District, Denton, TX.

American Farmland Trust (AFT). 2003. *Going, Going, Gone. Impacts of Land Fragmentation on Texas Agriculture and Wildlife*. Texas Land Trends. San Marcos, TX.

American Farmland Trust (AFT). 2009. *Status of State Pace Programs*. Farmland Information Center. Fact Sheet, Washington DC. Accessed July 12, 2009, Available at: http://www.farmlandinfo.org/documents/37757/State_PACE_05-2009_2.pdf.

Anderson, R., and M. Rockel. 1991. "Economic Valuation of Wetlands." Discussion Paper No. 065. American Petroleum Institute, Washington DC.

Andrews, D. 2008. Eastern Division Water Quality Manager. Tarrant Regional Water District. Streetman, TX. Personal Communication.

Banzhaf, S., D. Burtraw, D. Evans, and A. Krupnick. 2004. "Valuation of Natural Resource Improvements in the Adirondacks." Resources for the Future, Washington DC.

Barbier, E.B. 2007. "Valuing Ecosystem Services as Productive Inputs." *Economic Policy* January: 177-229.

Barrett, M.E., and R.J. Charbeneau. 1996. *A Parsimonious Model for Simulation of Flow and Transport in a Karst Aquifer*. Austin: Center for Research in Water Resources, Bureau of Engineering Research, Rep. 269, November.

Batchelor, B. 2008. Professor, Department of Civil Engineering. Texas A&M University. College Station, TX. Personal Communication.

Bauer, D.M., N.E. Cyr, and S.K. Swallow. 2004. "Public Preference for Compensatory Mitigation of Salt Marsh Losses: A Contingent Choice of Alternatives." *Conservation Biology* 18(2): 401-411.

Beasley, Steven D., W.G. Workman, and N.A. Williams. 1986. "Estimating Amenity Values of Urban Fringe Farmland: A Contingent Valuation Approach: Note." *Growth and Change* 17(4): 70-78.

Beattie, B.R. 2001. “The Disappearance of Agricultural Land: Fact or Fiction?” In T. L. Anderson and B.Y. Stanford, eds. *Agriculture and the Environment: Searching for Greener Pastures*. Stanford, CA. Hoover Institution Press, p. 1-22.

Bell, F.W. 1981. *Recreational Benefits for the Atchafalaya River Basin*. Washington, D.C: U.S. Department of Fish and Wildlife Service, Contract Number 14-16-009-80-009: 228.

Bell, F.W. 1997. “The Economic Valuation of Saltwater Marsh Supporting Marine Recreational Fishing in the Southeastern United States.” *Ecological Economics* 21: 243-254.

Bengston, D.N., J. O. Fletcher, and K.C. Nelson. 2004. “Public Policies for Managing Urban Growth and Protecting Open Space: Policy Instruments and Lessons Learned in the United States.” *Landscape and Urban Planning* 69:271-286.

Bergstrom, J.C., and J.R. Stoll. 1993. “Value Estimator Models for Wetlands-Based Recreational Use Values.” *Land Economics* 69 (2): 132-37.

Bergstrom, J.C., and R.C. Ready. 2006 “What Have We Learned from 20 Years of Farmland Amenity Valuation Research?” Dept. Agr Econ. Faculty Series Paper No. FS06-02, University of Georgia, June.

Beringer, J., L.P. Hansen, J.A. Demand, J. Sartwell, M. Wallendorf, and R. Mange. 2002. “Efficacy of Tranlocation to Control Deer in Missouri: Costs, Efficiency, and Outcome.” *Wildlife Society Bulletin* 30 (3): 767-774.

Beutnagel, T. 2008. Public Communications Department, Guadalupe-Blanco River Authority. Seguin, TX. Personal Communication.

Bittner, A., D. McLeod, R. Coupal, A. Seidl, and K. Inman. 2006. “Moffat County Land Use and Planning Survey Results.” Colorado State University and University of Wyoming Cooperative Extension Services.

Bowker, J.M., and J.R. Stoll. 1988. “Use of Dichotomous Choice Nonmarket Methods to Value the Whooping Crane Resource.” *American Journal of Agricultural Economics* 70 (2): 373-381.

Boyle, K.J., and J.C. Bergstrom. 1992. “Benefit Transfer Studies: Myths, Pragmatism, and Idealism.” *Water Resources Research* 28 (3): 657-663.

Brabec, E., S. Schulte and P.L. Richards. 2002. “Impervious Surfaces and Water Quality: A Review of Current Literature and Its Implications for Watershed Planning.” *Journal of Planning Literature* 16 (4): 499-514.

Bradley, C.A., S.E.J. Gibbs, and S. Altizer. 2008. "Urban Land Use Predicts West Nile Virus Exposure in Songbirds." *Ecological Applications* 18 (5): 1083-109.

Brander, L.M., R.J.G.M. Florax, and J.E. Vermaat. 2006. "The Empirics of Wetland Valuation: a Comprehensive Summary and a Meta-analysis of Literature." *Environmental and Resource Economics* 33: 223-250.

Brix, H. 1999. "How 'Green' Are Aquaculture, Constructed Wetlands and Conventional Wastewater Treatment Systems?" *Water Science and Technology* 40 (3): 45-50.

Brody, S.D., S. Zahran, W.E. Highfield, H. Grover, and A. Vedlitz. 2007. "Identifying the Impact of the Built Environment on Flood Damage in Texas." *Disasters* 32(1): 1-18.

Bulte, E., D.P. van Soest, G.C. van Kooten, and R.A. Schipper. 2002. "Forest Conservation in Costa Rica When Nonuse Benefits Are Uncertain but Rising." *American Journal of Agricultural Economics* 84: 150-160.

Cameron, T.A. 1988. "Using the Basic 'Auto-validation' Model to Assess the Effect of Environmental Quality on Texas Recreational Fishing Demand." Working paper, Dept. of Econ., University of California, Los Angeles.

Canadian Wildlife Service and U.S. Fish and Wildlife Service. 2007. *International Recovery Plan for the Whooping Crane*. Ottawa Recovery of Nationally Endangered Wildlife (RENEW) and U.S. Fish and Wildlife Service, Albuquerque, NM. 162. pp. Accessed March 20, 2008, Available at: http://ecos.fws.gov/docs/recovery_plan/070604_v4.pdf.

Capozza, D.R., and R.W. Helsley. 1989. "The Fundamentals of Land Prices and Urban Growth." *Journal of Urban Economics* 26: 295-306.

Cardoch, L., J.W. Day, Jr., J.M. Rybczyk, and G.P. Kemp. 2000. "An Economic Analysis of Using Wetlands for Treatment of Shrimp Processing Wastewater – A Case Study in Dulac, LA." *Ecological Economics* 33: 93-101.

Carle M.V., P.N. Halpin, and C.A. Stow. 2005. "Patterns of Watershed Urbanization and Impacts on Water Quality." *Journal of the American Water Resources Association* 41 (3): 693-708.

Carlsson, F., P. Frykblom and C. Liljenstolpe. 2003. "Valuing Wetland Attributes: An Application of Choice Experiments." *Ecological Economics* 47: 95-103.

Charbeneau R.J., and M. E. Barrett. 1998. "Evaluation of Methods for Estimating Stormwater Pollutant Loads." *Water Environment Research* 70 (7): 1295-1302.

Chicoine, D.L. 1981. “Farmland Values at the Urban Fringe: An Analysis of Sale Prices.” *Land Economics* 57 (3): 353-362.

Coase, R.H. 1960. “The Problem of Social Cost.” *Journal of Law and Economics* 3:1-44.

Cornes, R., and T. Sandler. 1996. *The Theory of Externalities, Public Goods, and Club Goods*, 2nd. ed. Cambridge: Cambridge University Press.

Costanza, R., R. d’Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O’Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. van den Belt. 1997. “The Value of the World’s Ecosystem Services and Natural Capital.” *Nature* 387: 253-260.

Cotteleer, G., T. Stobbe, and G.C. van Kooten. 2007. “Farmland Conservation in The Netherlands and British Columbia, Canada: A Comparative Analysis Using GIS-based Hedonic Pricing Models.” Working Paper, Dept. of Economics, University of Victoria.

Crompton, J.L. 2007. “A Review of the Effectiveness of States’ Purchase of Development Rights Programs in Addressing Conservation Goals.” Working Paper, Dept. of Rec., Parks and Tourism Sciences, Texas A&M University.

Cronk, J.K. 1996. “Constructed Wetlands to Treat Wastewater from Dairy and Swine Operations: A Review.” *Agriculture, Ecosystems and Environment* 58 (2-3): 97-114.

Daily, G.C., S. Polasky, J. Goldstein, P.M. Kareiva, H.A. Mooney, L. Pejchar, T.H. Ricketts, J. Salzman, and R. Shallenberger. 2009. “Ecosystem Services in Decision Making: Time to Deliver.” *Frontiers in Ecology and the Environment* 7 (1): 21-28.

Day, J.W., J.M. Rybczyk, L. Cardoch, W.H. Conner, P. Delgado-Sanchez, R.I. Pratt and A. Westphal. 2004. “A Review of Recent Studies of the Ecological and Economic Aspects of the Application of Secondary Treated Municipal Effluent to Wetlands in Southern Louisiana.” In L.P. Rozas, J.A. Nyman, C.E. Proffitt, N.N. Rabalais, D.J. Reed and R.E. Turner, eds. *Recent Research in Coastal Louisiana: Natural System Function and Response to Human Influence*. Louisiana Sea Grant College Program.

Demsetz, H. 1967. “Toward a Theory of Property Rights.” *The American Economic Review* 57 (2): 347-359.

Dugas, S., R. Hicks and P. Wright. 1998. "Effect of Removal of *Juniperus Ashei* on Evapotranspiration and Runoff in the Seco Creek Watershed." *Water Resources Research* 34 (6): 1499-1506.

Duke, J.M., and T.W. Ilvento. 2004. "A Conjoint Analysis of Public Preferences for Agricultural Land Preservation." *Agricultural and Resource Economics Review* 33(2):209-219.

Duke, J.M., R.J. Johnston, and T.W. Campson. 2007. *Preserving Farm and Forests in Sussex County, Delaware: Public Value*. Dept. of Food and Resource Econ. Res. Bull. No. RR07-02, University of Delaware. Accessed December 10, 2008, Available at: http://www.udel.edu/FREC/PUBS/FRECRR07-02.pdf.

Dunford, R.W., C.E. Marti, and R.C. Mittelhammer. 1985. "A Case Study of Rural Land Prices at the Urban Fringe Including Subjective Buyer Expectations." *Land Economics* 61 (1): 10-16.

Edwards Aquifer District. 2008. *Introduction to the Edwards Aquifer*. Available online: http://www.edwardsaquifer.net/intro.html. Accessed August 2008.

Engel, B., and J. Harbor. 2001. *Long-Term Hydrologic Impact Assessment Model (L-THIA)*. Accessed April 5, 2008, Available at: http://www.ecn.purdue.edu/runoff/lthianew.

Fausold, C.J., and R.J. Lilieholm. 1999. "The Economic Value of Open Space: A Review and Synthesis." *Environmental Management* 23 (3): 307-320.

Frossard, W., D. Andrews, A.H. Plummer, and L. Mokry. 2006. *Over the River and Through the Plants to Richland Chambers We Go*. Water Environment Federation Technical Exhibit and Conference, 2006. Accessed December 3, 2007, Available at: http://www.environmentalexpert.com/Files%5C5306%5Carticles%5C12640%5C376.pdf.

Geoghegan, J., L. Lynch, and S. Bucholtz. 2003. "Capitalization of Open Spaces into Housing Values and the Residential Property Tax Revenue Impacts of Agricultural Easement Programs." *Agricultural and Resource Economics Review* 32(1): 33-45.

Gobel, P., C. Dierkes, and W.C. Coldewey. 2007. "Storm Water Runoff Concentration Matrix for Urban Areas." *Journal of Contaminant Hydrology* 91 (1-2): 26-42.

Graham, P.L., L.S. Costello, and H.J. Mallon. 1974. "Estimation of Imperviousness and Specific Curb Length for Forecasting Stormwater Quality and Quantity." *Journal of the Water Pollution Control Federation* 46 (4): 717-725.

Greene, W.H. 2003. *Econometric Analysis*. 5th ed. Upper Saddle River, NJ: Prentice Hall.

Guiling, P., B.W. Brorsen, and D. Doye. 2009. "Effect of Urban Proximity on Agricultural Land Values." *Land Economics* 85 (2): 252-264.

Gunnels, J. 2008. Wildlife Biologist, Richland Creek Wildlife Management Area, Texas Parks and Wildlife Department. Streetman, TX. Personal Communication.

Haab, T.C., and K. E. McConnell. 2002. *Valuing Environmental and Natural Resources: The Econometrics of Non-Market Valuation*. Northampton, MA: Edward Elgar Publishing.

Hagen, D.A., J.W. Vincent, and P.G. Wells. 1992. "Benefits of Preserving Old-Growth Forests and the Spotted Owl." *Contemporary Policy Issues* 10: 13-26.

Hailu, Y.G., and C. Brown. 2007. "Regional Growth Impacts in Agricultural Land Development: A Spatial Model for Three States." *Agricultural and Resource Economics Review* 36 (1): 149-163.

Hamer, T., and M. Hamer. 2008. *Scottsdale Classic Car Auctions – The RM Difference*. Accessed January 20, 2008, Available at: //classiccars.about.com/b/2008/01/21/Scottsdale-classic-car-auctions-the-rm-difference.htm.

Hammer, T.R., R.E. Coughlin, and E.T. Horn. 1974. "The Effect of a Large Urban Park on Real Estate Value." *Journal of the American Institute of Planners* 40: 274-277.

Handbook of Texas Online, *s.v*. 2008. Accessed April 12, 2008, Available at: http://www.tshaonline.org/handbook/online/articles/CC/hcc19.html.

Hanley, N., J.F. Shogren, and B. White. 1997. *Environmental Economics in Theory and Practice*, 2nd. ed. London: Macmillan Press.

Harbor, J.M. 1994. "A Practical Method for Estimating the Impact of Land-Use Change on Surface Runoff, Groundwater Recharge and Wetland Hydrology." *Journal of the American Planning Association* 60 (1): 95-108.

Heal, G. 2000. "Valuing Ecosystem Services." *Ecosystems* 3: 24-30.

Heal, G.M., E.B. Barbier, K.J. Boyle, A.P. Covich, S.P. Gloss, C.H. Hershner, J.P. Hoehn, C.M. Pringle, S. Polasky, K. Segerson, and K. Shrader-Frechette. 2005. *Valuing Ecosystem Services: Toward Better Environmental Decision-Making*. Washington DC: The National Academies Press.

Heimlich, R.E., K.D. Weibe, R. Claasen, D. Gadsy, and R.M. House. 1998. *Wetlands and Agricultural: Private Interests and Public Benefits*. Washington DC: U.S. Department of Agriculture, ESCS for Agr. Econ. Rep. 765, October.

Hellerstein, D., C. Nickerson, J. Cooper, P. Feather, D. Gadsby, D. Mullarkey, A. Tegene, and C. Barnard. 2002. *Farmland Protection*: *The Role of Public Preferences for Rural Amenities*. Washington DC: U.S. Department of Agriculture, ESCS for Agr. Econ. Rep. 815, October.

Henderson, J., and B.A. Gloy. 2009. "The Impact of Ethanol Plants on Cropland Values in the Great Plains." *Agricultural Finance Review* 69 (1): 36-48.

Herdt, R.W., and W.W. Cochrane. 1966. "Farm Land Prices and Farm Technological Advance." *Journal of Farm Economics* 48: 243-264.

Hernandez, S., S.L. Locke, M.S. Cook, L.A. Harveson, D.S. Davis, R.R. Lopez, N.J. Silvey, and M.A. Fraker. 2006. "Effects of SpayVac ® on Urban Female White-Tailed Deer Movements." *Wildlife Society Bulletin* 34(5): 1430-1434.

Hoehn, J. 2006. "Methods to Address Selection Effects in the Meta Regression and Transfer of Ecosystem Values." *Ecological Economics* 60: 389-398.

Hydromantis, Inc. 2008. *CAPDETWorks*. Accessed August 1, 2008, Available at: http://www.hydromantis.com/software03.html.

Irwin, E.G. 2002. "The Effects of Open Space on Residential Property Values." *Land Economics*. 78 (4):465-481.

Irwin, E.G., and N.E. Bockstael. 2001. "The Problem of Identifying Land Use Spillovers: Measuring the Effects of Open Space on Residential Property Values." *American Journal of Agricultural Economics* 83 (3): 698-704.

Jackson, M. 2005a. *Bill Analysis, Agriculture and Coastal Resources Committee Report (as filed).* Accessed October 8, 2007, Available at: http://www.legis.state.tx.us/tlodocs/79R/analysis/doc/SB01273I.doc.

Jackson, M. 2005b. *Bill Analysis*, *Land & Resource Management Committee Report (substituted)*. Accessed October 9, 2007, Available at: http://www.legis.state.tx.us/tlodocs/79R/analysis/doc/SB01273H.doc.

Jenerette, G. D., W. A. Marussich, and J. P. Newell. 2006. "Linking Ecological Footprints with Ecosystem Valuation in the Provisioning of Urban Freshwater." *Ecological Economics* 59: 38-47.

Johnston, R.J., J.J. Opaluch, T.A. Grigalunas, and M.J. Mazzotta. 2001. "Estimating Amenity Benefits of Coastal Farmland." *Growth and Change* 32 (3):305-325.

Johnston, R.J., S.K. Swallow, T.J. Tyrrell, and D.M. Bauer. 2003. "Rural Amenity Values and Length of Residency." *American Journal of Agricultural Economics* 85(4):1000-1015.

Johnston, R.J., T.W. Campson, and J.M. Duke. 2007a. "The Value of Farm and Forest Preservation in Connecticut." Dept. of Agr. Econ., University of Connecticut.

_____ . 2007b. "The Value of Farm and Forest Preservation to Residents of Preston, Connecticut." Dept. of Agr. Econ., University of Connecticut.

_____. 2007c. "The Value of Farm and Forest Preservation to Residents of Mansfield, Connecticut." Dept. of Agr. Econ., University of Connecticut.

Khan, S.D. 2005. "Urban Development and Flooding in Houston Texas, Inferences from Remote Sensing Data Using Neural Network Technique." *Environmental Geology* 47: 1120-1127.

Kline, J., and D. Wichelns. 1996a. "Public Preferences Regarding the Goals of Farmland Preservation Programs." *Land Economics* 72(4): 538-549.

Kline, J., and D. Wichelns. 1996b. "Measuring Public Preferences for the Environmental Amenities Provided by Farmland." *European Review of Agricultural Economics* 23(4): 421-436.

Knight, R.L. 1997. "Wildlife Habitat and Public Use Benefits of Treatment Wetlands." *Water Science and Technology* 35 (5): 35-43.

Knight, R.L., R.A. Clarke, and R.K. Bastian. 2001. "Surface Flow (SF) Treatment Wetlands as a Habitat for Wildlife and Humans." *Water Science and Technology* 44 (11-12): 27-37.

Knowlton M.F., C. Cuvellier, and J.R. Jones. 2002. "Initial Performance of a High Capacity Surface-Flow Treatment Wetland." *Wetlands* 22 (3): 522-527.

Konarska, K.M., P.C. Sutton, and M. Castellon. 2002. “Evaluating Scale Dependence of Ecosystem Service Valuation: A Comparison of NOAA_AVHRR and Landsat TM Datasets.” *Ecological Economics* 41:491-507.

Kreuter, U. P., H.G. Harris, M. D. Matlock, and R.E. Lacey. 2001. “Change in Ecosystem Service Values in the San Antonio Area, Texas.” *Ecological Economics* 39: 333-346.

Lansford, N.H. Jr., and L.L. Jones. 1995. “Marginal Price of Lake Recreation and Aesthetics: An Hedonic Approach.” *Journal of Agriculture and Applied Economics* 27 (1): 212-223.

Lee, C.K., and J.W. Mjelde. 2007. “A Valuation of Ecotourism Resources Using a Contingent Valuation Method: The Case of the Korean DMZ.” *Ecological Economics* 63:511-520.

Lemberg, B. 2000. “Integrating Ecological, Hydrological, and Economic Models for Water Valuation in the Frio River Basin, Texas.” PhD dissertation, Texas A&M University.

Livanis, G., C.B. Moss, V.E. Breneman, and R.F. Nehring. 2006. “Urban Sprawl and Farmland Prices.” *American Journal of Agricultural Economics* 88 (4): 915-29.

Locke, S.L., C. Frentress, J.C. Cathey, C. Mason, R. Hirsch, and M.W. Wagner. 2007. “Techniques for Wetland Construction and Management.” Texas A&M University Agr. Exp. Sta. Res. Bull. No. SP- 316.

Loomis, H., P. Kent, L. Strange, K. Fausch, and A. Covich. 2000. “Measuring the Total Economic Value of Restoring Ecosystem Services in an Impaired River Basin: Results from a Contingent Valuation Survey.” *Ecological Economics* 33: 103-117.

Maestas, J.D., R.L. Knight, W.C. Gilgert. 2001. “Biodiversity and Land-Use Change in the American Mountain West.” *Geographical Review* 91 (3): 509-524.

Massachusettes Executive Office of Energy and Environmental Affairs. 2008. *Agricultural Preservation/ Transfer of Development Rights Rural Case Study Montgomery County, Maryland*. Accessed August 7, 2008, Available at: http://www.mass.gov/envir/smart_growth_toolkit/pages/CS-tdr-montgomery.html.

McCarl, B. 1999. “Limiting Pumping from the Edwards Aquifer: An Economic Investigation of Proposals, Water Markets and Springflow Guarantees.” *Water Resources Research* 35(4): 1257-1268.

McCarl, B. 2008. “Notes on the Value of Edwards Aquifer Water.” Unpublished, Texas A&M University.

McCleery, R.A., R.R. Lopez, N.J. Silvey, and D.L. Gallant. 2008. “Fox Squirrel Survival in Urban and Rural Environments.” *Journal of Wildlife Management* 72 (1): 133-137.

McGonagle, M.P., and S.K. Swallow. 2005. “Open Space and Public Access: A Contingent Choice Application to Coastal Preservation.” *Land Economics* 81 (4): 477-495.

McGrath, D.T. 2005. “More Evidence on the Spatial Scale of Cities.” *Journal of Urban Economics* 58 (1): 1-10.

McKinney, J.L. 2002. “Urbanization, Biodiversity, and Conservation.” *BioScience* 52 (10): 883-890.

McLeod, D., K. Inman, R. Coupal, and J. Gates. 2002. “Sheridan Land Use and Planning Survey Results.” University of Wyoming Agr. Exp. Sta. Res. Bull. No. B-1107.

Millennium Ecosystem Assessment. 2003. *Ecosystems and Human Well-Being: A Framework for Assessment*. Washington DC: Island Press. Accessed October 4, 2007, Available at: http://www.millenniumassessment.org/documents/document.300.aspx.pdf.

Mishan, E.J. 1969. “The Relationship between Joint Products, Collective Goods, and External Effects.” *Journal of Political Economy* 72 (3): 329-348.

Mjelde, J.W. 2009. AGEC 604 Notes. Unpublished, Texas A&M University.

Montgomery County, Department of Economic Development. *Transfer of Development Rights (TDR) Program Overview*. 2006. Accessed August 6, 2008, Available at: http://www.montgomerycountymd.gov/content/ded/agservices/pdffiles/tdr_info.pdf .

Newburn, D.A., and P. Berck. 2006. “Modeling Suburban and Rural-Residential Development beyond the Urban Fringe.” *Land Economics* 82 (4): 481-499.

O’Brien, J.S. 2005. Legislative Budget Board Committee Report (substituted). Accessed October 7, 2007, Available at: http://www.legis.state.tx.us/tlodocs/79R/fiscalnotes/pdf/SB01273F.pdf .

Ockerman, D.J. 2002. *Simulation of Runoff and Recharge and Estimation of Constituent Loads in Runoff, Edwards Aquifer Recharge Zone (Outcrop) and Catchment Area, Bexar County Texas, 1997-2000*. U.S. Geological Survey, Report 02-4241. Accessed November 28, 2007, Available at: http://pubs.usgs.gov/wri/wri02-4241/

Oden, M., K. Butler, and R. Paterson. 2003. “Preserving Texas Coastal Assets: Economic and Natural Resource Evaluation of Erosion Control Projects under the Coastal Erosion Planning and Response Act.” Technical Report Prepared for Texas General Land Office – Coastal Resources Division. Austin, TX.

O’Rear Henry, A. 1998. “Ecological and Economic Value Issues Associated with Texas Rive Agriculture.” MS Paper, Texas A&M University.

Owens, M.K., and R.W. Knight. 1992. “Water Use on Rangelands.” In *Water for South Texas*. Texas A&M University Agr. Exp. Sta. Res. Bull. No. CPR. 5043-5046:1-6.

Parsons, G.R. 1992. “The Effect of Coastal Land Use Restrictions on Housing Prices: A Repeat Sale Analysis.” *Journal of Environmental Economics and Management* 22: 25-37.

PlaceNames.com. 2008. *Richland-Chambers Reservoir*. Accessed August 2, 2008, Available at: http://www.placenames.com/us/p1385472/.

Plantinga, A.J., and D. J. Miller. 2001. “Agricultural Land Values and the Value of Rights to Future Land Development.” *Land Economics* 77 (1):56-67.

Plantinga, A.J., R.N. Lubowski, and R.N. Stavins. 2002. “The Effects of Potential Land Development on Agricultural Land Prices.” Resources for the Future, Discussion Paper 02-11. Washington DC.

Pope, C.A. III. 1985. “Agricultural Productive and Consumptive Use Components of Rural Land Values in Texas.” *American Journal of Agricultural Economics* 67 (1): 51-60.

Ready, R.C., and C.W. Abdalla. 2005. “The Amenity and Disamenity Impacts of Agriculture: Estimates from a Hedonic Pricing Model.” *American Journal of Agricultural Economics* 87(2):314-326.

Reuter, J.E., T. Djohan, and C.R. Goldman. 1992. "The Use of Wetlands for Nutrient Removal from Surface Runoff in a Cold Climate Region of California – Results from a Newly Constructed Wetland at Lake Tahoe." *Journal of Environmental Management* 36: 35-53.

Richardson, J.W., R.J. Fumasi, C. Gilliland, J.L. Outlaw, and C. Markley. 2009. "Impacts of Farm Income and Personal Income on Texas Land Values, 1965-2004." *Journal of the American Society of Farm Managers and Rural Appraisers (ASFMRA)*, p.16-24.

Rister, M.E. 2008. Professor, Department of Agricultural Economics. Texas A&M University. College Station, TX. Personal Communication.

Rolston, H. III. 2000. "The Land Ethic at the Turn of the Millennium." *Biodiversity and Conservation* 9:1045-1058.

Rosenberger, R.S., and J.B. Loomis. 1999. "The Value of Ranch Open Space to Tourists: Combining Observed and Contingent Behavior Data." *Growth and Change* 30 (3):366-383.

Rosenberger, R.S., and J.B. Loomis. 2003. "Benefit Transfer." In P. K. Boyle, and T. Brown (eds.). *A Primer on Non Market Valuation Champ*. Boston, MA: Kluwer Academic Publishers, p. 445-482.

Rosenberger, R.S., and R.G. Walsh. 1997. "Nonmarket Value of Western Valley Ranchland Using Contingent Valuation." *Journal of Agricultural and Resource Economics* 22(2):296-309.

Rousseau, D.P.L., E. Lesage, A. Story, P.A. Vanrolleghem, and N. De Pauw. 2008. "Constructed Wetlands for Water Reclamation." *Desalination* 218: 181-89.

Samuelson, P.A. 1954. "The Pure Theory of Public Expenditure." *Review of Economics and Statistics* 36 (4): 387-389.

Sander, H.A. 2009. "What's It Worth? Improving Land Use Planning Through the Modeling and Economic Valuation of Ecosystem Services." PhD Dissertation, University of Minnesota.

Schuerg, A. 2008. Executive Manager of Finances and Administration. Guadalupe-Blanco River Authority. Seguin, TX. Personal Communication.

Scott, M.J., G.R. Bilyard, S.O. Link, C.A. Ulibarri, H.E. Westerdahl, P.F. Ricci, and H.E. Seely. 1998. "Valuation of Ecological Resources and Functions." *Environmental Management* 22 (1): 49-68.

Sharp, Jr., J.M., and J.L. Banner. 1997. "The Edwards Aquifer: A Resource in Conflict." *GSA Today* 7 (8): 1-9.

Shi, Y.J., T.T. Phipps, and D. Colyer. 1997. "Agricultural Land Values under Urbanizing Influences." *Land Economics* 73 (1): 90-100.

Spash C.L., and A. Vatn. 2006. "Transferring Environmental Value Estimates: Issues and Alternatives." *Ecological Economics* 60: 379-388.

Steer, D., T. Aseltyne, and L. Fraser. 2003. "Life-Cycle Economic Model of Small Treatment Wetlands for Domestic Wastewater Disposal." *Ecological Economics* 44: 359-69.

Stephens, R. 2008. Wildlife Biologist. Comal County, Texas Parks and Wildlife Department. Boerne, TX. Personal Communication.

Stoll, J.R., and L.A. Johnson. 1984. "Concepts of Value, Nonmarket Valuation, and the Case of the Whooping Crane." *Transactions of the North American Wildlife and Natural Resources Conference* 49: 382-393

Straton, A. 2006. "A Complex Systems Approach to the Value of Ecological Resources." *Ecological Economics* 56: 402-411.

Sutton, S. G., J. R. Stoll, and R. B. Ditton. 2001. "Understanding Anglers' Willingness to Pay Increased Fishing License Fees." *Human Dimensions of Wildlife* (6): 115-130.

Tang, Z., B.A. Engel, B.C. Pijanowski, and K.J. Lim. 2005. "Forecasting Land Use Change and its Environmental Impact at a Watershed Scale**.**" *Journal of Environmental Management* 76 (1): 35-45.

Tarrant Regional Water District (TRWD). 2008. *Overview of Tarrant Regional Water District*. Accessed August 25, 2008, Available at: http://www.trwd.com/prod/AboutUs_Overview.asp.

Texas Center for Policy Studies. 2002. *Community and Economic Benefits of Texas Rivers, Springs and Bays*. Conference Proceedings, Austin, TX. Accessed August 22, 2008, Available at: http://www.texascenter.org/water/TCPSwaterconf2a.pdf.

Texas Parks and Wildlife Department (TPWD). 1998. *Freshwater Inflow Recommendation for the Guadalupe Estuary of Texas*. Accessed October 3, 2008, Available at:

http://www.tpwd.state.tx.us/landwater/water/conservation/freshwater_inflow/guadalupe/index.phtml.

Texas Parks and Wildlife Department (TPWD). 2008a. *Richland Creek WMA.* Accessed August 7, 2008, Available at: http://www.tpwd.state.tx.us/huntwild/hunt/wma/find_a_wma/list/?id=23.

Texas Parks and Wildlife Department (TPWD). 2008b. *Texas Rivers, Reservoirs, and Major Bays*. Accessed January 4, 2009, Available at: http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_mp_e0100_1070f_08.pdf.

Texas Parks and Wildlife Department (TPWD). 2009. *Texas Partners in Flight: Ecological Regions of Texas*. Accessed August 10, 2009, Available at: http://www.tpwd.state.tx.us/huntwild/wild/birding/pif/assist/pif_regions/.

Texas State Data Center, Office of the State Demographer. 2008. *Texas Population Estimates Program*. Accessed March 1, 2008, Available at: http://txsdc.utsa.edu/tpepp/2006projections/summary/.

Texas State Law. 2007. *Texas Legislature Online*. Accessed October 5, 2007, Available at: http://www.legis.state.tx.us/tlodocs/79R/billtext/pdf/SB01273F.pdf.

Texas Water Development Board (TWDB). 2007. *TWDB Existing Reservoirs*. 2nd Edition. Accessed January 9, 2009, Available at: www.twdb.state.tx.us.

Texas Water Development Board (TWDB). 2008. *Population and Water Demand Projections*. Accessed April 4, 2008, Available at: http://www.twdb.state.tx.us/data/popwaterdemand/Main.asp.

Tian, G. 2009. ECON 630 Notes. Unpublished, Texas A&M University.

Tietenberg, T. 2006. *Environmental and Natural Resource Economics*, 5th ed. New York: Harper Collins Publishers.

Thibodeau, F.R., and B.D. Ostro. 1981. “An Economic Analysis of Wetland Protection.” *Journal of Environmental Economics and Management* 12: 19-30.

Thompson, D. 2008. San Antonio Water System. San Antonio, TX. Personal Communication.

Thurow, T.L., and C.A. Taylor Jr. 1995. “Juniper Effects on the Water Yield of Central Texas Rangelands.” In *Water for Texas: Research Leads the Way*. Proceedings of the 24th Water for Texas Conference: 657-665. Texas Water Resources Institute, Texas A&M University.

The Trust for Public Lands. 2007. *The Economic Benefits of Land Conservation*. Accessed October 1, 2007, Available at: www.tpl.org.

Turner, R.K. 1991. "Valuation of Wetland Ecosystems." In J.B. Opschoor and D.W. Pearce, ed. *Persistent Pollutants: Economics and Policy*. Boston MA: Kluwer Academic, pp. 226-258.

Turner, R.K., J. Paavola, P. Cooper, S. Farber, V. Jessamy, and S. Georgiou. 2003. "Valuing Nature: Lessons Learned and Future Research Directions." *Ecological Economics* 46: 493-510.

United Nations Environment Program (UNEP). 2008. *Water Quality Improvement Technologies in Alternative Technologies for Freshwater Augmentation in Africa*. New York. Accessed October 16, 2007, Available at: www.unep.or.jp/ietc/publications/TechPublications/TechPub-8a/artificial.asp.

U.S. Department of Agriculture (USDA). 2006. *Agricultural Statistics for Crops and Livestock for 2006*. Washington DC. Accessed April 11, 2008, Available at: http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/index.asp.

U.S. Department of Agriculture (USDA). 2008. *Quick Stats*. Washington DC. Accessed April 24, 2008, Available at: http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/index.asp.

U.S. Department of Commerce, Bureau of the Census. 2008a. *American Fact Finder*. Washington DC. Accessed March 3, and August 15, 2008 and October 23, 2009, Available at: http://factfinder.census.gov/.

U.S. Department of Commerce, Bureau of the Census. 2008b. *New Orleans' Parishes Top Nation in Population Growth Rate*. Washington DC, March. Accessed October 29, 2009, Available at: http://www.census.gov/Press-Release/www/releases/archives/population/011635.html.

U.S. Department of Commerce, Bureau of Economic Analysis. 2008. *Personal Income for Metropolitan Areas for 2007*. Washington DC, September. Accessed September 30, 2009, Available at: http://www.bea.gov/regional/reis/drill.cfm.

U.S. Department Labor, Bureau of Labor Statistics. 2008. Washington DC. Accessed August 29, 2008, Available at: http://www.bls.gov/data/inflation_calculator.htm.

U.S. Environmental Protection Agency (USEPA). 1979. *Determining Wastewater Treatment Costs for Your Community*. FRD Report No. 20460. Washington DC, September.

U.S. Environmental Protection Agency (USEPA). 1980. *Construction Costs for Municipal Wastewater Treatment Plants: 1973-1978*. FRD Report No. 20460. Washington DC, November.

U.S. Environmental Protection Agency (USEPA). 1984. *The Cost Digest: Cost Summaries of Selected Environmental Control Technologies*. EPA Report No. 600/8-84-010. Washington DC, August.

U.S. Environmental Protection Agency (USEPA). 1993. *Constructed Wetlands for Wastewater Treatment and Wildlife Habitat: 17 Case Studies*. Report No. 832-R-93-005. Washington DC, May.

U.S. Environmental Protection Agency (USEPA). 1995. *A Framework for Measuring the Economic Benefits of Ground Water*. Report No. EPA 230-B-95-003. Washington DC, October. Accessed April 30, 2008, Available at: http://yosemite.epa.gov/ee/epa/eermfile.nsf/vwAN/EE-0259-1.pdf/$file/EE-0259-1.pdf.

U.S. Environmental Protection Agency (USEPA). 2006. *Protecting Water Resources with Higher-Density Development*. Report No. 231-R-06-001. Washington DC, January. Accessed April 12, 2008, Available at: http://www.epa.gov/smartgrowth/pdf/protect_water_higher_density.pdf.

U.S. Environmental Protection Agency (USEPA). 2007. *Wetlands and Water Quality Trading: Review of Current Science and Economic Practices with Selected Case Studies*. Report No. 600-R-06-155. Oklahoma, June.

U.S. Environmental Protection Agency (USEPA). 2008. *About Smart Growth*. Washington DC. Accessed May 5, 2008, Available at: http://www.epa.gov/smartgrowth/about_sg.htm.

Weicher, J.C., and R.H. Zeibst. 1973. "The Externalities of Neighborhood Parks: An Empirical Investigation." *Land Economics* 49: 99-105.

Weitzman, M.L. 2001. "Gamma Discounting." *The American Economic Review* 91(1): 260-271.

West, B.C., and J.A. Parkhurst. 2002. "Interactions between Deer Damage, Deer Density, and Stakeholder Attitudes in Virginia." *Wildlife Society Bulletin* 30 (1): 139-147.

Western Governors Association. 2002. *Purchase of Development Rights*. Denver CO: Western Governors Association. Accessed October 3, 2007, Available at: http://www.westgov.org/wga/publicat/pdr_report.pdf.

Wetlands Reserve Program (WRP). 1999. "Examples of Performance Standards for Wetland Creation and Restoration in Section 404 Permits and an Approach to Developing Performance Standards." WRP Technical Note WG-RS-3.3. Accessed January 23, 2008, Available at: http://el.erdc.usace.army.mil/wrtc/wrp/tnotes/wgrs3-3.pdf

Wilcox, B. 2008. Professor, Department of Ecosystem Science and Management, Texas A&M University. College Station, TX. Personal Communication.

Wilkins, N., A. Hays, D. Kubenka, D. Steinbach, W. Grant, E. Gonzalez, M. Kjelland, and J. Shackelford. 2003. *Texas Rural Lands. Trends and Conservation Implications for the 21st Century*. Texas A&M University Agr. Exp. Sta. Accessed November 3, 2007, Available at: http://irnr.tamu.edu/pdf/tx_rural_lands.pdf.

Woodward, R.T., and Y.S. Wui. 2001. "The Economic Value of Wetland Services: A Meta-analysis." *Ecological Economics* 37: 257-270.

Zellner, A. 1962. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." *Journal of the American Statistical Association* 57 (298): 348-368.

VITA

Name:	Memory Machingambi
Address:	Department of Agricultural Economics, 304H Blocker, College Station, TX 77843-2124
Email Address:	mmachingambi@tamu.edu
Education:	B.Sc. Agriculture Honors in Agricultural Economics, University of Zimbabwe, 1999 PhD, Agricultural Economics, Texas A&M University, 2010