ECOSYSTEM SERVICES FROM LOW INPUT CROPPING SYSTEMS AND THE PUBLIC'S WILLINGNESS TO PAY FOR THEM

By

Huilan Chen

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ABSTRACT

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This thesis intends to value off farm ecosystem services from low input cropping systems by estimating the public's willingness to pay for them. Chapter one summaries what kinds of off farm ecosystem services will increase by adopting low input cropping systems and how much they will increase. It quantifies field experiment results on ecosystem services at the state level under widespread adoption of low input cropping systems and identifies a set of ecosystem service increases that are thought to significantly affect the general public. Five ecosystem service changes including reductions in drain dredging, flood damage, high nitrate drinking water wells, eutrophic lakes, and greenhouse gas emission were identified as having a significant impact on the general public. Chapter one lays the scientific base for the services valued in chapter two.

Chapter two focuses on the economic valuation of ecosystem service changes. Two ecosystem service changes, eutrophic lakes reduction and greenhouse gas emission reduction are selected. The contingent valuation survey is applied. A mail survey was sent to 6000 randomly selected Michigan residents. Results show that Michigan residents are willing to pay for a decrease in eutrophic lakes, but only the 40% who are concerned about global warming are willing to pay for a decrease in greenhouse gas emission. Another finding is that people's probability of having zero willingness to pay is endogenous. It is sensitive to the scope of ecosystem service changes and some demographic variables such as household income and attitudes towards global warming. The implication is that studies that do not allow the share of people with zero willingness to pay to adjust to the magnitude of ecosystem service changes will undervalue increases in ecosystem services.

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LIST OF ABBREVIATIONS

KBS	Kellogg Biological Station
CSW	Corn-Soybean-Wheat Rotation
CS	Corn-Soybean Rotation
LTER	Long Term Ecological Research
WTP	Willingness to Pay
NASS	National Agricultural Statistics Service
USDA	United States Department of Agriculture
PES	Payment for Ecosystem Services
CV	Contingent Valuation
ABM	Attribute Based Method
NO	Nitric oxide
NO2	Nitrogen dioxide
N2O	Nitrous oxide
NOx	Nitrogen oxides
CH4	Methane
CO2	Carbon dioxide
GHG	Greenhouse gas
RUSLE	Revised Universal Soil Loss Equation
PSNT	Pre-sidedressing nitrate test
i.i.d.	Identically and independently distributed
EPA	Environmental Protection Agency
MCL	Maximum Contaminant level
TP	Total phosphorus
MDEQ	Michigan Department of Environmental Quality

INTRODUCTION

Agriculture is one of the most important managed ecosystems. Management decisions affect agricultural production outputs as well as off-farm ecosystem services. These off-farm ecosystem services are often public goods that affect the public's well-being. The public has certain demands for off-farm ecosystem services but there are not generally markets to provide them. "Payments for Environmental Services" (PES) programs are often used to provide incentive to farmers to supply off-farm ecosystem services. Current PES research often focuses on the supply-side, measuring costs to land owners for changing land management practices, but less attention has been paid to the demand side.

This thesis intends to investigate the demand side of these ecosystem services. Three research questions are investigated. First, what are these ecosystem services? Second, are they significant enough to have much impact on the general public? Third, if some of them significantly benefit the general public, what are people willing to pay to get these ecosystem services? The three research questions construct the basic structure of the thesis. By answering these three questions, a demand side picture of ecosystem service from agriculture is drawn.

In Chapter one, I try to answer the first and second question. It quantifies field experiment results on ecosystem services from low input cropping systems at the state level. By doing this, it identifies a set of ecosystem service changes that are thought to significantly affect the general public. Further, it measures how much these ecosystem services might change at the state level under widespread adoption of low input cropping systems. Chapter one lays the scientific base for the services valued in chapter two. First, it describes quantitatively the goods to be measured in chapter two. Second, it establishes the possible range of the goods to be valued in the contingent valuation survey in chapter two.

Chapter two focuses on the third research question. From chapter one, two ecosystem services are selected to be valued in this chapter. One is reduction in eutrophic lakes and the other is reduction in greenhouse gas emission. The contingent valuation method is applied to value the two ecosystem service changes. People's willingness to pay is estimated as a function of ecosystem service changes. The demand curves for the ecosystem services can be derived from this function.

CHAPTER 1 OFF-FARM ECOSYSTEM SERVICES FROM SELECTED LOW-INPUT CROPPING SYSTEMS: SCALING UP FROM FIELD EXPERIMENT RESULTS TO STATE-WIDE IMPACTS IN MICHIGAN

Abstract

Chapter 1 attempts to answer the research questions of which ecosystem services are generated from low input cropping systems, how large they would possibly be if the systems were adopted statewide, and whether they have a major effect on the general public in Michigan. This chapter lays the scientific basis of the types and quantities of ecosystem services to be valued in the next chapter.

This chapter first reviews scientific literature on the ecosystem services related to agricultural management practices and sorts out how agricultural management decisions would affect intermediate environmental changes such as soil erosion, nitrogen and phosphorus loss, greenhouse gas emission etc. These intermediate environmental changes will cause a set of off-farm ecosystem service changes. A mapping of linkages that goes from agricultural management practices to off-farm ecosystem service changes is set up. Based on the mapping, five final ecosystem service changes are identified and quantified at the state level. They include some of the supporting services and regulating services such as reduced drain dredging, reduced flood damage, reduction in eutrophic lakes, reduction in high nitrate drinking water wells, and reduced greenhouse gas emission.

The estimated maximum cost reduction in dredging from wide-spread adoption of low input cropping systems is about 1 million dollars per year, and the estimated cost reduction in flood damage is about 1.4 million dollars per year. By adopting low input cropping systems, it is estimated that Michigan may see a reduction of about two hundred eutrophic lakes and one thousand high nitrate wells that are above EPA's Maximum Contaminant level at the maximum. The maximum reduction of greenhouse gas from low input cropping systems is

estimated to be about 800 million kilograms each year. Finally, after thoroughly considering all of these services, their scale, and the other available valuation methods, we need to decide which ecosystem services to value in chapter 2.

1. Introduction

Agriculture has important ecosystem services functions including providing food, fiber and fuel. These are provisioning ecosystem services, as categorized by the Millennium Ecosystem Assessment(Millennium Ecosystem Assessment 2005). These ecosystem services have explicit prices because agricultural products are traded in the market. Farmers are able to capture the full economic value of them. These ecosystem services can be considered private goods. On the other hand, agriculture provides other off-farm supporting and regulating ecosystem services or disservices to soil, water and the atmosphere. For example, soil erosion rate on cultivated lands in major agricultural regions usually ranges from 10 to 100 t/ha/year, which is at least 10 times of the soil formation rate (Pimentel et al 1987). Land degradation has harmed soil productivity and increased offsite environmental effects such as drains and reservoir damage, flooding etc, (Pimentel et al 1987) Excessive nitrogen runoff from agriculture has possible negative environmental impacts such as coastal hypoxia, nitrous oxide and nitrogen dioxide emissions into the atmosphere, and increased nitrate concentration in groundwater (Robertson and Vitousek 2009). These ecosystem services or disservices from agriculture are affecting both the general public and the farming community. People are not able to prevent others from getting them, and the consumption of these goods from some people does not affect the consumption from others. Therefore, most of the off-farm ecosystem services can be considered as public goods.

Certain kinds of farming practice changes are able to increase off-farm ecosystem services. The long term ecological research (LTER) of row crop agriculture at the Kellogg

Biological Station has shown that several low input cropping systems are able to provide offsite ecosystem services such as better carbon sequestration, less nitrate leaching to waters, less phosphorus runoff from soil (Robertson and Vitousek 2009, Daroub et al 2001, Syswerda et al 2010). Including cover crop in a rotation and organic farming have better water retention in soil, reduce soil erosion and preserve soil organic matter that sustains crop growth (Reganold et al 1987). Other scientific literature recognizes the positive environmental effect of specific cropping systems from field experiments (Borin et al 1997, Brye et al 2002).

On the other hand, field experiment results on the ecosystem increases from low input cropping systems are not sufficiently informative in the policy context. In the perspective of decision makers, if the changes to low input cropping systems can bring are significant at the state or national scale, then it is meaningful to provide economic incentives to adopt them. Otherwise any policies that encourage them will not make significant changes so they are not worth implementing. Field experiments do not give decision makers such information because ecosystem service changes are measured at the field scale instead of at a state or national scope. In order to give more insights on the ecosystem service changes at a wider scope, it is necessary to link field experiment results to biophysical simulation models that can simulate effects over large areas and estimate this scale up effects of those field experiments at the regional scale.

The scale-up effect study is insightful in that it estimates a portfolio of multiple ecosystem service changes from various cropping systems. Decision makers are able to decide which ecosystem service changes they value most and then allocate more public money on their supply. Current public payment programs are generally compensating farmers for their direct cost of adopting environmentally friendly farming practices. They pay farmers according to their cost and the number of acres they participate in the program. These payment programs fail to induce farmers to supply what the public want most. (Smith 2006)

Moreover, these public payment programs do not consider the marginal benefits of different ecosystem services in the supply portfolio so they do not maximize the supply of the most valuable ecosystem services under certain budget constraints. As a result, they are not efficient (Smith, 2006). To design an economically efficient incentive to increase the supply of ecosystem services from agriculture, the marginal benefit of increasing ecosystem services needs to be estimated (Costanza et al 1998, Howarth and Farber, 2002).

In order to get an accurate and consistent estimate of the economic value of the ecosystem service bundle, a holistic approach is necessary in valuing multi-dimensional environmental goods (Randall 2002). Adding up piece-wise value estimates of each dimension of the good will overestimate the holistic value because the method ignores the budget constraint and substitution effect in consumer's valuation process (Hoehn and Randall 1989). Therefore, studies on the aggregate effect on ecosystem service changes are very important in deciding what the multi-dimensional environmental good is, which is a fundamental step in the holistic valuation of the good (Loomis et al 2000).

This chapter will focus on estimating the scale-up effect of ecosystem service changes from low input cropping systems. By imposing reasonable assumptions in the calculation, the paper will expand field study results to state wide environmental changes in Michigan and translate them into ecosystem service changes that can be perceived by the public. The second part of the paper will give an overview of how farming practices contribute to several ecosystem service changes. The third part will set up a map of linkages from cropping systems to perceivable ecosystem service changes and identify the target cropping systems and ecosystem service changes we want to measure. The fourth part will describe the general method to quantify ecosystem service changes. The fifth part will present detail calculations and discuss the concluding results and the limitation of the estimates.

2 Off-farm ecosystem services by changing farming practices

2.1 Soil erosion related ecosystem services

Tillage method plays a key role in reducing soil erosion. No tillage, ridge tillage and other conservation tillage methods can reduce soil erosion significantly (FAO 2003). Conservation tillage is usually better at holding back moisture in soil and retains more organic matter in soil by keeping plant and crop residuals in soil longer. The added organic matter increases the soil's ability to retain water and help reduce soil erosion (Reganold et al 1987, NRCS 2009).

Another farming practice that helps preserve soil is the use of cover crops. Cover crops such as clover, alfalfa and legumes improve the water-holding capacity of the root zone in the field, making it better at retaining water in soil. They also increase soil water infiltration (Joyce et al 2002).

Reduced soil erosion has on-site ecosystem services such as improving soil fertility and increasing crop production (Pimentel et al 1987, Pimentel and Kounang, 1998). These onsite ecosystem services will not be discussed in the paper because they are benefiting farmers instead of the general public. They can be considered as private goods. Offsite ecosystem services from reduced soil erosion come from less sediment damage, which include reduced earth-dam failures, less siltation of harbors and channels, increased reservoir storage, preservation of wildlife habitat, less disruption of stream ecology, decreased flooding and cost of water treatment. (Gray and Leiser, 1989, Clark 1985).

2.2 Surface freshwater related ecosystem services

Most phosphorus compounds are not volatile and basically stored in solid forms such as earth, dust and human bodies. Most of them are neither soluble nor stable in water. Therefore, phosphorus loss from agricultural land to the waters is mainly in the form of soil erosion (Correll 1998, Hutciiinson 1957). As a result, soil erosion is closely related to phosphorus loading from soil to the surface freshwater ecosystems and any farming practices that influence soil erosion on land, such as tillage method and cover crops, also have an impact on phosphorus runoff (Poudel et al 2001, Borin et al 1997).

Phosphorus is the limiting factor of the trophic status of freshwater ecosystems in the US (Correll 1998). As phosphorus fertilizer input to the soil exceeds agricultural production outputs, the excess phosphorus fertilizer finally goes to aquatic ecosystems and causes eutrophication in some of the aquatic environment (Carpenter et al 1998). Now phosphorus from fertilizer runoff is the key factor of the trophic status of lakes (Carpenter et al 1998, Robertson 1996, Sharpley et al 2001). Eutrophication of waters affects habitat for fish and other aquatic lives and recreational activities in those freshwater ecosystems.

2.3 Nitric oxide, nitrogen dioxide and nitrous oxide emissions

Nitric oxide, nitrogen dioxide and nitrous oxide from soil come from biological processes of nitrification, denitrification and chemodenitrification. Better nitrogen storage helps reduce agricultural emission of NO, NO_2 and N_2O.

Nitrogen fertilizers contribute to NO, NO_2 and N_2O increase (Bouwman 1996) because inorganic nitrogen fertilizer increases the process of nitrification and denitrification. Agricultural management practices like fertilizer type, fertilization/irrigation method, harvesting, burning and tillage, land use change and spatial patterns of agricultural management have influences on NO, NO_2 and N_2O emission from soil (Hall et al 2002). Tillage is considered an important factor in nitrogen retention. Tillage method significantly influences nitrogen conservation by slowing the biological decomposition of nitrogen from soil organic matter. The slow-down of the process can improve nitrogen mineralization and immobilization (Bayer et al 2000, Angers et al 1997, Halvorson et al 2002) and reduce NO_x emissions (Venterea et al 2005). Cover crops are beneficial in nitrogen fixation (Drinkwater et al 1998) but field experiments have shown mixed results on its effect on N_2O emission. Some have shown that cover crops increase N_2O emission (Bouwman 1996) but others have shown cover crops reduced N_2O emission during thaw (Wagner-Riddle and Thurtell 1998).

Biogenic nitric oxide and nitrogen dioxide (NO_x) from soil has proven to have significant contribution to regional air pollution. Williams et al (1992) estimate that in summer months, NO_x emissions from soil can contribute to 14% of combustion emissions in the US; 66% of these NO_x emissions come from fertilized agriculture. Nitrous oxide is an important kind of greenhouse gas that has 310 times of the global warming potential of carbon dioxide (Forster et al 2007).

2.4 Ground water related ecosystem services

Tillage methods, fertilizer use and fertilization methods that reduce NO_x emission also reduce nitrate leaching into ground water. Cover crops help in fixing nitrogen in soil and reduce nitrogen loss to groundwater (Poudel et al 2001, Borin et al 1997). The pre-sidedressing nitrate test (PSNT) is a useful tool for farmers to apply moderate but not excessive amount of nitrogen fertilizer and helps reduce excessive nitrogen loss.

Extensive use of nitrogen fertilizer in agriculture has contributed to the ground water contamination. Nitrate pollution often occurs in agricultural irrigation areas where fertilizer input is heavy and nitrate leaching rate is high (Power and Schepers 1989). Nitrogen from crop fertilizer is one of the major sources of nitrate in groundwater (MDEQ 2003).

2.5 Global warming

Net global warming potential from agricultural systems is the sum effect of soil organic carbon storage, methane emission and oxidation and nitrous oxide emissions (Mosier et al 2005). Carbon sequestration is the process of removing carbon from the atmosphere and depositing it in a reservoir (UNFCCC 2010). Several farming practices have effects either on greenhouse gas emissions, carbon sequestration or nitrogen retention. First, reduced nitrogen fertilizer input is helpful in reducing nitrous oxide, nitrogen dioxide and carbon dioxide. It is also an effective way to increase methane oxidation (Palm et al 2002). It is a farming practice that mitigates global warming.

Conservation tillage is one of the important management practices to enhance carbon sequestration and nitrogen retention. In conventional tillage, crop residuals are more easily decomposed by microorganisms and release more carbon dioxide (Reicosky and Lindstrom 1993). Conservation tillage leaves 30% or more crop residues covering the soil (Soil Science of America 2009), especially in no tillage case, crop residuals are decomposed more slowly so that carbon and nitrogen are largely in the form of soil organic matter in soil (Bayer et al 2000, Dick et al 1998). Conventional tillage cropping system can emit eight times more of net global warming potential than the no-till system (Robertson et al 2000). Data from global field experiments show that on average, a switch from conventional tillage to no-till can sequester 57 ± 14 grams of carbon per square meter per year (West and Post 2002).

Some field experiments show that cover crop helps increase carbon pool in soil (Lal et al 2004, Reicosky et al 1995). However, some study indicates that the benefits of cover crops on increased carbon sequestration can be offset by frequent tillage (Sainju et al 2002) while another proves the other way around (Robertson et al 2000). The effect of combining cover crop and frequent tillage is not clear.

Rotation complexity also enhances carbon sequestration. According to West and Post's estimate (2002), enhancing rotation complexity can sequester an average 8- 32 grams of carbon per square meter per year, excluding a change from continuous corn to corn-soybean rotation which may not result in a significant accumulation of soil organic matter.

2.6 Off-farm pesticide pollution

The rate and extent of the emission during pesticide application, predominantly as spray particle drift, depends primarily on the application method such as equipment and technique, the formulation and environmental conditions. The emission after application depends primarily on the properties of the pesticide, soils, crops and environmental conditions such as temperature, moisture, wind speed etc (Van den Berg et al 1999, Scholtz et al 2002).

Pesticide emission is a major source of onsite air pollution but it sometimes also has offsite effects. Some pesticides have been shown to be transported through the air and decomposed in aquatic environment and become a regional environmental problem (Glotfelty et al 1987, Voldner and Schrueder 1990, Scholtz et al 2002, Majewski et al 1998, Baker et al 1996). That pesticide can get several thousand fold concentrated in fog droplets may cause possible health problems (Glotfelty et al 1987).

2.7 Human health

High nitrate exposure in drinking water may cause Methemoglobiemia, commonly known as blue baby syndrome, a blood disorder that impairs the ability of hemoglobin to transport oxygen and carbon dioxide, leading to tissue hypoxemia and even death (Wright et al 1999). It mainly affects infants under six months old (MDEQ 2004, Walton 1951).

Possible negative effects on human health of nitrate include reproductive and developmental defects in offspring. Health studies have shown some signs of high risks but the association is not sufficiently determined (Fan and Steinberg, 1996).

Health studies on pesticide have confirmed some negative health effects. Direct exposure of organophosphates is associated with acute health problems such as nausea, dizziness, vomiting, headaches, abdominal pain, skin and eye problems and chronic health problems such as respiratory problems, memory disorders, dermatologic conditions, childhood cancer, depression, neurologic deficits, miscarriages and birth defects (Ecobichon 1996, Zahm and Ward 1998, Daniels et al 1997). Direct exposure of farmers and indirect exposure of their children are much more risky compared with the offsite public (Eskenazi et al 1999, Coye 1986, McCauley et al 2006, Baker et al 1996, Fenske et al 2002, Fenske et al 2000).

2.8 Animal and insect population

Animal experiment results have shown that the reproduction and offspring development are seriously hampered at very high nitrate level while no significant effect has been observed at nitrate-nitrite concentration below 500 ppm (Fan et al 1987)

Acute exposure to pesticide may cause reduced activity, weight loss and physical abnormalities (Hecnar 1995). Repeated exposure to low concentration of nitrate has negative effect on the offspring survivorship, animal growth and neurodevelopment (Ekenazi et al 1999, Hecnar 1995).

3 Quantifying ecosystem services: possible mapping of functions from cropping systems to off-farm ecosystem service changes

3.1 Environmental quality functions and ecosystem service functions: a conceptual framework for quantification

Scientific literature measure the exact quantity of environmental changes caused by farming practice changes. For example, they measure how many tons of nitrogen would leach into ground water by adopting different cropping systems (Poudel et al 2001, Borin et al 1997), how many tons of carbon and nitrogen would be fixed in soil or emit into the atmosphere if conservation tillage method was adopted (Robertson et al 2000, Reicosky and Lindstrom 1993, Bayer et al 2000, Dick et al 1998). However, one environmental change may provide one or more ecosystem services as a joint product (Fisher et al 2009). For example, soil erosion reduction influences both sediment and phosphorus loading to waters. Sediment reduction improves drainage siltation, local flooding, reservoir damage etc (Clark 1985). Less phosphorus loading reduces nutrients in lakes. One environmental quality change may lead to several ecosystem service changes. Therefore, we need to understand how one environmental quality change would be mapped into several ecosystem service changes then we should estimate each ecosystem service change separately.

To map from agricultural practice changes to ecosystem service changes, we should go through two steps: first, we need to know the quantitative linkages from cropping systems to environmental quality changes, Second, we need to find out linkages from each environmental quality change to relevant ecosystem services changes. The two sets of quantitative linkages will be combined together and give a full picture of how much cropping systems would change the "intermediates" (environmental qualities) and then how much the "intermediates" would change the "end products" (ecosystem services).

In the first step, let us consider environmental quality as a function of a set of variables (this set might include infinite number of variables). Environmental quality is a vector of n dimensions which is denoted by $(q_1, q_2, ..., q_n)$. Then we can use a set of arbitrary functions $q_1(X)$, $q_2(X)$, …, $q_n(X)$ to denote the general environmental function where X is the vector of independent variables that influence environmental quality. Agricultural practice factor vector C can be considered a subset of X that is independent from other subset Y such as climate, industry, policy etc. In most cases, environmental quality variables will influence one another. For example, soil erosion will affect phosphorus loading from land to waters because phosphorus is usually in the form of soil solid matters. Therefore, other environmental quality should also be included into the functions. Then if C changes from C^0 to C^1 while other variables are held as constant, then environmental quality change $(\Delta q_1, \Delta q_2, ..., \Delta q_n)$ can be expressed as

$$\Delta q_1 = q_1 (C^1, q_2^1, q_3^1, \ldots, q_n^1 | Y) - q_1(C^0, q_2^0, q_3^0, \ldots, q_n^0 | Y) \quad (1)$$

$$\Delta q_2 = q_2 (C^1, q_1^1, q_3^1, \ldots, q_n^1 | Y) - q_2(C^0, q_1^0, q_3^0, \ldots, q_n^0 | Y) \quad (2)$$

…

$$\Delta q_n = q_n (C^1, q_1^1, q_2^1, \ldots, q_{n-1}^1 | Y) - q_n(C^0, q_1^0, q_2^0, \ldots, q_{n-1}^0 | Y) \quad (3)$$

In the second step, we consider the multidimensional ecosystem services as a vector of m dimensions $(es_1, es_2, \ldots, es_m)$. Then it is a set of functions of environmental quality vector $(q_1, q_2, \ldots, q_n)$ and other variable vector Z. Moreover, it is possible that ecosystem services influence one another. So the ecosystem service functions are expressed as

$$es_1 = es_1(q_1, q_2, \ldots, q_n, es_2, es_3, \ldots, es_m, Z) \quad (4)$$

$$es_2 = es_2(q_1, q_2, \ldots, q_n, es_1, es_3, \ldots, es_m, Z) \quad (5)$$

…

$$es_m = es_m(q_1, q_2, \ldots, q_n, es_1, es_2, \ldots, es_{m-1}, Z) \quad (6)$$

Vector Z contains all other exogenous variables that influence a particular ecosystem service. Z can be climate, related ecological, geological, physical processes, economic and policy factors etc. Suppose Z is holding constant, then a change in environmental quality from $(q_1^0, q_2^0, \ldots, q_n^0)$ to $(q_1^1, q_2^1, \ldots, q_n^1)$ by $(\Delta q_1, \Delta q_2, \ldots, \Delta q_n)$ will cause ecosystem service changes by

$\Delta es_1 = es_1(q_1^1, q_2^1, \ldots, q_n^1, es_2^1, es_3^1, \ldots, es_m^1 |Z) - es_1(q_1^0, q_2^0, \ldots, q_n^0, es_2^0, es_3^0, \ldots, es_m^0 |Z)$ (7)

$\Delta es_2 = es_2(q_1^1, q_2^1, \ldots, q_n^1, es_1^1, es_3^1, \ldots, es_m^1|Z) - es_2(q_1^0, q_2^0, \ldots, q_n^0, es_1^0, es_3^0, \ldots, es_m^0 |Z)$ (8)

…

$\Delta es_m = es_m(q_1^1, q_2^1, \ldots, q_n^1, es_1^1, es_2^1, \ldots, es_m^1|Z) - es_m(q_1^0, q_2^0, \ldots, q_n^0, es_1^0, es_2^0, \ldots, es_{m-1}^0 |Z)$ (9)

3.2 Estimation methods for environmental quality functions and ecosystem service functions

If the functional forms of all q_1 $(C, q_2, q_3, \ldots, q_n| Y)$, q_2 $(C, q_1, q_3, \ldots, q_n| Y)$, ..., q_n $(C, q_1, q_2, \ldots, q_{n-1}| Y)$ and $es_1(q_1, q_2, \ldots, q_n, es_2, es_3, \ldots, es_m |Z)$, $es_2(q_1, q_2, \ldots, q_n, es_1, es_3, \ldots, es_m |Z)$, ..., $es_m(q_1, q_2, \ldots, q_n, es_1, es_2, \ldots, es_{m-1} |Z)$ were estimated, we would be able to estimate the ecosystem change vector $(\Delta es_1, \Delta es_2, \ldots, \Delta es_m)$. However, it is a very difficult task to estimate all the environmental quality functions and ecosystem service functions. Some functions are relatively easy to estimate and the model has been widely accepted. For example, the Revised Universal Soil Loss Equation has been widely used to calculate how land management factors would change soil erosion. For the first kind of functions, we can use these models directly to solve our problems. Some functions have been estimated but the parameters of the functions are only valid in the particular research area. For example, the hydrological models that estimate the nitrate, phosphorus concentration in water. For the second kind of functions, we should look for the closest estimates of the function parameters that best fit our background conditions. If we cannot find an appropriate function to rely on, then we'll have to impose several assumptions to set up a special functional form. Then our task is to estimate the parameters for the special functional form. For many other functions, they have not been estimated so far. Examples are the health effect function, morbidity risk function of nitrate and pesticide and the biodiversity function. For the last kind of functions, we're not going to estimate them in this paper.

3.3 Specification of the problem

3.3.1 Selected low-input cropping systems in the LTER at Michigan State University

The long term ecosystem research (LTER) of Kellogg Biological Station (KBS), Michigan State University has conducted over 15 years of research on the ecosystem services from row crop agriculture (Robertson 1999, Paul 1997). KBS LTER has identified that compared with the conventional corn-soybean-wheat rotation, several low input cropping systems can provide improved levels of one or more of the ecosystem services. Those low input cropping systems have one or more of the following features:

- Less or no tillage
- Increased rotation complexity by putting cover crops in rotation
- 2/3 of conventional fertilizer input
- 2/3 of conventional pesticide
- Effective fertilizer management by using Pre-Sidedress Nitrogen Test (PSNT) to test nitrogen available in soil before applying nitrogen fertilizer.

The LTER study showed that low input cropping systems increased some offsite ecosystem service changes (Farber et al 2009, Robertson et al 2000), including:

- Lower global warming potential by better carbon sequestration and lower N_2O, CO_2

and CH_4 emissions

- Less nitrate leaching by lower nitrogen fertilizer use
- Habitat for birds, insects and other animals

Other field experiment results showed other offsite environmental benefits from low input cropping systems such as reduced phosphorus runoff (Daroub et al 2001) and reduced soil erosion (Reganold et al 1987)

To investigate farmers' willingness to accept payments to adopt low input cropping systems, a farm-level survey was implemented by the Department of Food, Agricultural and resource Economics, Michigan State University in 2008 (Jolejole 2009). The study estimates the farm level supply curves of low input cropping systems. Table 1.1 showed the profiles of some low input cropping systems. System 4 were consistent was modeled on one of the KBS-LTER treatments.

Table 1.1 cropping systems from the 2008 farmer's willingness to accept payment for the adoption of low input cropping systems survey (Jolejole 2009)

Farming practices	Low-input cropping systems			
	1	2	3	4
Rotation	Corn-soybean rotation	Corn-soybean rotation	Corn-soybean-wheat rotation	Corn-soybean-wheat rotation
Cover Crops	No	Yes	Yes	Yes
Tillage	Chisel plow with cultivation as needed	Chisel plow with cultivation as needed	Chisel plow with cultivation as needed	Chisel plow with cultivation as needed
Soil Test	PSNT always	PSNT always	PSNT always	PSNT always
Fertilizer	Full rate	Full rate	Full rate	Reduced rate (1/3)
Pesticide	Full rate	Full rate	Full rate	Reduced rate (1/3)

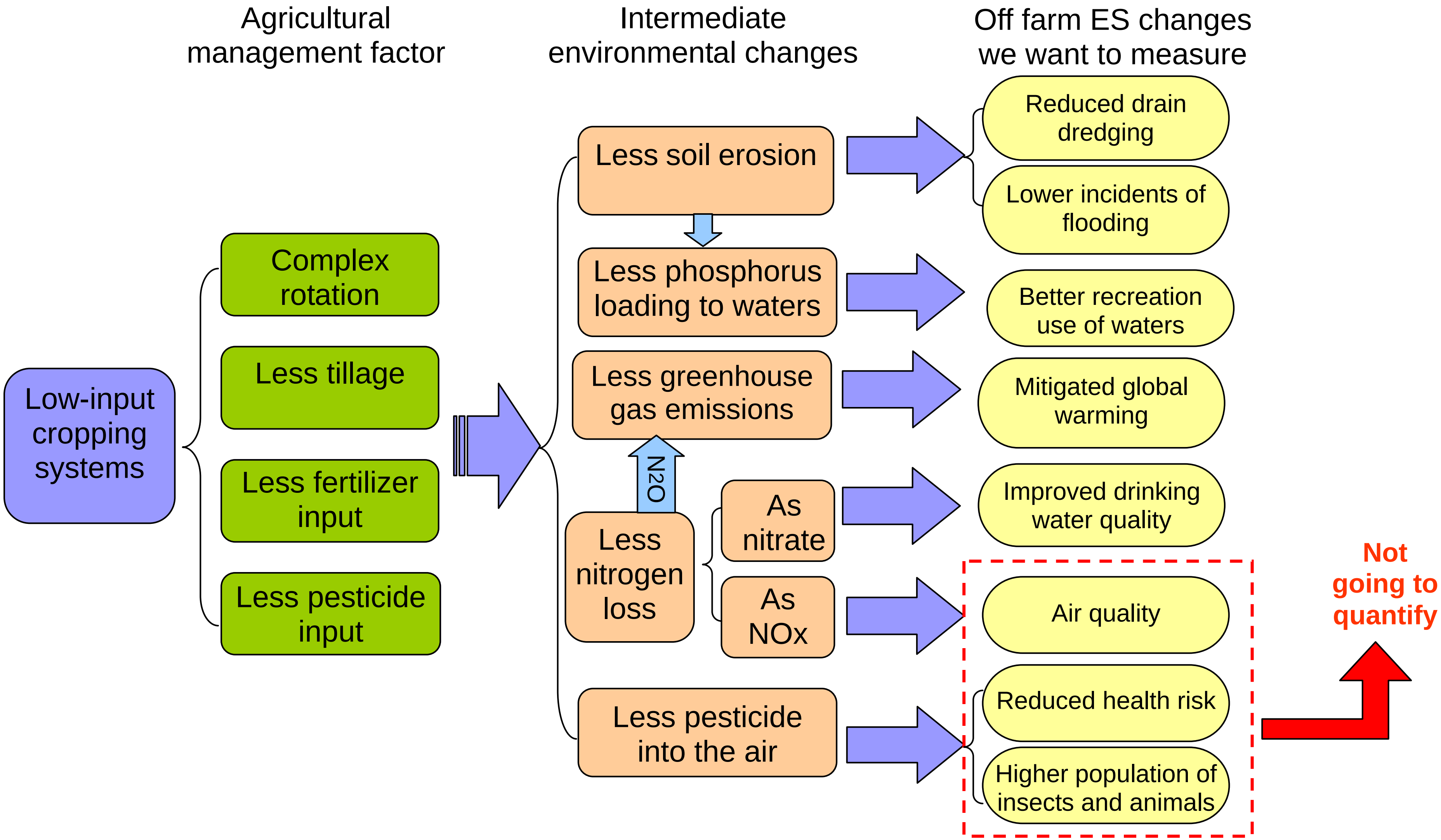
3.3.2 Linkages and ecosystem service changes we want to measure

Figure 1.1 describes the linkages to quantify the ecosystem service (the "mapping"). Cropping systems are decomposed into combinations of several agricultural management factors: rotation complexity, tillage method, fertilizer input and pesticide use. These elements have impacts on six dimensions of intermediate environmental quality: soil erosion, phosphorus loading to waters, greenhouse gas emission, nitrogen loss as nitrate into waters, nitrogen loss as NO_x and N_2O into the atmosphere and pesticide pollution. Furthermore, there are interactions among intermediate environmental changes. Soil erosion is responsible for the majority of phosphorus runoff into waters (Correll 1998). Nitrogen loss from farming has various forms: nitrogen as nitrate that affects ground water quality, nitrogen as NO_2 and NO (NO_x) that affects regional air quality and nitrogen as N_2O that is a kind of greenhouse gas.

Intermediate environmental quality will cause eight major categories of off-farm ecosystem services. Less soil erosion from land will reduce sediment loading to drains and rivers. The drain dredging cost will decrease. Moreover, less soil erosion will lower the probability of local flooding by causing drainage siltation, raising river beds and water level etc. Less phosphorus loading to fresh waters will improve the eutrophic status of lakes, reducing excess plant growth and algal blooms. It will improve the joy of recreational activities like fishing, boating and swimming. Nitrogen loss in the form of nitrate will go to ground water. Reduced nitrogen loss from land will reduce the nitrate concentration in ground water and improve drinking water quality. Nitrogen loss as NO_x will improve the air quality. Nitrogen as nitrous oxide emission contributes to the global warming. Less pesticide use can reduce relevant health risk and increase the population of insects and animals.

Figure 1.1 Mapping linkages from agricultural management factor to off-farm ecosystem service change

For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.



Finally, there are eight categories of off-farm ecosystem services we want to measure: soil erosion would reduce drain dredging and incidents of local flooding; phosphorus loading to waters would affect recreation use like fishing, boating and swimming; greenhouse gas (GHG) emissions would affect global warming; nitrogen loss as nitrate would affect drinking water quality; nitrogen loss as NO_x would affect perceivable air quality; pesticide would affect human health risk and higher population of insects and animals. These eight categories of ecosystem service changes have direct economic implications to humans. Dredging cost and flood damage are direct economic costs from soil erosion. The other six categories have important economic value to humans, although they don't have explicit prices.

In order to quantify the last three categories, the impacts must be significant, and quantitative relationship between environmental input and health reaction is necessary. Existing literature shows that although the exposure of nitrate/nitrate and pesticide in the general public is detectable but is generally much lower than among agricultural field workers (Majewski et al 1998, Fenske et al 2000, Baker et al 1996, Eskenazi et al 1999). The reduction in nitrate/nitrite and pesticide exposures in the general public has an unknown marginal health impact. Furthermore, quantitative results in literature are not sufficient to estimate the reduced risk in human health or animal populations. Epidemiologic studies have shown correlations between nitrate from drinking water and infant developmental effects but the cause and effect relationship cannot be drawn (Fan and Steinberg 1996). Experimental results with animals might not be applied to human health problems because the probability that the general public would encounter such high concentration of nitrate/nitrate as in lab experiment is very low (Fan and Steinberg 1996). Health impacts of pesticides are better acknowledged but assessments of health risks under certain doses are very rare. There is one of the few studies on the morbidity probability distribution analysis of ambient pesticide concentration (Lee et al 2002). Nevertheless, results from one site specific study are not conclusive of the generalization of the risk and dose relationship. Because existing literature does not provide sufficient results to estimate the quantities of the last three categories of ecosystem service changes, they are not quantified in this chapter.

3.3.3 Specification of environmental quality functions and ecosystem functions

We define the intermediate environmental quality vector from changing agricultural management practices as (q_s, q_p, q_{GHG}, q_n) where q_s is the soil erosion, q_p is the phosphorus loading to waters, q_{GHG} is the greenhouse gas emission and q_n is the nitrate leaching into groundwater. Then the changes in q_s, q_p, q_{GHG}, q_n as $\Delta q_s, \Delta q_p, \Delta q_{GHG}, \Delta q_n$ can be specified as:

$$\Delta q_s = q_s(C^1, q_p^1, q_{GHG}^1, q_n^1 | Y) - q_s(C^0, q_p^0, q_{GHG}^0, q_n^0 | Y) \quad (10)$$

$$\Delta q_p = q_p(C^1, q_s^1, q_{GHG}^1, q_n^1 | Y) - q_p(C^0, q_s^0, q_{GHG}^0, q_n^0 | Y) \quad (11)$$

$$\Delta q_n = q_n(C^1, q_p^1, q_s^1, q_{GHG}^1 | Y) - q_n(C^0, q_p^0, q_s^0, q_{GHG}^0 | Y) \quad (12)$$

$$\Delta q_{GHG} = q_{GHG}(C^1, q_p^1, q_s^1, q_n^1 | Y) - q_{GHG}(C^0, q_p^0, q_s^0, q_n^0 | Y) \quad (13)$$

Where C is the agricultural management factor and Y is other exogenous variables that hold constant.

Among the four variables, q_p is affected by q_s and the rest are mutually unaffected. Therefore, equation (1) to (4) can be simplified as

$$\Delta q_s = q_s(C^1 | Y) - q_s(C^0 | Y) \quad (14)$$

$$\Delta q_p = q_p(C^1, q_s^1 \mid Y) - q_p(C^0, q_s^0 \mid Y) \qquad (15)$$

$$\Delta q_n = q_n(C^1 \mid Y) - q_n(C^0 \mid Y) \qquad (16)$$

$$\Delta q_{GHG} = q_{GHG}(C^1 \mid Y) - q_{GHG}(C^0 \mid Y) \qquad (17)$$

Then we define the ecosystem service vector as (es_{dredge} es_{flood} $es_{recreation}$ es_{gw} es_{dw}) where es_{dredge} is the reduced dredging cost in drains and rivers, es_{flood} is the reduced flood damage cost, $es_{recreation}$ is the recreational aspects of lakes, es_{gw} is the global warming and es_{dw} is the drinking water quality. The set of ecosystem service functions are

$$es_{dredge} = es_{dredge}(q_s, q_p, q_{GHG}, q_n, es_{flood}, es_{recreation}, es_{gw}, es_{dw}, Z) \qquad (18)$$

$$es_{flood} = es_{flood}(q_s, q_p, q_{GHG}, q_n, es_{dredge}, es_{recreation}, es_{gw}, es_{dw}, Z) \qquad (19)$$

$$es_{recreation} = es_{recreation}(q_s, q_p, q_{GHG}, q_n, es_{dredge}, es_{flood}, es_{gw}, es_{dw}, Z) \qquad (20)$$

$$es_{dw} = es_{dw}(q_s, q_p, q_{GHG}, q_n, es_{dredge}, es_{flood}, es_{recreation}, es_{gw}, Z) \qquad (21)$$

$$es_{gw} = es_{gw}(q_s, q_p, q_{GHG}, q_n, es_{dredge}, es_{flood}, es_{recreation}, es_{dw}, Z) \qquad (22)$$

where Z is the vector of other exogenous variables that are held constant

The five categories of ecosystem services do not affect each other so the interaction among ecosystem services can be ignored. Dredging cost and flood damage are affected by

q_s. Recreation aspects of lakes are affected by q_p. Global warming is affected by q_{GHG} and drinking water quality is affected by q_n. Then equations (18)- (22) are rewritten as

$$es_{dredge} = es_{dredge}(q_s, Z) \quad (23)$$

$$es_{flood} = es_{flood}(q_s, Z) \quad (24)$$

$$es_{recreation} = es_{recreation}(q_p, Z) \quad (25)$$

$$es_{dw} = es_{dw}(q_n, Z) \quad (26)$$

$$es_{gw} = es_{gw}(q_{GHG}, Z) \quad (27)$$

A change in environmental quality from $(q_s^0, q_p^0, q_{GHG}^0, q_n^0)$ to $(q_s^1, q_p^1, q_{GHG}^1, q_n^1)$ will cause ecosystem service changes by

$$\Delta es_{dredge} = es_{dredge}(q_s^1 |Z) - es_{dredge}(q_s^0 |Z) \quad (28)$$

$$\Delta es_{flood} = es_{flood}(q_s^1 |Z) - es_{flood}(q_s^0 |Z) \quad (29)$$

$$\Delta es_{recreation} = es_{recreation}(q_p^1 |Z) - es_{recreation}(q_p^0 |Z) \quad (30)$$

$$\Delta es_{dw} = es_{dw}(q_n^1 |Z) - es_{dw}(q_n^0 |Z) \quad (31)$$

$$\Delta es_{gw} = es_{gw}(q_{GHG}^1 |Z) - es_{gw}(q_{GHG}^0 |Z) \quad (32)$$

Then our task is to estimate equations (14)- (17) and (28)-(32)

4 Function estimation and results

4.1 Soil erosion and related ecosystem services

4.1.1 Soil erosion estimates

The Revised Universal Soil Loss Equation (RUSLE) is a popular model for calculating soil erosion (Institute of Water Research Michigan State University 2008). It calculates the soil erosion rate by the following formula:

$$q_s = R * K * LS * C * P$$

Where R is the rainfall runoff erosivity factor; K is the soil erodibility factor which represents the susceptibility of soil to erosion and the rate of runoff; L is slope length factor and S is slope steepness; C is the cover management factor, which is the rotation each year; P is the support practice factor.

Variables R, K, LS, P remain constant when changing land management practices. Then the percentage change in soil erosion is

$$q_s1/ q_s^0 - 1 = (R * K * LS * P * C^1) / (R * K * LS * P * C^0) -1 = C^1/ C^0 -1$$

$q_s^1/ q_s^0 - 1$ is the percentage reduction in soil erosion for different crop rotations. Denote this percentage reduction as w, then

$$\Delta q_s = q_s^1 - q_s^0 = q_s^0 (q_s^1/ q_s^0 - 1) = w\, q_s^0 \qquad (33)$$

Where q_s^0 denotes soil erosion amount in the conventional cropping system, q_s^1 denotes soil erosion in the target low input cropping system and w denotes the soil erosion reduction rate. Plugging in C^0 as the corn-soybean rotation and C^1 as corn-soybean-wheat rotation and corn-soybean-wheat with cover crops yields different w for four target cropping systems (Table 1.2). The calculation of Table 1.2 is presented in Appendix 2. Here we do not consider the chisel plow tillage method.

Table 1.2 Soil erosion reduction rate of different cropping systems

Cropping systems	Soil erosion reduction rate (w)

Table 1.2 (cont'd)	
Corn-soybean rotation	0
Corn-soybean with cover crops	50.0%
Corn-soybean-wheat with cover crops	70.6%
Corn-soybean-wheat with cover crops and reduced input	70.6%

Soil erosion volume in cropland in Michigan was 11.9 G kg/year (USDA 2003). Corn-soybean rotation takes up 22% of total area of cropland in Michigan (Padgitt et al 2000) and 28% of total soil erosion from cropland (Appendix 1). Therefore, the soil erosion from conventional corn-soybean rotation $qs^0 = 11.9 * 28\% = 3.3$ G kg/year.

Then the estimated Δq_S ranges from 0 to about 2.3 G kg/year (Table 1.3).

Table 1.3 Soil erosion reduction rates of different cropping systems

Cropping systems	Soil erosion reduction in G kg/year (Δq_S)
Corn-soybean rotation	0
Corn-soybean with cover crops	1.65
Corn-soybean-wheat with cover crops	2.33
Corn-soybean-wheat with cover crops and reduced input	2.33

4.1.2 Drain dredging cost

There are no dredging cost functions that are suitable to use in our situation, therefore assumptions have to be made to impose a certain functional form. We assume that dredging cost is proportional to soil erosion when other variables are constant. Then the dredging cost function where other variables are constant except the soil erosion variable becomes

$$es_{dredge}(q_s \mid Z) = l\, q_s$$

Where l is the coefficient that needs to be estimated

Then equation (19) becomes

$$\Delta es_{dredge} = l\,(q_s^{1} - q_s^{0}) = l\,\Delta q_s \qquad (34)$$

The coefficient l can be interpreted as the dredging cost for a unit of soil erosion as well as the marginal cost for a unit increase in soil erosion. Previous literature has provided information on the dredging cost per unit of soil erosion. Ribaudo (1986) estimates the dredging cost of both navigable waterways and drainage ditches as $40,800,000 in Lake States (Wisconsin, Michigan and Minnesota) in 1983. The source of this dredging cost estimate comes from average annual dredging costs by the Corps of Engineers for maintaining navigable waterways. The total annual soil erosion of the three states is 181,000,000 tons. Then the average dredging cost per ton of soil erosion would be 40,800,000/181,000,000= $0.23. This value is equivalent to $0.50 in 2010 as in purchasing power (US Department of Labor 2010).

With l = 0.50 and Δq_s estimated in Table 1.4, Δes_{dredge} ranges from 0 to 1 million dollars per year.

Table 1.4 Reduced dredging cost of different cropping systems

Cropping systems	Reduced dredging cost in USD (Δes_{dredge})
Corn-soybean rotation	0
Corn-soybean with cover crops	826,000
Corn-soybean-wheat with cover crops	1,170,000

Table 1.4 (cont'd)

Corn-soybean-wheat with cover crops and reduced input	1,170,000

4.1.3 Flood damage cost

Less soil erosion will lower the probability of local flooding. The probability of flooding will influence the expected cost of flood damage cost each year. Because we did not find any quantitative study on soil erosion and the probability of flooding, instead we assume that flood damage cost is proportional to soil erosion when other variables are held constant. Therefore the flood damage cost change in equation (20) is

$$\Delta es_{flood} = m\,(q_s^{1} - q_s^{0}) = m\,\Delta q_s \qquad (35)$$

The coefficient m stands for the flood damage cost for a unit of soil erosion as well as the constant marginal flood damage cost for a unit increase of soil erosion. Ribaudo (1986) estimates annual flooding damage due to sediment of \$59,100,000 (in 1983 dollars) in three Lake States. The estimate is based on Clark's estimate on flood damages caused by soil erosion in increased flood heights due to channel aggradations, increased flood volumes due to sediment loads, direct sediment damages to urban and nonurban areas and reduced agricultural productivity (Clark 1985). The total annual soil erosion of the three states is 181,000,000 tons. Then the average flooding damage per ton of soil erosion would be 59,100,000/181,000,000=0.33. It is equivalent to \$0.72 in 2010 in purchasing power (US Department of Labor 2010).

With m=0.72 in equation (35), the flood damage cost reduction ranges from 0 to about \$2 million each year (Table 1.5).

Table 1.5 Reduced flooding damage cost of different cropping systems

Cropping systems	Reduced flooding damage cost in USD (Δes_{flood})
Corn-soybean rotation	0
Corn-soybean with cover crops	1,190,000
Corn-soybean-wheat with cover crops	1,680,000
Corn-soybean-wheat with cover crops and reduced input	1,680,000

4.2 Phosphorus and eutrophic lakes

4.2.1 Phosphorus runoff function

Most of the phosphorus runoff from land is in the form of soil solid matters. Therefore, we assume that phosphorus runoff from cropland is proportional to the soil erosion rate. Then the percentage change in phosphorus runoff due to different cropping systems becomes

$$\Delta q_p / q_p^0 = \Delta q_s / q_s^0 = w \qquad (36)$$

where q_p^0 denotes the phosphorus run off in the conventional corn-soybean rotation cropping system, Δq_p denotes the phosphorus runoff reduction after adopting low input cropping systems.

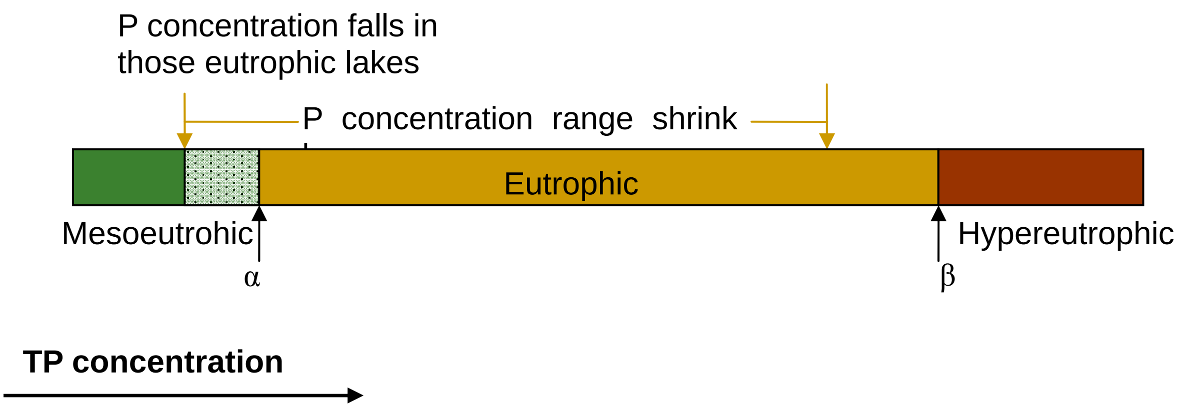
The percentage change in phosphorus runoff is the same as the soil erosion reduction rate in Table 1.2.

4.2.2 Reduction in eutrophic lakes

Many hydrological models estimate how phosphorus loading to lakes and rivers would change the trophic status of lakes. However, the parameters of the hydrological models are usually estimated locally. They are not suitable for the scale up estimates. Then we need to simplify the hydrological process of phosphorus in lakes. First, we assume that total phosphorus (TP) concentration in eutrophic inland lakes is uniformly distributed between the range of (α, β) (β>α). If a lake's TP falls below α, then it becomes mesoeutrophic and recreational quality in the lake will significantly improve. Lakes with TP above β are hypereutrophic lakes. TP in those lakes will be reduced by switching to alternative cropping systems but will never fall below α. They stay eutrophic afterward. Recreational quality will not significantly improve in those lakes. So we only consider those within (α, β) and estimate how many of them will fall below α after changing cropping systems.

Further, we assume that reduced phosphorus input will lead to the same percentage decrease, denoted by r, of TP in all inland lakes.

Figure 1.2 Distribution change of eutrophic lakes after a uniform phosphorus reduction



In Figure 1.2, the bar denotes the distribution of lakes by their TP concentration. TP concentration increases from the left to the right. TP concentration below α is mesoeutrophic, which is the healthy state. TP between (α, β) are eutrophic. TP higher than β is hypereutrophic. Under the uniform decrease assumption, a decrease in TP concentration by r will switch the TP concentration distribution of all lakes from a range of (α, β) to somewhere below α and β. Then the dotted part of the distribution will fall below α and become "healthy". The purple part can be calculated as

$$\Delta es_{recreation} = r\alpha / [(\beta-\alpha)(1-r)] * N_{eutro}^{0} \quad (37)$$

Where N_{eutro}^{0} is the number of eutrophic lakes in Michigan currently

r can be decomposed into the product of four ratios

$$r = (\Delta q_p / q_p^0) * (q_p^0 / \Delta TP_{fert}^0) * (\Delta TP_{fert}^0 / \Delta TP) * (\Delta TP / TP^0) \quad (38)$$

Where

ΔTP_{fert}^{0} is the phosphorus input to lakes that comes from fertilizer in cropland

ΔTP is the phosphorus input to lakes from all sources

TP^0 is the phosphorus stock in lakes at the status quo

$\Delta q_p / q_p^0$ is the percentage change in phosphorus input from corn-soybean rotation cropland, which is w (equation 36). $q_p^0/\Delta TP_{fert}^0$ is the percentage contribution of corn-soybean cropland phosphorus input to total cropland phosphorus input. This ratio is the same as the soil erosion contribution of corn-soybean cropland to all cropland in Michigan, which is 28%. $\Delta TP_{fert}^0 / \Delta TP$ is the percentage contribution of cropland phosphorus input to annual phosphorus input from all sources. Cropland fertilizer accounted for 54.8% of the annual inputs of phosphorus to the Great Lakes (Correll 1998). $\Delta TP/ TP^0$ is the flow-to-stock ratio in lakes. This ratio will change dynamically and the hydrological dynamic varies according to lake depth, volume, discharge of the outlet and time (Ahlgren et al 1988, Chapra 1980). It is very difficult to estimate one overall ratio for all inland lakes in Michigan. Therefore, we have to assume that this ratio will range from 0 to 1. In the following calculation, we will estimate the upper bound of r, where this ratio is 1. Then from equation

(38) we estimated r in target cropping systems.

Table 1.6 Percentage reductions in total phosphorus concentration of different cropping systems

Cropping systems	% reduction in TP concentration (r)
Corn-soybean rotation	0
Corn-soybean with cover crops	7.6
Corn-soybean-wheat with cover crops	10.8
Corn-soybean-wheat with cover crops and reduced input	10.8

TP criteria for eutrophication in inland lakes in Michigan is between 20-50 μg/L, above which are hypereutrophic and below which are mesotrophic and oligotrophic (Bednarz 2007). Then β=50, α=20.

Now Michigan has over 11000 inland lakes. A survey by the US Geological Survey and Michigan Department of Environmental Quality showed that of the 730 public access inland lakes sampled from 2001 to 2005, 27% were eutrophic and 4% were hypereutrophic (Bednaz 2007). Then N_{eutro}^{0} = 11000 * 27% = 3000. Substitute α, β, N_{eutro}^{0} and r into equation (37), then $\Delta es_{recreation}$ ranges from 0 to 240 (Table 1.6).

Table 1.7 Reduced eutrophic inland lakes of different cropping systems

Cropping systems	Reduced eutrophic inland lakes ($\Delta es_{recreation}$)
Corn-soybean rotation	0
Corn-soybean with cover crops	164

Table 1.7 (cont'd)	
Corn-soybean-wheat with cover crops	240
Corn-soybean-wheat with cover crops and reduced input	240

4.3 Nitrate and drinking water quality

4.3.1 Nitrate leaching reduction

The long term ecological research of Kellogg Biological Station at Michigan State University measures the nitrate leaching rate by switching from conventional corn-soybean-wheat rotation $(q_n^{\ 0},\ C^0)$ to low input cropping systems $(q_n^{\ 1},\ C^1)$ (Table 1.8). However, the KBS LTER treatments are not completely consistent with the cropping systems in Table 1.1. The only treatment consistent with Table 1.1 is corn-soybean-wheat rotation with cover crops and reduced input, which is System 4 in Table 1.1. Alternatively, we need to look for appropriate second hand field experiment data on nitrate leaching of other cropping systems in Table 1.1.The study from Strock et al (2004) compares the nitrate loss in conventional corn-soybean cropping system and corn-soybean rotation with cover crops in Minnesota. However, due to soil, climate and other site specific characteristics, it is not appropriate to compare the nitrate loss rate from Strock et al's with that from KBS LTER. Instead, the relative scale, the percentage reduction of nitrate compared with conventional practices, is an appropriate option because the relative scale eliminates the effect of other site specific characteristics except treatment variables.

Table 1.8 Nitrate leaching reduction of low input cropping systems in the KBS LTER experiments (Syswerda et al, 2010).

Cropping systems	Nitrate Leaching reduction in kg/ha/yr (q_n^1)
Table 1.8 (cont'd)	
Conventional corn-soybean-wheat rotation	62
Corn-soybean-wheat with cover crops and reduced input	24
Corn-soybean-wheat with no tillage	42
Corn-soybean-wheat with organic input	19

Let s denote the percentage reduction of nitrate leaching of different cropping systems compared with conventional corn-soybean cropping system. Then

$$s = (q_n^1 - q_n^0) / q_n^0 = \Delta q_n / q_n^0 \quad (39)$$

Where q_n^0 denotes the nitrate leaching rate from conventional corn-soybean cropping system and q_n^1 denotes the nitrate leaching rate from low input cropping systems.

Estimates of s are presented in Table 1.9. From Stock et al's study (2004), the corn-soybean with cover crops can reduce nitrate loss by 13%. Note that the percentage reductions of corn-soybean-wheat cropping systems in Table 1.9 are computed with conventional corn-soybean-wheat rotation as the baseline because the baseline cropping system in KBS LTER experiment is corn-soybean-wheat rotation. Compared with conventional corn-soybean rotation, the addition of wheat in rotations can reduce nitrate leaching (McDowell and McGregor 1980). As a result, the percentage reductions of these three low input cropping systems from KBS LTER should be higher if using conventional corn-soybean rotation as a baseline. Therefore, the reduction estimates in these three cropping systems in Table 1.9 can serve as conservative estimates. There are currently no appropriate field experiment data for us to estimate the nitrate leaching reduction rate of corn-soybean-wheat with cover crops.

Table 1.9 Nitrate leaching reduction rate in different cropping systems in KBS research

Cropping systems	Nitrate leaching reduction rate (s)
Corn-soybean rotation	0
Corn-soybean with cover crops	13% [a]
Corn-soybean-wheat with cover crops	Unknown
Corn-soybean-wheat with cover crops and reduced input	61% [b]
Corn-soybean-wheat with no tillage	32% [b]
Corn-soybean-wheat with organic input	69% [b]

a. Cited from Strock et al 2004

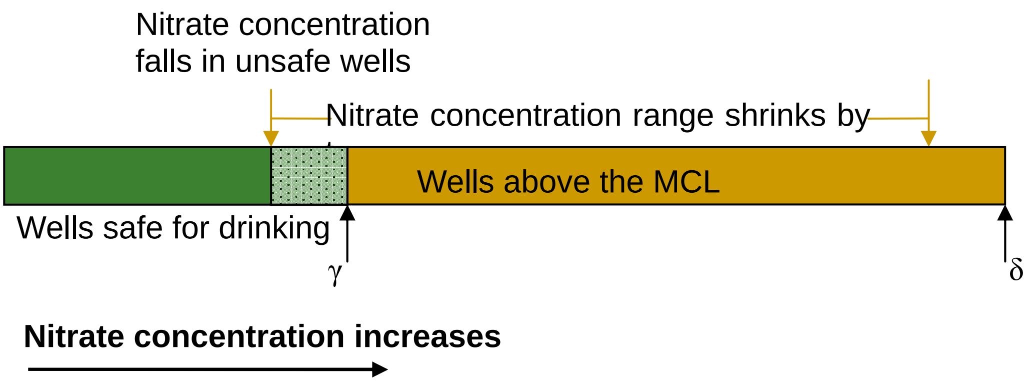
b. Calculated from Syswerda et al 2010

4.3.2 Drinking water quality

Similar to the problem of phosphorus concentration modeling, the hydrological models on nitrate concentration in ground water were local and did not fit our goal of the state wide estimates. Then again, we need to make assumptions to simplify the drinking water quality function. First, we assume that unsafe private drinking water wells have nitrate concentration within a range (γ, δ) ($\delta>\gamma$) and they are uniformly distributed within this range. Wells with nitrate below safe standard γ are safe for drinking. δ is the maximum nitrate concentration in the region.

Further, we assume that reduced nitrate leaching from corn-soybean cropland would lead to the same percentage decrease, denoted by t, in nitrate concentration in all private water drinking wells.

Figure 1.3 Distribution changes of nitrate wells after a uniform nitrate reduction



In Figure 1.3, the bar denotes the distribution of drinking water wells ordered by nitrate concentration. Nitrate concentration increases from the left to the right. Nitrate concentration below the maximum contaminant level (MCL), denoted by γ, is safe for drinking. Wells with nitrate higher than γ are considered having potential health risk. Under the uniform decrease assumption, a decrease in nitrate concentration by t will switch the range of nitrate concentration in those lakes from a range of (γ, δ) to a lower range at somewhere below γ and δ. The dotted part is the percentage that unsafe wells would become safe after changing cropping systems. The purple part can be calculated using equation (40)

$$\Delta es_{dw} = M_{unsafe}^{0} * t\gamma / [(\delta - \gamma)(1-t)] \qquad (40)$$

Where M_{unsafe}^{0} is the number of unsafe wells currently

Similarly, t can be decomposed into the product of four ratios

$$t = (\Delta q_n / q_n^0) * (q_n^0 / \Delta NT_{crop}^0) * (\Delta NT_{crop}^0 / \Delta NT) * (\Delta NT / NT^0)$$

(41)

Where

ΔNT_{crop}^{0} is the nitrate input to groundwater that comes from fertilizer in cropland

ΔNT is the nitrate input to groundwater from all sources

NT^{0} is the nitrate stock in groundwater currently

$\Delta q_n / q_n^{0}$ is s (equation 39). $q_n^{0}/\Delta NT_{crop}^{0}$ is the percentage contribution of corn-soybean cropland nitrate input to total cropland nitrate input, which is assumed to be the same as the ratio of the corn-soybean rotation area to total cropland area (22% as estimated by Padgitt et al 2000). $\Delta NT_{crop}^{0}/ \Delta NT$ is the percentage contribution of cropland nitrate input to annual nitrate input from all sources. In the Midwest Corn Belt area, nitrogen fertilizer from cropland contributed to minimum 55-60% of nitrate in lake water in peak season. For the whole year, the minimum percentage ranged from 0 to 60% (Kohl et al 1981). $\Delta NT/ NT^{0}$ is the flow-to-stock ratio in groundwater. This ratio is highly variable in different area and there is no overall estimate for the Michigan area. Therefore, we have to assume that this ratio will range from 0 to 1. In the following calculation, we will assume this ratio is 1 in order to get the maximum estimate of t. Then from equation (40) we can estimate t (Table 1.10).

Table 1.10 Percentage reduction in nitrate concentration in different cropping systems

Cropping systems	Percentage reduction in nitrate concentration (t)
Corn-soybean rotation	0.0%
Corn-soybean with cover crops	1.7%
Corn-soybean-wheat with cover crops	Unknown

Table 1.10 (cont'd)

Corn-soybean-wheat with cover crops and reduced input	8.1%
Corn-soybean-wheat with no tillage	4.3%
Corn-soybean-wheat with organic input	9.2%

The maximum contaminant level (MCL) for nitrate/nitrite in drinking is 10 mg/l to prevent observable health effects. Babies under 6 months old who drink water containing nitrate/nitrite in excess of the MCL could develop methemoglobinemia, commonly known as the blue baby syndrome (EPA 1976). Several regional studies show that the highest nitrate concentrations in wells in Michigan is about 20mg/L and about 1-5% of drinking water wells contain nitrate above the MCL (Kim et al 2002, Aichele 2000, Thomas 2002). Then $\gamma=10$, $\delta=20$. There are about 1.1 million private drinking water wells in Michigan (MDEQ 2008). We can estimate that M_{unsafe}^{0} ranges from 11,000 to 56,000. Then substitute the values into equation (40), we can estimate Δes_{dw} (Table 1.11)

Table 1.11 Reduction in unsafe wells in different cropping systems

Cropping systems	Reduction in unsafe wells (Δes_{dw})
Corn-soybean rotation	0
Corn-soybean with cover crops	196-978
Corn-soybean-wheat with cover crops	Unknown
Corn-soybean-wheat with cover crops and reduced input	986- 4929
Corn-soybean-wheat with no tillage	498- 2490
Corn-soybean-wheat with organic input	1129-5643

4.4 Greenhouse gas emission and global warming

4.4.1 Greenhouse gas emission

Instead of estimating the greenhouse gas emission function, we adopt the field experiment results of the KBS LTER on the global warming potential of several cropping systems (Robertson et al 2000). The KBS LTER treatments are not completely consistent with cropping system profiles in Table 1.1 but unfortunately there are no appropriate second hand data for our estimates of the corn-soybean with cover crops and corn-soybean-wheat with cover crops. We have to leave these two cropping systems to future studies. We calculate the reduction Δq_{GHG} as the global warming potential reduction from conventional corn-soybean system to low input cropping systems (Table 1.12).

Table 1.12 Global warming potential reduction of different cropping systems compared with conventional practices

Cropping systems	Global warming potential reduction in kg/ha/year of CO_2 equivalent (Δq_{GHG})
Corn-soybean rotation	0
Corn-soybean with cover crops	Unknown
Corn-soybean-wheat with cover crops	Unknown
Corn-soybean-wheat with cover crops and reduced input	510
Corn-soybean-wheat with no tillage	1000
Corn-soybean-wheat with organic input	730

4.4.2 Scale up global warming effect

The scale up effect of greenhouse gas emission reduction is calculated by equation 42.

$$\Delta es_{gw} = a\,(q_{GHG}^{1} - q_{GHG}^{0}) = a\,\Delta q_{GHG} \quad (42)$$

Where a is the area of the corn-soybean rotation cropland; q_{GHG}^{0} is the global warming potential from conventional corn-soybean cropping system; q_{GHG}^{1} is the global warming potential from low input cropping systems.

There are 2,030,000 acres of corn-soybean rotation cropland in Michigan in 2008 (NASS 2008), which is equivalent to 820,000 ha. Then we can estimate Δes_{gw} (Table 1.13).

Table 1.13 Global warming effect of different cropping systems

Cropping systems	Reduced GHG in kg of CO_2 equivalent per year (Δes_{gw})
Corn-soybean rotation	0
Corn-soybean with cover crops	Unknown
Corn-soybean-wheat with cover crops	Unknown
Corn-soybean-wheat with cover crops and reduced input	419,150,000
Corn-soybean-wheat with no tillage	821,862,000
Corn-soybean-wheat with organic input	599,960,000

5 Discussion

Five categories of ecosystem service changes were quantified as for the whole state. They were reduction in annual drain and river dredging cost, flood damage cost, nitrate in private drinking water wells, eutrophic lakes and global warming potential. Other ecosystem service changes were not quantified because of insufficient information in existing literature.

Further scientific studies are necessary to estimate the scale up effect of perceivable air quality, health risks and population of animals and insects from low input cropping systems.

The maximum dredging cost saving and flood damage cost saving by switching to low input cropping systems were estimated to be $964,000 and $1,380,000 for the whole state respectively. The benefit from reducing soil erosion related damage is significant. However, compared with the 10 million population in Michigan, the reduced annual dredging cost and flood damage cost per capita were only $0.11 and $ 0.13 respectively, which were too small to significantly affect people's household budget.

The reduction of high nitrate wells above the MCL needs further discussion. High nitrate in drinking water might cause adverse health effects such as higher probability of cancer but those associations were not deterministic (Weyer et al 2001, Fan and Steinberg 1996, Townsend et al 2003). The only health risk that has been widely recognized was the blue baby syndrome which generally occurred among babies under six months old (MDEQ 2003). However, not only nitrate in drinking water but infection and inflammation could cause the disease (Avery 1999). Moreover, the blue baby syndrome is rare nowadays. Historical data before 1951 showed that there were only seven reported blue baby syndrome cases in wells with nitrate above MCL in Michigan during 1945-1950 (Walton 1951). The probability for a case occurring at a well above MCL is only at the 1 in 100,000 scale.[1] Now there are about 33,000 wells above the MCL in Michigan and the nitrate concentration in drinking water is lower than it was at the 1950s, so it can be roughly estimated that there would be one case occurring every three years. In addition, the fatality rate of the blue baby syndrome was 7-8% (American Public Health Association 2000). If it were to be measured, it

[1] There were seven reported cases of blue baby syndrome from 1945-1950. At that time, water sample drawn from Michigan showed that 7% of sampled wells were above the MCL (Walton 1951). At average, there were 1.4 cases every year and there were roughly 1,100,000*7%=77,000 wells above the MCL in Michigan. So the probability that a case occurred at a well above the MCL was 1.4/77,000=1.8/100,000.

can be estimated with other methods such as benefit transfer.

Another potential environmental problem caused by excess nitrogen is hypoxia in coastal areas, which is known as dead zones. The outlet of the Great Lakes to the ocean is from the Gulf of St Lawrence. The bottom water zone of Laurentian Channel in the Gulf of St Lawrence is suffering from hypoxia for decades but the major cause of hypoxia is the ocean circulation patterns (Gilbert et al 2005). Moreover, the riverine nitrogen export per square kilometer from the Great Lakes- St. Lawrence region to the North Atlantic are the second lowest in North America and the third lowest among 13 regions of the North Atlantic Basin. Nitrogen fertilizer takes up over 50% of total anthropogenic nitrogen inputs (Howarth et al 1996). The majority of the nitrogen fluxes to the Laurentian Channel is deposited as organic sediments rather than in the water column and the bottom water remains nitrogen deficient (Thibodeau et al 2010). It implies that the nitrogen input in the bottom water does not contribute much to the aquatic productivity nor the hypoxia problem in the bottom water of the Gulf of St Lawrence. Therefore, we did not quantify the impact of low input cropping systems on coastal hypoxia problem.

The estimated reduction in eutrophic lakes was significant. The estimates were based on strong assumptions. First, we assumed that there would be a uniform decrease in phosphorus concentration in all lakes. As a matter of fact, there should be a dramatic decrease in lakes near agricultural area. There should be an unbalanced reduction in phosphorus concentration among lakes in agricultural area and those in nonagricultural area. On the other hand, the eutrophic lake distribution in Michigan was concentrated in agricultural areas (Bednarz 2007). It means that eutrophic lakes in agricultural areas were possibly benefiting more in phosphorus reduction from low input cropping systems. So there should be more eutrophic lake reduction if the spatial impact was taken into consideration. The estimates we got from the uniform decrease assumption were conservative. Due to limited time and resource, we could only start with the simplest model in this paper. However, it would be worthwhile to continue with this framework and go further to consider the spatial aspect of this issue.

The estimates of global warming potential were relatively straight forward. The 2000 emission level in Michigan was 180 billion kg of CO_2 equivalent (U.S. Public Interest Research Group Education Fund, 2006). No tillage cropping system achieved the highest reduction in global warming potential of 822 million kg annually. It was about 0.5% of the 2000 emission level. The reduction was significant because the corn-soybean rotation only took up only 22% of total cropland in Michigan and the majority of the greenhouse gas emission came from fossil fuel.

In conclusion, of the five ecosystem service changes we estimate, four of them are significant except the health benefit of reduction of high nitrate wells. The estimates are summarized in Table 1.14. Reduced dredging cost and reduced flood damage cost were measured in dollar terms so the economic benefit of these two ecosystem service changes is explicit. On the other hand, the reduction in eutrophic lakes and greenhouse gas are expressed in physical terms. To estimate the economic benefits of these two ecosystem service changes, further research is required and it will be elaborated in Chapter Two.

Table 1.14 Summary of estimates of five ecosystem services changes of low input cropping systems

Cropping systems	Reduced dredging cost in USD (Δes_{dredge})	Reduced flooding damage cost in USD (Δes_{flood})	Reduced eutrophic inland lakes ($\Delta es_{recreation}$)	Reduction in unsafe wells (Δes_{dw})	Reduced GHG in kg of CO_2 equivalent per year (Δes_{gw})
Corn-soybean rotation	0	0	0	0	0
Corn-soybean with cover crops	826,000	1,190,000	164	196-978	Unknown
Corn-soybean-wheat with cover crops	1,170,000	1,680,000		Unknown	Unknown
Corn-soybean-wheat with cover crops and reduced input	1170000	1,680,000		986- 4929	419,150,000
Corn-soybean-wheat with no tillage	Not calculated	Not calculated	240	498- 2490	821,862,000
Corn-soybean-wheat with organic input	Not calculated	Not calculated	240	1129-5643	599,960,000

APPENDICES

Appendix 1.1 Calculating the percentage of soil erosion from corn-soybean rotation land to soil erosion from total cropland in Michigan

Corn-soybean rotation takes up 22% of total area of cropland in Michigan and below is a portfolio of major crops in Michigan [2]. Using the RUSLE model, their relative soil erosion rates to the corn-soybean rotation (by changing only the C factor) are calculated in Column (2).

Table 1.15 Calculating weighted relative soil erosion rate of different crops

Crop Name	Area (acres)	Soil erosion relative to CS land	Weights by area	Weighted relative soil erosion
	(1)	(2)	(3)=(1)/subtotal of (1)	(4)=(2)*(3)
Wheat	433783	0.15	0.161	0.0237
Oats	63485	0.12	0.024	0.0028
Dry bean	259026	0.85	0.096	0.0819
Sugar beets	180054	0.41	0.067	0.0275
CS rotation	1760000	1	0.653	0.6527
Subtotal	2991772		1.000	0.789

The weighted average soil erosion rate of this portfolio is 0.789 relative to that of corn-soybean rotation cropland. There are 8 million acres of cropland in Michigan. The above portfolio takes up 2.7 million of them. We assume that the rest 5.3 million has the same soil erosion rate of the portfolio, then the average soil erosion rate of total cropland in Michigan is 0.789 relative to corn-soybean rotation cropland. Then the percentage of soil erosion from CS

[2] NASS. (2008). "Michigan County Estimates." From http://www.nass.usda.gov/Statistics_by_State/Michigan/Publications/County_Estimates/index.asp

rotation out of total cropland is

CS area * CS soil erosion rate/ (Total cropland * cropland erosion rate)

=(176000 * 1)/ (8,000,000*0.789) = 28%

Appendix 1.2 Calculation of soil erosion reduction rates of different cropping systems

The calculation is based on the RUSLE online soil erosion assessment tool, Institute of Water Research, Michigan State University, http://www.iwr.msu.edu/rusle/

On the RUSLE website, click on "Calculate soil erosion", then "Agricultural Land" then select "Kalamazoo" county where KBS is located. For slope, slope length and soil, just select the first choice applicable. As long as these factors remain the same in all cropping systems, the soil erosion reduction rate compared with the conventional cropping system does not change.

1. Calculating soil erosion rate of the corn-soybean conventional cropping system.

Select "Corn for grain" at year 0, "Soybean" at year 1 and so forth until year 5. For tillage practices select "spring plow" each year. Then the average soil erosion rate is 0.34 ton/acre/year.

2. Calculating soil erosion rate of the corn-soybean rotation with cover crops

Click on "Click here to enter C factor manually". At that page, enter "Corn for grain" at year 0, "Soybean" at year 1 and so forth until year 5. For tillage practices select "Chisel plow" each year. To find an appropriate C factor, click the link at the bottom. To be consistent with the KBS treatment, alfalfa is chosen as the cover crop. The C factor for corn, grain after alfalfa at year 1 with spring plow is 0.1 and for soybean after alfalfa with spring plow is 0.11. Enter 0.11 at year 1, 0.1 at year 2 and so forth. Then the average soil erosion rate is 0.17 ton/acre/year.

3. Calculating soil erosion rate of the corn-soybean-wheat rotation with cover crops

Similar to the way we calculate the soil erosion rate of the corn-soybean rotation with cover crops. We plug in the rotation each year and enter chisel plow as tillage practices. The C factor for wheat after alfalfa is not available. So we have to leave it blank. Then the average soil erosion rate is 0.1 ton/acre/year.

Reduced input of pesticide and fertilizer does not have significant impact on the soil erosion rate. Neither the PSNT has significant impact on soil erosion rate. Therefore we assume that System 1 (corn-soybean rotation with PSNT) has the same erosion rate of the conventional (corn-soybean rotation without PSNT) and that System 4 (corn-soybean-wheat rotation with cover crops and reduced input) has the same erosion rate of System 3 (corn-soybean-wheat rotation with cover crops). Then we can calculate the soil erosion reduction rates in Table 1.2

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CHAPTER 2 MICHIGAN PUBLIC'S WILLINGNESS TO PAY FOR REDUCTIONS IN EUTROPHIC LAKES AND GREENHOUSE GAS DUE TO CHANGES IN LAND USES: A CONTINGENT VALUATION STUDY

Abstract

Chapter 2 focuses on the economic valuation of two ecosystem services from widespread adoption of the low input cropping systems discussed in Chapter 1. The contingent valuation survey method is used to estimate the Michigan public's willingness to pay for reductions in eutrophic lakes and greenhouse gas emission. In 2009, a contingent valuation mail survey was sent to 6000 households in Michigan resulting in a 40% response rate. The contingent valuation question is designed as a dichotomous choice referendum with income taxes as the payment vehicle. Respondents' willingness to pay is modeled as a function of program cost, the scope of the reduction in eutrophic lakes and GHGs, attitude variables and demographics. We also model the "spike probability," the probability of zero willingness to pay, as endogenous. The models are analyzed using random effect probits.

Respondents' willingness to pay depends on the scope of reductions in eutrophic lakes, attitude towards global warming, age, income, education and whether they are voters. The scope effect of greenhouse gas reduction exists only among those who were concerned about global warming. Those unconcerned about global warming are not willing to pay anything for a reduction in GHG. The results also show that the spike probability is endogenous; that is, the probability of zero willingness to pay is determined by the scope of environmental changes, income and attitude towards global warming. Finally, sample willingness to pay is \$175 per household per year to get either 170 fewer eutrophic lakes or a 0.52% GHG reduction from the 2000 level.

1 Introduction

1.1 Agriculture as a managed ecosystem

Agriculture is one of the important managed ecosystems where interactions of human activities and natural resources are intensive and ecosystem service outputs are strongly affected by management decisions (Swinton et al 2007, Zhang et al 2007). As a managed ecosystem, agriculture provides various ecosystem services and disservices to human society. It provides food, fiber and fuel. Apart from the provisioning ecosystem services, agriculture also provide regulating and supporting ecosystem functions such as water retention (Fawcett et al 1994, Blevins et al 1983), nutrient cycling (Wyland et al 1996), crop pollination (Kremen et al 2004), soil formation and conservation (Brussaard 1997). It also contributes to biodiversity (Tscharntke et al 2005), global warming (Mosier et al 2005) and other cultural and aesthetic purposes. Nevertheless, it outputs disservices if it is not managed properly by agricultural practices. For example, conventional intensified agriculture would degrade soil fertility in the long run compared with organic farming (Maeder et al 2002). Frequent tillage would increase soil erosion on farmland, reduce soil organic matter as well as more greenhouse gas emissions (Robertson et al 2000). High rate of chemical fertilizer use would cause nitrate pollution and eutrophication of waters as excess chemicals run into ground water and surface waters (Spalding and Exner 1993). Pesticide use would harm biodiversity by killing beneficial insects and animals (Maeder et al 2002). Toxic chemical use in agriculture would pose health risks to people (Rosenstock et al, 1991).

On the other hand, flows of ecosystem services and disservices from agriculture can be managed by land management decisions. In contrast with the examples that generate disservices previously mentioned, organic farming would increase the soil organic matter and improve soil structure and fertility. No-tillage farming would have better water retention and soil erosion. In addition, no-tillage cropping system can reduce 85% of the global warming potential than the conventional tillage counterparts (Robertson et al 2000). Helpful farm management tools can decide the optimum use of chemical fertilizer to reduce nitrogen and phosphorus runoff from land, which would improve ground water pollution and surface water eutrophication. Reduced use of pesticide would help preserve biodiversity as well as reduce health risks.

Scientific literature has shown that some low-input cropping systems are able to supply several ecosystem services as well as maintaining comparable yields to conventional cropping systems. The Long-term Ecological Research (LTER) of row crop agriculture by the Kellogg Biological Station at Michigan State University has been studying the long term ecosystem services of some of those low-input cropping systems. The low input cropping systems tested in KBS' research are combinations of one or more of the following farming practices:

- Multiple crops rotations
- The use of cover crops
- No tillage
- Use of organic fertilizer
- Reduced rate of nitrogen and phosphorus fertilizers
- Reduced rate of pesticide use

These low input cropping systems are able to generate several ecosystem service flows such as better carbon sequestration, less nitrate leaching to water, phosphorus retention in soil and less soil erosion (Robertson et al 2000, Syswerda et al 2010, Daroub et al 2001).

1.2 Rationale for the study

1.2.1 Policy and research gaps and challenges of the topic

The United States has offered public payment programs to encourage environmentally friendly land management practices since the 1930s. Examples were Conservation Reserve (CRP) and Environmental Quality Incentives (EQIP) programs. The 2002 Farm Bill strengthened the support for more environmentally friendly farming practices. It authorized the Conservation Security Program which offers financial and technical assistance to eligible private landowners who wish to adopt conservation land management practices (USDA 2004). Those public programs have increased flows of one or more ecosystem services from agricultural land. However, most of these public payment programs were supply-side based which aimed to compensate the land owner's cost of changing land uses and land management practices. The demand side is largely ignored in these public payment programs. The public is paying for environmentally friendly land management activities rather than the actual environmental outcomes (Smith 2006). Similarly, the ongoing multifunctional agriculture policy reform debates in Europe have little ideas of what the public demand and the optimal public good supply (Hall et al 2004). Ignoring the public's demand for environmental outcomes reduces the economic efficiency of these public payment programs for agriculture.

In the demand side story of the public payment programs, valuation of ecosystem services remains essential. However, valuation of ecosystem services is a very challenging task although some non market valuation techniques have been well developed. One challenge is the complexity of the environmental goods to be valued. First, the ecosystem services flows from agricultural land have multiple dimensions and the dimensions are expanding as more and more ecosystem services are recognized to be important to human beings. Besides the water regulation, water retention, soil formation and fertility, soil retention, more and more ecosystem services such as climate regulation, landscape, biodiversity, pollination are being identified as important ecosystem outputs from agriculture. Carbon sequestration function of land is raising more and more attention because of its important role in mitigating global warming. The number of dimensions of the environmental outputs is expected to increase with the advances of scientific research. Second, it is very difficult to set up the quantitative relationships between ecosystem service outputs and land management decisions. Human-nature interactions are extremely intensive in agricultural ecosystems. Environmental outputs can be considered as functions of natural inputs and human management factors. However, these ecological functions are extremely difficult to be identified because of the complexity of an ecosystem. One management factor change would involve one or more ecological changes and those ecological changes would interact with each other. The final "outputs" from the system are the sum of all relevant ecological changes and their interactions. Scientific literature on ecosystem services from agriculture and environmentally friendly farming practices have provided important experimental results on the quantities of one or more measurable outputs from changing farming practices such as carbon sequestration, nitrogen retention, phosphorus runoff, soil fertility. Those studies were helpful to address the second problem we just mentioned. However, most of them are onsite outputs which would go offsite into other ecosystems such as lakes, rivers, atmosphere and then finally to the general public. Therefore, they are "intermediate" environmental outputs rather than the endpoint outputs received by the public. The translations from the intermediate outputs to the endpoint outputs require challenging efforts in examining the interactions in other ecosystems.

Because of the challenges above, the valuation of ecosystem services flows from agriculture is rudimentary and further research is required. Despite the difficulties, there are efforts to value ecosystem services from freshwater ecosystems, wetlands and farmland amenities. Most of them try to value a set of ecosystem service outputs from the ecosystem. However, due to the complexity of the good being valued, some studies did not have clear definitions of the good. It was vaguely defined as "environmental improvements" or “environmental amenities” or a specific public program (Gurluk 2006, Dubgaard 1994, Bergstrom et al 1985, Drake 1992, Beasley et al 1986, Bowker and Didychuk 1994, Halstead 1984, Pruckner 1995). Relevant ecosystem services were not presented to the public. Some studies did decompose the good into several ecosystem services outputs and presented the good to the public but the descriptions of ecosystem services were mostly qualitative (Loomis et al 2000, Holmes et al 2004, Xu et al 2003, Stevens et al 1995). If the public was not given sufficient information of relevant ecosystem services, there were potential pitfalls for misevaluation. They might overvalue or undervalue certain ecosystem services.

1.2.2 Objective of the study

This study explores the willingness of Michigan households to pay for environmental services. Specifically, we apply the contingent valuation to estimate changes in a set of ecosystem services that come from switching to low-input cropping systems from conventional corn-soybean cropping systems in Michigan. The scientific basis for the changes in ecosystem services for these systems comes from research conducted by the NSF-Funded Long Term Ecological Research site on row crop agriculture. In order to address challenges in valuing ecosystem services, we tried to decompose the good into multiple ecosystem service outputs from low input cropping systems and derive the marginal value of each output separately. Specifically, although low-input cropping systems offer many environmental benefits, two are particularly noteworthy to members of the general public, reduced lake eutrophication and mitigation of greenhouse gas emission. The two ecosystem services were presented quantitatively to the public in the CV questionnaire.

1.3 Layout of the chapter

The paper is organized as follows. In the next section, valuation literature on relevant ecosystem services from agriculture is reviewed and analyzed. Then the third section comes with elements in contingent valuation study design and how those elements fit in the ecosystem service valuation background. In the fourth and fifth section, the Probit model of contingent valuation and the empirical model are presented respectively. The layouts of survey design and implementation results are given in the sixth section. Model estimation results and WTP analysis are discussed in the final part.

2 Current research gaps

2.1 Gaps in valuing ecosystem services from agriculture

There are two basic approaches to value a set of ecosystem service outputs from an ecosystem. One is to value each ecosystem service output and add the values together. One example is Costanza's paper in *Nature* (Costanza et al 1997) to estimate the economic value of the world's ecosystem services. One critique to this approach is that it will lead to double counting of benefits (Serafy 1998). The summation method is problematic in economic sense that individuals are facing budget constraints and have to make tradeoffs between different ecosystem services. Simply adding up the values of each ecosystem services will lead to an overestimate of the set of outputs (Hoehn and Randall 1989). Another approach is the holistic approach which takes the set of ecosystem services as one good and estimates its economic value. The method addresses the double counting issues and the overestimate issues of the former approach (Loomis et al, 2000). The limitation of the holistic approach is that it requires valuing the set of ecosystem services with one single valuation method at one time. One appropriate method for valuing one ecosystem services may not be the same case for another. For example, the contingent valuation method which is appropriate to value the non use value of some ecosystem services is not appropriate to value of food production increase, which is essentially a market good. In its application to empirical studies, there are no studies that value a complete set of ecosystem services outputs with one single method. More commonly, they value more than one ecosystem services outputs at one time. The good being valued has multiple dimensions.

Attempts have been made in valuing the ecosystem services from other ecosystems using the holistic approach. Some studies value a set of ecosystem services of rivers (Gurluk 2006, Loomis et al 2000, Holmes et al 2004, Xu et al 2003) and considerable efforts have been put in valuing ecosystem services from wetlands (reviews from Boyer and Polasky 2009, Brander et al 2006, Brouwer et al 1999, Woodward and Wui 2000). The contingent valuation method is applied in most of those studies. Some studies value ecosystem service benefits from an actual developmental project (Gurluk 2006). Ecosystem service outputs are not decomposed into multiple dimensions but were concentrated in one dimension named "improved environmental quality". The definition of the good is vague and was not presented clearly. The underlying assumption is that the survey respondents have sufficient knowledge of what they will get and how much they will get. This assumption is rarely sufficient in practice. Others decompose the set of ecosystem services into multiple dimensions and present all dimensions to the respondents in the survey (Loomis et al 2000, Holmes et al 2004, Xu et al 2003, Stevens et al 1995). Those studies have clear definitions of the good being valued but the levels of each dimension are qualitative. Respondents are told about different ecosystem services and how they would change in the hypothetical voting scenario but the descriptions of changes are qualitative. Some do give quantitative descriptions of possible environmental changes but they are not the direct measurements of final ecosystem service outputs (Loomis et al 2000). It means that respondents have to make assumptions on the quantities of each ecosystem service outputs in order to get an exact understanding of the good. This insufficient information problem may lead to inconsistent estimates of their true WTPs (Boyle 2003).

Valuation literature on ecosystem service from agriculture focuses on valuing farmland amenities. The farmland amenities being valued in most of the studies are essentially a package of various ecosystem services such as improved environment, landscape (Drake 1992), aesthetic and cultural values (Bergstrom et al 1985). The hedonic pricing model (Irwin and Bockstael 2001, Irwin 2002) and the contingent valuation survey (Dubgaard 1994, Bergstrom et al 1985, Drake 1992, Beasley et al 1986, Bowker and Didychuk 1994, Halstead 1984, Pruckner 1995) are two most commonly used methods to derive the economic value of farmland amenities. The hedonic model derives the marginal value of farmland amenities from observed real estate prices. The economic values from the method is the total economic values of the set of ecosystem services from a piece of farmland but no further decomposition of the this value into single ecosystem service values is possible. The contingent valuation method valued people's willingness to pay for farmland amenities by setting up hypothetical market scenarios. By decomposing the good into multiple dimensions (the term "attributes" used in the CV literature), the CV method is able to derive the marginal WTP for each dimension as well as the WTP for the whole good. However, in previous studies, each dimension of the ecosystem service outputs was not quantified and valued individually (Bergstrom et al 1985, Beasley et al 1986). Respondents are asked to vote on land use change programs but relevant ecosystem services outputs from the programs are not given in the survey. Similarly, those studies assume that the public have sufficient information on the categories and quantities of ecosystem services they would get from the whole package of "environmental amenities" when performing the valuation task. However, this assumption is debatable. As a matter of fact, the actual quantities of outputs from an ecosystem required long term scientific research (Magnuson 1990). The scale-up impacts of ecosystem service change on the general public required even more extensive scientific research on related ecosystem interactions. Moreover, the value derived from the studies is the total value of a piece of farmland rather than that of one single ecosystem service from the land. The differences in WTP estimates in those models cannot be quantitatively explained by differences in ecosystem service outputs, which should be a very important factor in determining the economic values of farmland.

2.2 Gaps in spike models in contingent valuation

The spike model was introduced to deal with the zero willingness to pay problem in contingent valuation (Kristrom 1997). A spike probability parameter was introduced to model the probability of an individual of having zero or negative WTP. The spike probability can be modeled as one single parameter (Werner 1999, Kristrom 1997) or it can be modeled as a function of covariates (Strazzera et al 2003, Berrens et al 2001, An et al 1996, Hu 2006). The covariates used in previous studies were demographic variables. None of those studies considered the scope effect of environmental change on the spike probability, that is, how the scale of environmental changes would affect the spike probability. However, from the comments from our survey, some respondents complained about the scale of environmental changes and chose not to get it even if it was free. So it is a reason to investigate whether the scope effect also exists in people’s spike probability, apart from their WTP.

3 Contingent valuation methodologies in valuing ecosystem services

The contingent valuation method sets up a hypothetical market for the public to buy an environmental good which would increase their utility or accept payments for an environmental good if it decreases their utility. The willingness to pay or willingness to accept is considered as an appropriate measure of the economic value of the good.

The biggest challenge of the contingent valuation method in valuing ecosystem services is to define the “environmental good” to be measured. The good in this case is a set of multiple ecosystem service changes by changing farming practices. It usually has more than one dimension and each dimension of ecosystem service change has a certain range where the change can be achieved by changing farm management decisions. Another challenge in defining the good is that the ecosystem service changes that the public experiences are different from those that farmers can offer through changes in practices. The environmental changes that the farmers offer are on-site intermediate changes that would go off-site into other ecosystems such as waters, soil and the atmospheres and are transformed into other kinds of ecosystem services when the general public receives them at the end. For example, farmers reduce on farm nitrogen fertilizer use and it has benefits like less nitrate leaching into ground water and less NO_x emissions into the atmosphere. When these benefits come to the general public, what they experience are safer drinking water, better perceivable air quality and reduced health risk. The nitrogen fertilizer use, nitrate leaching and NO_x emissions are finally transformed as the final products of drinking water quality, air quality and health risk reduction. The set of final products are directly experienced and consumed by the public. Therefore, it is the environmental good that we would like to describe to the public and ask them to place their value on. We should calibrate the final products with the intermediate products that farmers offer. Preliminary studies on the science of the ecosystem service changes are necessary to determine the possible dimensions and ranges of those ecosystem service changes.

In the description of the environmental good in the survey, detailed and specific information is necessary, especially when people were not aware how they may benefit from the change. The survey should provide the range of changes people are asked to value, how those changes are going to affect their life (Boyle 2003). These rules should apply to the description of multiple ecosystem service changes as well because the good has multiple dimensions and is complicated, rather than one single environmental change. Questions to probe respondents' understanding of the changes are necessary in assessing the validity of the valuation. (Boyle 2003, Arrow et al 1993) Specified baseline and measure of changes will help individuals to make tradeoffs between benefits from various ecosystem services (Toman 1998, Loomis et al 2000).

The design of provision mechanism should balance between credibility and protest. It should be credible to respondents. If it is not real enough, some people may not take the valuation question seriously. However, if the provision mechanism is realistic, some people may protest to the whole scenario just because they dislike this real provision mechanism. (Boyle 2003). When designing the provision mechanism in ecosystem service changes from agriculture, some politically sensitive issues should be taken into consideration. Agricultural subsidies for farmers have been a controversial issue especially when the public are worrying the huge deficit in the government budget. The idea of "paying farmers to reduce pollution" may generate protests among those who are against agricultural subsidies.

The selection of payment vehicle should also consider the tradeoff between credibility and payment vehicle rejection (Boyle 2003). Moreover, the selection of payment vehicle should be incentive compatible. Some of the ecosystem service changes from agriculture are semi public goods such as better drinking water quality but many are pure public goods such as global warming mitigation, reduced soil erosion, lake water quality etc. Therefore, the payment vehicle should avoid the strategic behaviors of free riders. On the other hand, tax as the payment vehicle may exclude the free rider behaviors in the survey and makes the scenario realistic enough to vote on. However, during economic recession when our survey was completed, raised tax is a very sensitive issue and may generate considerable protests.

The time frame of payment should match the benefit period of the respondents so that they don't have to discount the cost and benefit themselves (Boyle 2003). To match the two periods is not straight forward in valuing ecosystem services from agriculture but can be a very complicated issue. Some issues are noteworthy. One is that there is time lag for actual ecosystem service changes to happen. The lags may vary from one or two years or more than twenty years to take effect. For example, nitrate concentration in ground water is a long term evolving process that may take decades. A longer time lag may happen between the reduction of greenhouse gas reduction and global temperature decline. Another challenge is the accumulative effect of actual ecosystem service changes. The scale of benefits may change overtime and the change may not be linear. Due to the complexity and uncertainty with actual ecosystem service changes, it is very difficult to give a time frame that completely matches the benefit period in the survey. Instead, it can be largely simplified as an infinite period and the changes would happen as long as the payment was in place.

Because the majority of the ecosystem service changes from agriculture are public goods, the dichotomous choice referendum is more incentive compatible and better avoids free riding or strategic overbidding tendencies than other choices such as open ended payments and payment card (Bateman and Turner 1993, Boyle 2003). The anchoring effect is also minimal among all response choice format choices (Boyle 2003). However, the yea-saying bias may occur in the dichotomous choice response format and results in the fat tail of the WTP distribution (Desvousges et al 1993). But the yea-saying bias can be reduced by providing respondents who vote ‘no’ opportunities to show support to the program (Blamey et al 1999).

Follow-up questions after the WTP question are recommended in order to better understand people’s responses to the WTP question (Arrow et al 1993). Respondents may have uncertainties when they first deal with complicated ecosystem service valuation tasks, so in the mail survey, closed ended follow-up questions on their reasons for the WTP question may induce the respondents to vote differently from their true intention. Open ended follow-up questions give respondents opportunities to express their ideas freely without inducing them to some pre-assumed reasons. Lower protest rate may be achieved when allowing people to express ambivalent and other opinions (Blamey et al 1999, Ready et al 1995). However, it may suffer from low response rates of that question. Certainty follow-up questions asking how certain the respondents are with their answers are helpful in ecosystem service valuation because respondents may be uncertain in valuing complex environment goods. It also has nice properties in data estimation and lower protest rate (Champ and Bishop 2001).

The identification of protesters is important in the CV survey of ecosystem service valuation because the goods to be measured contain politically sensitive issues such as global warming and agricultural subsidies. If a considerable amount of protesters were not excluded from the sample, the estimated WTP would be underestimated. Screening questions for protesters and misleading responses includes (Boyle 2003, Arrow et al 1993)

- Whether they doubt the feasibility of the proposed action
- Whether they refuse to accept the component of the scenario (provision mechanism, payment vehicle)
- Whether they feel that their votes will have no significant effect on the outcome of the hypothetical referendum
- Whether they believe in the scenarios
- Whether they understand the CV question
- Whether they take the CV question seriously

The above screening questions in the mail survey may undermine the CV scenario. Therefore, they should be carefully worded and put in the right section of the survey.

The attribute based method (ABM) is used when valuing multiple ecosystem service changes. The ABM method is to estimate the economic value of an environmental good by dividing the good into several attributes and varying the levels of the attributes in different survey versions (Holmes and Adamowicz 2003). The ecosystem service changes to be valued have multiple dimensions in nature, so ABM turns out to be the appropriate method. By changing the quantities of the good presented to the respondents, the ABM can test the scope effects in the CV survey which results from inability of the respondents to know the difference in quantity changes (Carson and Hanemann 2005).

The CV survey to value ecosystem service changes should reduce the hypothetical bias as much as possible. There are several choices to solve the problem. Cheap talk design which gives a short speech on the hypothetical bias problem to the respondents to reduce hypothetical bias in lab experiments CV (Cummings and Taylor 1999) and some mail CV survey (List et al 2006) but failed in the other (List 2001). It did not reduce WTP for knowledgeable consumers (Lusk 2003, List 2001). Moreover, it is too long for respondents to read through in mail survey. Certainty follow-up question is able to identify certain boundaries of dichotomous choices (Champ and Bishop 2001). Similarly, polychotomous choice format was able to set up certain boundaries of WTP by allowing respondents to choose from a range of intensity of their votes (Ready et al 1994).

Finally, in the CV survey, sampling population should be relevant to the benefits and costs of the environmental good being valued (Carson 2000). The beneficiaries of most ecosystem service from agriculture are the general public. Therefore, the sample should be drawn from all residents.

4 Theoretical model

In the neoclassic economic analysis framework I'm using, the consumer behavior is motivated by utility maximization, which is defined by

$$
\begin{aligned}
&\underset{X}{Max}\, U(X, q) \\
&S.t. \quad I \geq rX \\
&\qquad\quad q \geq 0
\end{aligned}
\tag{1}
$$

Where U denotes consumer's utility, X denotes the quantities of market goods consumed, q denotes the environmental quality, r denotes the price of market goods and I denotes the consumer's income. By solving equations (1), we can derive the indirect utility function. The duality of the utility maximization problem is to minimize consumer's expenditure, given a certain level of utility U^0. We can rewrite this problem as

$$
\begin{aligned}
&\underset{X}{Min}\; E(X, q) = rX \\
&S.t. \quad U(X, q) \geq U^0 \\
&\qquad\quad q \geq 0
\end{aligned}
\tag{2}
$$

The expenditure function $E(U^0, r, q)$ is derived from equations (2), which is the minimum cost to get to utility level U^0.

If environmental quality changes from q_0 to q_1, consumers' expenditure to get to utility level U^0 will change too, then their WTP to pay for the environmental quality changes can be defined as

$$
WTP = E(U^0, r, q_0) - E(U^0, r, q_1) \tag{3}
$$

It is possible that people will have zero or negative WTP. People with zero WTP for a particular good have the utility curve that won't change no matter how many of the good they consume and they would not pay anything for it. Negative WTP means that the increase in the good would reduce people's utility. The zero and negative WTP respondents should be distinguished from those who vote “no” to the program but are willing to pay for it at a lower price. For the latter, the good contributes to their utility and they have a positive WTP. The conditional estimates of WTP would be lower if zero and negative WTP respondents were not excluded in the estimation (Haab and McConnell, 2002).

The paper by Kristrom (1997) introduced the spike model to deal with zero and negative WTP problems in the contingent valuation surveys where the zero and negative WTP respondents can be identified in the survey. Here we discuss the zero WTP case only because eutrophic lakes reduction and greenhouse gas reduction are unlikely to reduce people’s utility, if not to increase it. In the spike model, another parameter p, defined as the probability of a zero WTP to occur is introduced into the linear utility model. Therefore, the cumulative distribution function of WTP is

$$G(WTP) = \begin{cases} p & \text{if } WTP = 0 \\ (1-p)D(WTP) & \text{if } WTP > 0 \end{cases} \tag{4}$$

where $D(WTP)$ is the distribution of WTP conditional on $WTP > 0$

Considering the spike probability suggested by Kristrom, the theoretical model in the paper is set to model two level decisions of the respondents, the spike probability and their WTP conditional on positive WTP.

4.1 WTP conditional on WTP>0

Suppose that conditional WTP is a random variable whose value depends on the distribution of the stochastic term u_{ij}. Specifically, we assume WTP is positive therefore the exponential form is imposed to make sure the WTP function is positive

$$WTP_i \mid_{WTPi>0} = \exp\left(\frac{\delta}{\alpha} + \frac{\beta}{\alpha}\Delta q_j + \frac{\gamma}{\alpha} Z_i + \frac{u_{ij}}{\alpha} \right) \quad (5)$$

where WTP is the person's willingness to pay for environmental improvements, Δq denotes change in environmental quality, Z includes other explanatory variables and u is the random term. Subscript i denotes the respondent, subscript j represent status j (after paying for environmental improvement). δ, α, β and γ are fixed parameters,

To choose between the status quo and status j, denote the choice variable as Y_i and cost of the improvement as t_i. Y_i equals 1 if the respondent chooses to pay for environmental improvements and equals 0 if the respondent declines to pay.

$$\begin{aligned} P(Y_i = 1 \mid WTP > 0) &= P\{WTP_i > t_i\} \\ &= P\left\{ \exp\left(\frac{\delta}{\alpha} + \frac{\beta}{\alpha}\Delta q_j + \frac{\gamma}{\alpha} Z_i + \frac{u_{ij}}{\alpha} \right) > t_i \right\} \\ &= P(\delta + \beta\Delta q_j + \gamma Z_i + u_{ij} > \alpha \ln t_i) \\ &= P(\delta - \alpha \ln t_i + \beta \Delta q_j + \gamma Z_i + u_{ij} > 0) \end{aligned} \quad (6)$$

If we assume that u_{ij} has a $N(0, \sigma^2)$ distribution,

$$\begin{aligned} P(Y_i = 1 \mid WTP > 0) &= P\left(\frac{\delta - \alpha \ln t_i + \beta \Delta q_j + \gamma Z_i}{\sigma} > -\frac{u_{ij}}{\sigma} \right) \\ &= \Phi\left(\frac{\delta}{\sigma} - \frac{\alpha}{\sigma}\ln t_i + \frac{\beta}{\sigma}\Delta q_j + \frac{\gamma}{\sigma} Z_i \right) \end{aligned} \quad (7)$$

Where $\Phi(\cdot)$ is the cumulative distribution function of the standard normal distribution. This is the basic Probit model for binary responses. From equation (7) we can derive the log likelihood function and get the maximum likelihood estimates of parameters δ/σ, α/σ, β/σ and γ/σ.

4.2 Spike probability

Instead of modeling the spike probability as one parameter p, the paper assumes respondent's spike probability is a function of both environmental change variables and other covariates:

$$p(\Delta q_j, Z_i) = P(WTP = 0) = \Phi(a + b\,\Delta q_j + c\ Z_i) \quad (8)$$

Assuming no covariance between people's conditional WTP and spike probability, equations (7) and (8) can be estimated independently.

With the spike probability, the probability that a respondent would vote yes to a program was a product of the probability of voting yes conditional on positive WTP (equation 7) and one minus the spike probability (equation 8), which can be written as

$$\begin{aligned} P(Y_i = 1) &= P(Y_i = 1 \mid WTP > 0) \times P(WTP > 0) \\ &= P\left(\frac{\delta - \alpha \ln t_i + \beta\,\Delta q_j + \gamma\,Z_i}{\sigma} > -\frac{u_{ij}}{\sigma}\right) \times \left(1 - p(\Delta q_j, Z_i)\right) \\ &= \Phi\left(\frac{\delta}{\sigma} - \frac{\alpha}{\sigma}\ln t_i + \frac{\beta}{\sigma}\Delta q_j + \frac{\gamma}{\sigma} Z_i\right) \times \left(1 - \Phi(a + b\,\Delta q_j + c\ Z_i)\right) \end{aligned}$$

(9)

4.3 Welfare calculation

To simplify notation, we rewrite the conditional WTP function (equation (5)) as

$$WTP_i|_{WTPi>0} = \exp\left(\frac{\delta}{\alpha} + \frac{\beta}{\alpha}\Delta q_j + \frac{\gamma}{\alpha}Z_i + \frac{u_{ij}}{\alpha}\right)$$
$$= \exp\left(\delta^* + \beta^*\Delta q_j + \gamma^* Z_i + \alpha^* u_{ij}\right) \quad (10)$$

Then we can compute the median and expectation of the conditional WTP_i.

$$Median\left(WTP_i|_{WTPi>0}\right) = \exp\left(\delta^* + \beta^*\Delta q_j + \gamma^* Z_i\right) \quad (11)$$

$$E\left(WTP_i|_{WTPi>0}\right) = \exp\left(\delta^* + \beta^*\Delta q_j + \gamma^* Z_i + \frac{(\alpha^*\sigma)^2}{2}\right)$$

(12)

The unconditional mean WTP can be computed as the following

$$E(WTP_i) = (1-p)E(WTP_i|WTP_i > 0)$$
$$= \left[1 - p\left(\Delta q_j, Z_i\right)\right]\exp\left(\delta^* + \beta^*\Delta q_j + \gamma^* Z_i + \frac{(\alpha^*\sigma)^2}{2}\right) \quad (13)$$

In the fixed spike probability case, $p\left(\Delta q_j, Z_i\right)$ is a constant $p\left(\Delta q_j, Z_i\right) = \overline{p}$. In the endogenous spike probability case, $p\left(\Delta q_j, Z_i\right)$ is a function of $\Delta q_j, Z_i$.

To compute the unconditional median WTP, remember that

$$G\left(WTP_{median}\right) = 0.5$$

Then $WTP_{median} = 0$ if $p \geq 0.5$.

For $p < 0.5$,

$$WTP_{median} = \exp\left(\delta^* + \beta^* \Delta q_j + \gamma^* Z_i + \alpha^* \sigma \Phi^{-1}\left(\frac{0.5 - p(\Delta q_j, Z_i)}{1 - p(\Delta q_j, Z_i)}\right)\right)$$

(14)

4.4 Econometric model: random effects probit

The estimation of the model depends on the distribution assumption of random term u_{ij}. Previous discussions are based on the assumption that u_{ij} is independently and identically distributed. However, in most CV surveys, more than one program is offered to a respondent. It means that the actual data from the survey will have more than one observation for each respondent i. Then the identically and independently distributed (i.i.d.) assumption of u_{ij} may not be satisfied. We need to estimate the model using the panel data econometric method.

In the panel data case, we assume that the stochastic part has two components.

$$u_{ij} = \mu_i + v_{ij} \qquad (15)$$

where μ_i is the unobservable individual specific error and v_{ij} denotes the remainder disturbance. Assume that the latter is i.i.d. with a normal distribution of mean zero. Further assumptions should be made on whether μ_i is a fixed parameter or a random variable in order to estimate the model. If μ_i is treated as a fixed parameter, it is called the fixed probit analysis. However, estimating μ_i with other parameters introduces the incidental problem which leads to inconsistent estimates of other parameters (Wooldridge 2002). Therefore, instead of assuming μ_i is a fixed parameter; the random effect probit analysis treats it as a random variable. Further, it assumes that μ_i is independent from other explanatory variables and has a distribution of $N\left(0,\sigma_u^2\right)$, Then the joint distribution of $\left(Y_{i1},Y_{i2},\ldots Y_{ij},\ldots,Y_{iT}\right)$ conditional on t, q and Z, denoted by f can be written as

$$f\left(Y_{i1},Y_{i2},\ldots,Y_{iT} \mid t,q,Z;\theta\right)$$
$$=\int_{\infty}^{\infty}\left[\prod_{j=1}^{T} f\left(Y_{ij} \mid t_{ij},q_{ij},Z_i;\delta^*,\alpha^*,\beta^*,\gamma^*\right)\right]$$
$$\times\left(1/\sigma_\mu\right)\phi\left(\mu/\sigma_\mu\right)d\mu_i \tag{16}$$

$$f\left(Y_{ij} \mid t_{ij}, q_{ij}, Z_i; \delta^*, \alpha^*, \beta^*, \gamma^*\right)$$

$$= \Phi\left(\frac{\delta}{\sigma} - \frac{\alpha}{\sigma}\ln t_{ij} + \frac{\beta}{\sigma}q_{ij} + \frac{\gamma}{\sigma}Z_i + \mu_i\right)^{Y_{ij}}$$

$$\times\left[1 - \Phi\left(\frac{\delta}{\sigma} - \frac{\alpha}{\sigma}\ln t_{ij} + \frac{\beta}{\sigma}q_{ij} + \frac{\gamma}{\sigma}Z_i + \mu_i\right)\right]^{(1-Y_{ij})}$$

$$= \Phi\left(\delta^{**} - \alpha^{**}\ln t_{ij} + \beta^{**} q_{ij} + \gamma^{**}Z_i + \mu_i\right)^{Y_{ij}}$$

$$\times\left[1 - \Phi\left(\delta^{**} - \alpha^{**}\ln t_{ij} + \beta^{**} q_{ij} + \gamma^{**}Z_i + \mu_i\right)\right]^{(1-Y_{ij})}$$

(17)

where θ is the vector of all parameters to be estimated which contains $\delta^{**}, \alpha^{**}, \beta^{**}, \gamma^{**}$ and σ_{μ}.

Then if we plug in N observation values of $\left(Y_{i1}, Y_{i2}, \ldots Y_{ij}, \ldots, Y_{iT}\right)$, then we can derive the log likelihood function for equation (7) and (8) and obtain the maximum likelihood estimators for the parameters.

5 Model specification: Description of explanatory variables and hypotheses

In the theoretical model described in section 4, there are three large categories of explanatory variables that would have an impact on respondent's probability of voting "yes" and their WTP to pay for the ecosystem service changes. They are ecosystem service changes variable Δq, cost variable t and other explanatory variables Z.

Ecosystem service change variables were determined by the preliminary study which scaled up the outputs of several ecosystem service changes in Michigan if selected low input cropping systems were to be adopted. The details of this study were elaborated in Chapter 1.

Chapter 1 concluded that two categories of ES changes merited further data collection and analysis: eutrophic lakes reduction and reduction in global warming potential. These two variables constructed the ES change variable vector q. In the empirical model, we divided Z into four subcategories of variables: version variable, demographic variables, related experience variables and attitude variables. Each subcategory contains one or more than one variables. The descriptions of each variable under each category and subcategory are presented in Table 2.1.

6 Survey design and implementation

The questionnaire had five parts. The first part was the information section about lake eutrophication and global warming. Respondents were given information about the current status, how their life would be affected and how land management practices would affect those environmental qualities. The second part gave respondents the maximum range of those ES changes that a land management program could bring. The third part was the referendum CV questions which asked the respondents to vote on three proposed land stewardship programs. The fourth part was the attitude questions that probed respondents' attitudes on various environmental issues. The last part was the demographic questions.

6.1 Survey design

6.1.1 Survey attributes and values

The survey design used the attribute based method (ABM). ABM separates an environmental good into multiple dimensions and varies in each dimension to form different states of the good as a choice set for the respondents (Holmes and Adamowicz 2003). The dimensions of the good were called "attributes", the states of each dimension were "values" of an attribute.

The first two survey attributes are eutrophic lakes and greenhouse gas reduction. In Chapter 1 we estimate the quantities of five ecosystem service changes from low input cropping system, which are reduction in drain dredging cost and flood damage cost, eutrophic lakes, high nitrate wells and greenhouse gas reduction. The benefit for reducing health risks of high nitrate wells can be estimated with other methods such as benefit transfer. So reduction in high nitrate wells is not included in the contingent valuation survey either. The cost savings in drain dredging and flood damage are already estimated in dollar term, it is problematic to ask the respondents to place a monetary value on a dollar cost saving in the contingent valuation survey. As a result, reductions in drain dredging cost and flood damage cost are not included in the contingent valuation survey either. Finally, the set of ecosystem service changes to be measured in the contingent valuation survey has two components: reduction in eutrophic lakes and global warming potential. These two components construct the ES change variable vector q in the empirical model. The maximum reduction of eutrophic lakes that low input cropping systems could bring is about 200 and the maximum reduction of greenhouse gas was 0.6% of the 2000 emission level in Michigan (see results in Chapter 1). The basic values of the two attributes had five levels: zero change, low change, median change, high change and double change. The "double change" level was the double of the maximum reduction.[3] The values are presented in Table 2.1.

Another attribute in the survey design was respondent's share of cost for the proposed

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[3] In pretest interviews in the contingent valuation survey, some respondents reported that the ecosystem service changes were too small although they still passed the scope test. To reduce the probability of scope insensitivity problem, we doubled the original maximum change as the new range of the two attributes.

land stewardship program. This attribute was the cost variable in the empirical model. The cost was expressed as the respondent's own share of increased annual federal income tax. The levels of the cost were $10, $30, $50, $100, $200 per year. The cost levels were set according to the data from the questionnaire pretest interviews. From the pretest data, we made the hypothesis that the WTP of the respondents had a positively skewed distribution with median WTP at around $50.

The last attribute in the CV survey was the provision mechanism to provide such ecosystem service changes. To test the hypothesis that the provision mechanisms in the WTP question has significant effect on respondents' WTP and our interests in agricultural ecosystem services, two alternative provision mechanisms were devised. One version of the questionnaire told the respondents that the land stewardship program was to pay farmers to adopt environmentally friendly farming practices to achieve the stated ecosystem service changes ("agricultural-farmer"). In the information section of that version, respondents were told about the agricultural contribution to lake water quality and global warming. The other version of the questionnaire told them that the program was to pay general land owners to change their current land management practices ("land management"). The matching information section told respondents about the land management contribution to the two environmental qualities.

Table 2.1 Explanatory variables, definitions, unit of measure and levels of survey attributes , survey of 6000 Michigan households, autumn 2009

Variable name	Definition	Unit	Survey attributes	Attribute levels
Environmental change variables				
lake	Eutrophic lakes that would be reduced if the program were to be implemented		Yes	0, 70, 140, 200, 400
GHG	Greenhouse gas reduction compared with the 2000 emission level that would be achieved if the program were to be implemented	%	Yes	0, 0.2, 0.4, 0.6, 1.2
Cost variable				
cost	The amount of annual tax increase that would be used to fund the program	$/year	Yes	10, 30, 50, 100, 200
Other explanatory variables				
Version variable				
farm	Whether the questionnaire version is the agricultural-farmer version or the general land management version		Yes	0-land management, 1-farmer
Demographic variables				

Table 2.1 (cont'd)

income	The household pretax income of the respondent	$/year	No	
age	Age of the respondent	Year	No	
gender	Gender of the respondent		No	1-male, 2-female
education	Education level of the respondent		No	1-Some high school or less, 2-high school diploma, 3-technical training beyond high school, 4-some college, 5-college degree, 6-some graduate work, 7-graduate degree
LenResi	Expected length of future residency in Michigan		No	1-less than 1 year, 2-1-5 years, 3-5-10 years, 4- more than 10 years
FamSize	Size of the respondent's household		No	
farmer	Whether the respondent is a farmer or works on a farm		No	1-yes, 0-no
EnvOrg	Whether the respondent belongs to an environmental organization		No	1-yes, 0-no
forest	Whether the respondent is a forester or works in forests		No	1-yes, 0-no
voter	Whether the respondent is a registered voter		No	1-yes, 0-no
resi	Whether the respondent considers himself/herself as Michigan resident		No	1-yes, 0-no

Table 2.1 (cont'd)

Related experience variables			
fish	Frequencies of the respondent goes fishing in inland lakes in Michigan	No	1-never, 2-in some years, 3-in most years, 4-every year
swim	Frequencies of the respondent goes swimming in inland lakes in Michigan	No	1-never, 2-in some years, 3-in most years, 4-every year
boat	Frequencies of the respondent goes boating in inland lakes in Michigan	No	1-never, 2-in some years, 3-in most years, 4-every year
hike	Frequencies of the respondent hike near inland lakes in Michigan	No	1-never, 2-in some years, 3-in most years, 4-every year
Attitude variables			
gw	Whether the respondent is concerned about global warming	No	1-yes, 0-no

6.1.2 Hypothetical WTP questions design

The contingent valuation (CV) questions used as the policy context a land stewardship program that would cover land owners' cost of adopting environmentally friendly land management practices. The program would achieve different levels of reduction in high nutrient lakes and greenhouse gas emission, depending on its cost.

The CV question used the dichotomous choice referendum format. Respondents were asked to vote on three separate land stewardship programs that reduced high nutrient lakes and greenhouse gas emission at different levels and all three programs cost the same (however, the cost varied among different versions of the questionnaire). If more than 50% percent of the voters voted on the program, it would be implemented and they would have to pay the cost.

The payment vehicle in the CV questions was expressed as a fixed amount of federal income tax increase. To exclude the externality of the federal income tax, respondents were told that money raised in Michigan would only be used in Michigan. The payment was annual and the environmental improvements would be achieved as long as the income tax was in effect.

If the respondent voted "no" for the WTP question, a follow-up question asked them whether they would vote for the program if it did not cost them anything. This question was used to identify the respondents with zero WTP. It is necessary to set up zero or negative WTP questions because large proportion of zeroes or a negative WTP will have a significant effect on the estimation of the model.

Another certainty follow-up question asked how certain they were of their answers to the WTP question. Certainty follow-up questions had lower protest/non response rates because they allowed respondents to express ambivalence. Certainty follow-up questions was also able to identify certain boundaries of dichotomous choices (Champ and Bishop 2001)

There was an open ended question probing on their reasons for their vote on the WTP question. It was used to probe on protesters against the payment vehicle, the provision mechanism and any other elements in the hypothetical scenario. It can be used to identify respondents with positive, zero or negative WTP.

6.1.3 Experimental design of attributes

The experimental design procedure was used to construct an attribute combination plan to be presented to the respondents (Holmes and Adamowicz 2003). The full factorial design allows all the main effect and interaction between attributes to be estimated in the model (Holmes and Adamowicz 2003). However, the full factorial plan in this case has 5^4=625 combination. Due to the budget constraint of the survey, a fractional design plan was adopted, dropping some of the interaction effects between attributes. The main effect experimental design plan of the four attributes should satisfy several conditions and constraints.

First, for each version of the questionnaire, each respondent was given three referendum CV questions to vote on[4]. So in each version of the questionnaire, the farm variable should be the same for all three CV questions.

Second, in each version of the questionnaire, the cost variable was the same for all three CV questions. Having the same cost for the three different programs made respondent's valuation task easier because they had to compare the eutrophic lakes and greenhouse gas changes to only one cost.

Third, in the proposed program to vote on, at least one level of the attributes lake and GHG is larger than zero. The reason is straightforward: it would make no improvement in the environment if both eutrophic lakes and greenhouse gas emission did not change; it would

4 Three CV questions are sufficient for panel data analysis on individual's WTP.

just be the status quo.

Fourth, in the same version of the questionnaire, one program does not dominate another, which means that not both the lake and GHG attribute values in one program are higher or lower than those in another program.

Fifth, if possible, the numbers should be evenly distributed over the ranges of lake and GHG reduction.

In addition, there is no substantial correlation between the question sequence within a questionnaire (i.e., first, second or third) and the design attributes.

Finally, the total correlations between all four attributes are as small as possible to make sure all combinations are orthogonal.

The initial main effect orthogonal plan of 24 attribute combinations was generated by SPSS 17.0. Then it was adjusted to satisfy the above seven constraints. To lower the correlations between attributes, the lake and GHG attribute values were allowed to adjust to represent a continuous change from zero to double change and not confined within the original five levels. The continuously changing lake and GHG variables more closely resemble the actual situation where environmental qualities were changing gradually and continuously. The final plan had 42 attribute combinations in 14 versions of the questionnaire (Appendix 15). It had a correlation matrix whose off diagonal correlations were all below 0.05.

6.1.4 Validation questions design

A set of Questions screen for protest and types of misleading responses (Boyle 2003, Arrow et al 1993) were included in the questionnaire. Those questions aimed to test:

- whether respondents refuse to accept the component of the scenario (provision mechanism, payment vehicle)

- whether they feel that their votes will have no significant effect on the outcome of the hypothetical referendum
- whether they believe in the scenarios

Those questions were placed in the attitude questions in part four so that they were least likely to undermine the hypothetical CV questions. The screening questions, together with people's comments on the open ended questions, would effectively screen out the above three types of misleading responses.

6.2 Survey pretest

Five rounds of questionnaire pretest were conducted during May and June 2009. People were randomly intercepted at campus food court and two shopping malls in the Greater Lansing area in Michigan. Fifty-one randomly intercepted respondents and four graduate students at Michigan State University participated in the pretest. The pretest method was the questionnaire booklet and then the one-to-one semi-structured in-person interview. Both the questionnaire booklet and the interview script were given to interviewers. Each randomly intercepted respondent was paid for their time and effort in the pretest.

The primary goal of the survey pretest was to test the validity of the CV questionnaire. The key validation criteria were (Arrow et al 1993, Boyle 2003, Carson 2000)

- respondents understand the CV question
- they take the CV question seriously
- they understand the environmental improvements described
- they understand the valuation tasks
- they are sensitive to the scope of environmental changes

After five rounds of pretest and further changes to the questionnaire, the above five criteria were satisfied.

The pretest data on the WTP questions was also used to make hypothesis on ranges of people's WTP. The data was used to set up levels of the cost attribute in the questionnaire design.

6.3 Survey implementation

The survey population is Michigan residents because they are beneficiaries of the ecosystem service changes to be measured. The sample was purchased from Survey Sampling International Inc. The sample was randomly selected from Michigan landline telephone directory by Survey Sampling International Inc. It was proportional to the number of households in each county. The sample size was 6000.

The survey mailing followed a modified version of Dillman's tailored design method (Dillman 2000). We had five contacts with the respondents. Personalized prenotice letters with a printed, blue ink signature were sent to respondents a week before the questionnaire packages were mailed out. Then the first round of the questionnaire came two weeks after the prenotice letter. The questionnaire package contained a personalized cover letter with blue printed signature, a questionnaire booklet and a business reply envelope. Then personalized reminder postcards with blue printed signature were sent one week after the questionnaire package. Four weeks later, the second round of the questionnaire package with a revised cover letter was sent as the fourth contact. Another reminder postcard was sent four weeks after the second round questionnaire as the final contact.

There were 480 bad addresses in the sample address list and the bad address rate was 8.0%. Forty respondents from the sample were reported dead and forty respondents had moved out of Michigan. Forty-nine respondents refused to answer the survey. Final responses were 2215 for a final response rate of 41% (Appendix 7).

7 Data analysis

7.1 Protest votes, misunderstanding and other misleading votes

To probe on people's reasons for their votes, we put an open ended question "what were your top two reasons for your vote in Question X" after each voting question. Eighty-five percent of the respondents who answered the questionnaire wrote some comments in at least one of the three follow-up questions. There were rich information to analyze their reasons as well as to identify protests, misunderstanding and other misleading votes. We used the content analysis method to analyze this qualitative data. From the data we extracted 32 themes that were related to their reasons for the votes (Appendix 5). From these 32 themes, there were 6 themes that indicated protests, misunderstanding and other misleading votes. The six themes were "Disagree with government regulation / waste", "Reject provision mechanism", "rejection of tax", "Reject the regime of program or payment", "Don't believe the scenario" and "clear misunderstanding". Responses that fell within the first four types ("Disagree with government regulation / waste", "Reject provision mechanism", "rejection of tax" and "Reject the regime of program or payment",) were considered as protests. Those that belonged to the last type "clear misunderstanding" were misunderstanding votes. Those who mentioned the "Don't believe the scenario" theme did not think that the scenario was true and it was another type of misleading votes that needed to be screened out.

Taxes and government intervention took up the largest proportion of the protests. About 10.1% of the votes rejected taxes and 6.7% of the votes rejected government intervention. Other protests against provision mechanism and regime of the tax were low. Protest votes took up 18.6% of the total. There were only 2.2% disbelief votes and less than 1% misunderstanding votes. The total of the six themes took up 22% of the total. The protest rate was moderate, considering the economic recession at the survey time.

7.2 Descriptive statistics of explanatory variables

To identify respondents with zero WTPs, another follow-up question "would you vote for this program if it did not cost you anything?" was asked after a respondent voted "no" on the voting question. Excluding the protest, disbelief and misunderstanding votes, 16.9 % of the rest of the votes were "no" answers. These answers implied that about 17% of the respondents felt no increase in their utility when eutrophic lakes and greenhouse gas emission were reduced. The proportion of zero WTP is significant; therefore we would expect that zero WTPs would have a significant impact on model estimation and WTP estimates.

After screening out the protest, disbelief, misunderstanding and zero WTP votes, the percentage of "yes" votes declined as the cost of the program increased and correspondingly the percentage of "no" votes increased (Figure 2.1). The result confirmed our expectations that the respondents were sensitive to the price or cost of the program.

Other descriptive statistics were presented in Table 2.2. The total number of votes was 4128. Among the 4128 votes in the sample, over half of the votes were "yes". Further, 17% of the total respondents had zero WTP. If the zero WTPs were subtracted from the 47% of the "no" votes, we can see that only 30% voted "no" conditional on being a respondent with positive WTP.

The "LenResi" variable stands for expected future residency in Michigan (Table 2.1). The mean of 3.7 (Table 2.2) showed that the majority of respondents in the sample would continue to live in Michigan for 5-10 years or more. Variable "resi" indicates whether the respondent considered himself Michigan resident (Table 2.1). The mean of 0.99 (Table 2.2) showed that 99% of the respondents considered themselves Michigan residents. The statistics of "LenResi" and "resi" indicated that the majority of the sample were residents and would continue to live long in Michigan. The results of our survey reflected local residents' long-term interests and concerns about Michigan.

From Table 2.2, we found that the “gender” variable was slightly skewed. More men than women were in the sample. Similarly, the “age” variable was skewed towards the middle-to-old aged respondents with a mean age of 55. Family sizes (variable “FamSize”) were small with an average of 2-3 people. Although not presented in Table 2.2, another frequency analysis of the sample showed that the household pretax income distribution (“income” variable) had a right skewed distribution with median income of $42500. It was consistent with the $48,606 household median income statistics from the Michigan census data (USDA, 2008).

About 95% of the sample was voters (“voter” variable in Table 2.2). This statistics gave credit to the validity of the CV scenario. Because most of the sample was voters, the referendum format in the CV scenario was credible to the respondents and they tended to treat the hypothetical CV questions more seriously.

The sample had very low proportion of farmers (variable “farmer”), foresters (variable “forest”) and members of environmental organizations (variable “EnvOrg”). Neither of them made up more than 10% of the sample.

The respondents showed moderate interests in lake related activities in the sample. The mean values of variables “fish”, “swim”, “boat” and “hike” were all around 2.3, which means that average respondents in the sample engaged in recreational activities in inland lakes in some years or most of the years. On the other hand, the respondents had a neutral to negative attitude towards global warming (variable “gw”). Only 40% of the sample said they were concerned about global warming and 60% were not. If people are skeptical towards global warming, they are less likely to be willing to pay for the greenhouse gas reduction and be sensitive to the changes of it in the voting questions.

Figure 2.1 Frequencies of votes by program costs

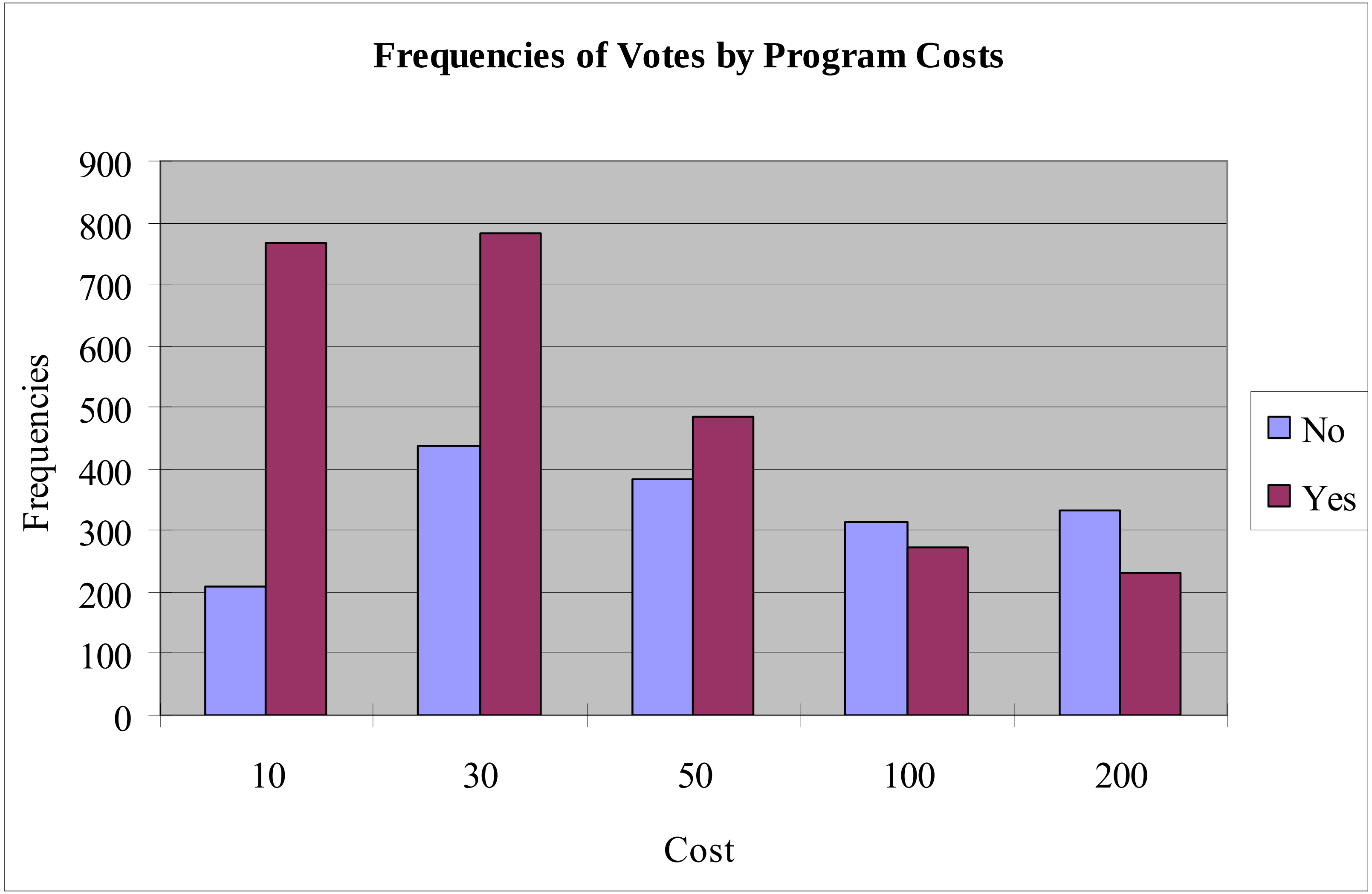


Table 2.2 Definition, observation, mean, standard deviation, minimum and maximum values of variables

Variable	Definition	Obs	Mean	SD	Min	Max
ref	Respondent's vote on the proposed program. Ref=1 if yes	4128	0.53	0.50	0	1
spike1	Whether a respondent has zero WTP spike1=1 if has zero WTP	1430	0.17	0.37	0	1
farm	Questionnaire version (farmer/land management)	1430	0.48	0.50	0	1
lncost	Logarithm of the annual tax increase to fund the program	1430	3.70	0.99	2.30	5.30
lake	Eutrophic lakes that would be reduced if the program were to be implemented	1430	169	111	0	400
GHG	Greenhouse gas reduction compared with the 2000 emission level that would be achieved if the program were to be implemented	1430	0.53	0.32	0	1.2
LenResi	Expected length of future residency in Michigan	1430	3.7	0.69	1	4
resi	Whether the respondent considers himself/herself as Michigan resident	1430	0.99	0.10	0	1
gender	Gender of the respondent	1430	1.34	0.47	1	2
FamSize	Size of the respondent's household	1430	2.55	1.37	0	9
age	Age of the respondent	1430	54.8	15.3	13	96.5
farmer	Whether the respondent is a farmer or works on a farm	1430	0.04	0.19	0	1
forest	Whether the respondent belongs to an environmental organization	1430	0.02	0.13	0	1
EnvOrg	Whether the respondent is a forester or works in forests	1430	0.08	0.27	0	1

Table 2.2 (cont'd)

income	The household pretax income (in $1,000)	1430	68.63	50.24	5	250
education	Education level of the respondent	1430	4.27	1.73	1	7
fish	Frequencies of the respondent goes fishing in inland lakes in Michigan	1430	2.18	1.17	1	5
swim	Frequencies of the respondent goes swimming in inland lakes in Michigan	1430	2.38	1.14	1	5
boat	Frequencies of the respondent goes boating in inland lakes in Michigan	1430	2.43	1.11	1	5
hike	Frequencies of the respondent hike near inland lakes in Michigan	1430	2.25	1.15	1	5
voter	Whether the respondent is a registered voter	1430	0.95	0.23	0	1
gw	Whether the respondent is concerned about global warming. Gw=1 if concerned	1430	0.40	0.49	0	1
gw_GHG	Product of gw and GHG	1430	0.21	0.33	0	1.2

7.3 Conditional WTP model

The “lncost” variable was also significant in the model. The higher the program cost, the less likely people would vote yes. The result was consistent with the frequency analysis of Figure 2.1. When the cost was getting higher, people with lower WTP than the given cost would vote “no”.

The coefficient of variable “lake” was significant in the conditional WTP equation. It was significant because people were concerned about lakes. Descriptive statistics in Table 2.2 showed that the majority had favorable view on lake related activities. When given the statement “Whether or not I visit lakes, just knowing that they are clean is important to me,” 90% of the respondents chose “strongly agree” or “agree”. Therefore the lakes in Michigan were likely of both use and non use value to the respondents. The more reduction in eutrophic lakes, the more likely they would vote yes on the program.

On the other hand, variable “GHG” failed the scope test, and respondents’ votes were not sensitive to differences of greenhouse gas reduction in the scenarios. From the descriptive statistics of people’s concerns about global warming we knew that 60% were unconcerned about global warming. So the scope test probably failed among those respondents. If a considerable proportion of the respondents were not concerned about global warming, the “GHG” variable would become insignificant. As a result, an interaction term was added to probe the relationship between people’s attitudes towards global warming and their WTP. The “gw” variable was derived from the question “how concerned are you about global warming”. There were four types of responses “very concerned”, “somewhat concerned”, “somewhat unconcerned”, “not at all concerned”. A new variable was created, “gw”, which equaled to 1 if the respondents were very concerned or somewhat concerned and equaled to 0 if otherwise. An interaction term “gw_GHG” was added to the model, which was the product of the “gw” and “GHG”. Both of the “gw” main effect term and the interaction term were significant. The main effect term “gw” showed that if people were concerned about global warming, they were likely to vote yes. The interaction term showed that GHG reduction did matter for those who cared about global warming. The scope test passed in those respondents that were concerned about global warming. No interaction term was required for eutrophic lakes because almost all respondents cared about lakes.

In the demographic variable group, variables “age”, “income”, “education” and “voters” were significant. The positive sign of “age” means that older people are more likely to vote yes than younger people. The same positive signs of “income” and “education” variables mean that people with higher income and higher education tend to vote yes. Voters are more likely to vote yes than non-voters. Other demographic variables were not significant, which means that those variables would not have an effect on people’s probability of voting yes or their WTP. It did not matter to their votes or WTP no matter how long they expected to live in Michigan, how large their family size was, whether they considered themselves a Michigan resident, whether they were male or female, whether they were farmers, foresters or environmental organization members.

We originally made the hypothesis that the provision mechanism in the questionnaire would affect people’s votes and WTP. To test the hypothesis, we created two versions: the farm version, where farmers were going to provide the eutrophic lake and GHG reduction, and the general land version where land owners in general were to provide the changes (“farm” variable, see descriptions in Table 2.1). However, the “farm” variable turned out insignificant in the model. The respondents were not sensitive to whether the reduction was provided by farmers or not. Agricultural-farmer or land management versions of the questionnaire would not affect their probability of voting yes nor WTP.

To capture potential correlations due to the repeated questions per person (panel data), the parameter ρ in Table 2.3 was the ratio of the variance of individual error to the sum variance of individual error and remainder disturbance. The larger it is, the more significant the individual effect across a person's answers within the data. The ρ in the conditional WTP model was 0.93 and it was significant in likelihood ratio test. The null hypothesis of $\rho = 0$ was rejected. Therefore, there was an individual effect in the data and it cannot be omitted in model estimation. Compared with the cross sectional probit model, the random effect probit for panel data was more appropriate to analyze our dataset.

The parameter σ_u was the standard error of individual error term. It was 3.61. The Wald chi-square test showed that the model was significant and it had explanatory power on the dependent variable ref.

The prediction power of the model was desirable. 82.3% of the "yes" votes were predicted correctly using the model; 69.4% of the "no" votes were predicted correctly. In total, 77.6% of the predictions were correct.

7.4 Spike probability model

Another finding is that the probability that a respondent had a zero WTP (the spike probability) was endogenous. Variables "lake", "GHG", "income", "gw" were significant in the random effects probit model for the spike (Table 2.3). The significant coefficients of "lake" and "GHG" showed that there was scope effect of eutrophic "lake" and "GHG" reduction on people's spike probability. Further, the negative sign of both the coefficients implied that the higher the reduction in eutrophic lakes and GHG, the lower probability the respondent would have zero WTP. The result was consistent with our intuition. Respondents were more likely to place no value on the reductions (i.e., not be willing to pay anything for it) when the reductions were small. The higher the reductions, the more likely people would place a positive value on it (i.e., the more likely they were willing to pay for it).

The spike probability was also significantly affected by people's concern about global warming. The negative sign of "gw" showed that people who were concerned about global warming were less likely to vote against the program. Because they were concerned about global warming, they were more willing to pay for GHG reduction, which means they had a positive WTP.

Income was another factor that affected the spike probability. Higher income people were less likely to have zero WTP. Perhaps because high income people have more discretionary income, they were more likely to be willing to pay for environmental improvements.

The "farm" variable was not significant in the spike model either. It means that whether the reduction was provided by farmers or not did not affect the spike probability. The fact that the farm variable was not significant in the conditional WTP model or the spike probability model showed that the provision mechanism difference in this case did not affect people's WTP at all. No matter who provided the eutrophic lakes and GHG reduction, neither the conditional nor the unconditional WTP would change, nor do people's votes on the hypothetical programs.

Other demographic variables were not significant except "income". It means that people did not vary in their chances of having zero WTP by their expected length of living in Michigan, their residency, gender, family size, age, education or whether they were farmers, foresters or environmental organization members. Whether they were voters would not affect the spike probability either.

The related experience variables "fish", "swim", "boat", "hike" did not have an impact on the spike probability. They did not affect the conditional WTP equation either. The two findings implied that the frequencies they used the lakes did not affect their WTP for eutrophic lake and GHG reduction. They did care about lake quality but how often they went on such recreational activities in lakes did not affect their WTP.

The Wald chi square test was significant, so the spike probability model had explanatory power on the data. The standard error of individual error term was 2.43. ρ value was 0.855, which means the variance of the individual error took up 85.5% of the sum of variance. The likelihood test of $\rho=0$ was rejected so the individual error was significant and the random effects probit was the appropriate econometric model.

Although the model turned out to be a good fit to the dataset, it did not do well in predicting the binary outcome. Using a naïve prediction threshold of 0.5, the model predicted that none of the sample had zero WTP because the predicted spike probability for each respondent was lower than 0.5. When the mean share of "ones" in the data is far from 0.5, it is not unusual for the probit to have a significant power to discriminate yes votes from no votes yet not yield any predictions that cross the 0.5 threshold.

Table 2.3 Estimation results of proposed models

	Conditional WTP		Spike probability	
N	3433		4128	
Groups	1296		1430	
Dependent variables (Y)				
ref			spike1	
Explanatory variables	**coefficient**	**P>|z|**	**coefficient**	**P>|z|**
farm	-0.0929	0.697	0.0475	0.774
lncost	-1.42***	<.001		
lake	0.00379***	<.001	-0.004***	<0.001
GHG	-0.156	0.549	-0.383**	0.032
LenResi	-0.0788	0.66	0.205	0.107
resi	1.64	0.196	-0.908	0.267
gender	0.176	0.518	-0.0839	0.655
FamSize	-0.0243	0.812	0.0154	0.822
age	0.0297***	0.001	-0.00269	0.674
farmer	-0.642	0.324	0.566	0.193
forest	0.775	0.408	0.0453	0.945
EnvOrg	0.575	0.196	0.129	0.686
income	0.0148***	<.001	-0.00424**	0.031

Table 2.3 (cont'd)

education	0.181**	0.023	-0.00278	0.96
fish	0.214	0.126	0.0989	0.311
swim	0.0858	0.589	0.00115	0.991
boat	0.144	0.386	0.0218	0.853
hike	0.135	0.316	0.0991	0.282
voter	1.71***	0.002	-0.340	0.35
_cons	-2.44	0.162	-0.858	0.45
gw	1.51***	<.001	-1.28***	<0.001
gw_GHG	0.617*	0.079		
	Wald χ^2 (21)=234.3***		Wald χ^2 (19)= 104.6**	
$\ln\sigma_u^2$	2.57		1.77	
σ_u	3.61		2.43	
ρ	0.929		0.855	
log likelihood	-1449.1		-1350.7	
Likelihood- ratio test of ρ=0	$\bar{\chi}^2$ (01) = -1382.33***		$\bar{\chi}^2$ (01) = 827.36***	
% of correct prediction of Y=1	82.3		0	
% of correct prediction of Y=0	69.4		100	
% of correct prediction	77.6		83.2	

Note: * for P<0.1, ** for P<0.05, *** for P<0.01

7.5 Comparison of the fixed spike model and the endogenous spike model in the probability of voting yes and WTP estimates

In the fixed spike model, we did not use the spike probability model to predict the spike probability. Instead, we used the observed spike probability, which was the proportion of zero WTPs in the sample. The fixed spike probability p was 0.169. Then we computed the mean and median annual WTP under the fixed spike probability according to equation (10) and (11). The sample mean WTP is $175 per household annually for reductions of 170 eutrophic lakes and 0.52% GHG emissions from the 2000 level. The number of household in Michigan was 3.8 million in 2000 (US Census Bureau, 2010). If the sample values are representative of all households in Michigan, then the aggregate annual WTP for the whole state would be $665 million.

The sample mean marginal WTP for one eutrophic lake reduction was $0.45 per household per year. Multiplied by the household number of 3.8 million, the aggregate marginal WTP for one eutrophic lake reduction was $1.7 million per year for the whole state.

The sample mean marginal WTP for 1% reduction of GHG from the 2000 level was $141 per household per year for those who were concerned about global warming. For those who were not concerned about global warming, their marginal WTP for 1% reduction of GHG was zero. In the sample, 40% of the respondents were concerned about global warming. If we assumed that there were also 40% of the households concerned about global warming in Michigan, there were 1.52 million households were concerned about global warming. Then we computed the aggregate marginal WTP for 1% GHG reduction by multiplying the marginal WTP per household by 1.52 million households. It was $214 million per year for the whole state.

Instead of assuming the spike probability was exogenous and constant, the endogenous spike model examined the scope effect of eutrophic lakes and GHG reduction on the conditional WTP as well as on the spike probability. The endogenous spike model suggested that the quantity of eutrophic lakes and GHG reduction would affect not only the conditional WTP but also their chances of having zero WTPs. From equation (9) and (10), we knew that the conditional WTP and the spike probability would affect respondent's unconditional probability of voting yes and their unconditional WTP. Moreover, model estimation results in Table 2.3 supported the endogenous spike model over the fixed spike one. It showed that the spike probability was indeed endogenous. Therefore, it was worthwhile to compare the two models with their estimates in the unconditional probability of voting yes and unconditional WTP.

The difference in the unconditional probability of voting yes was illustrated in Figure 2.2. The probabilities were plotted as functions of eutrophic lakes reduction "lake" (2.2a) and functions of GHG reduction "GHG" (2.2b) respectively. The probability functions displayed similar patterns in the lake case and the GHG case. Compared with the fixed spike model, the endogenous spike model had a steeper curve. As the reduction in eutrophic lakes and greenhouse gas increased, the spike probability decreased in the endogenous spike model while the fixed spike probability remained constant. The conditional probability of voting yes also increases faster in the endogenous spike model according to equation (6). The function of two models intersected each other in the lake case (2.2a). Because the fixed spike probability was higher than the endogenous one when eutrophic lake reduction was zero and had a lower slope, the two functions intersected when eutrophic lake reduction was about 40. The two functions did not intersect in the GHG case (2.2b) because the fixed one started lower and had a lower slope. It should be noted that in both Graph 2.2a and 2.2b, the unconditional probability of voting yes was not zero even when the reduction in lake and GHG was zero. It was because the functions were the cross sections of a multidimensional probability function of all categories of variables including environmental change variables, demographic variables, cost variables, attitude variables and the interaction term. When other variables took non zero values, the probability function was not necessarily zero even if one of the environmental change variables was zero. In other words, people would still vote yes when eutrophic lake reduction was zero because the GHG reduction was non zero.

The unconditional mean WTPs were plotted as functions with respect to eutrophic lake reduction (Figure 2.3a) and functions with respect to GHG reduction (Figure 2.3b). The unconditional mean WTP functions in Figure 2.3 had similar patterns with the unconditional probability functions in Figure 2.2. When reduction in eutrophic lakes and greenhouse gas increased, the endogenous spike probability decreased while the fixed spike probability remained constant, then the unconditional mean WTP increased faster in the endogenous spike case. Therefore, the unconditional mean WTP functions were steeper in the endogenous spike model. Similar to Figure 2.2, the endogenous spike function and the fixed spike one intersected when eutrophic lake reduction was 40 (2.3a) but did not intersect in the GHG case. It can be inferred that everything else remaining constant, when the eutrophic lake reduction was 40, the predicted endogenous spike probability was equal to the observed fixed spike probability. On the other hand, the endogenous spike probability would never be equal to the fixed spike probability at a positive value of GHG reduction, holding others constant.

Figure 2.2 Probability of voting yes as a function of environmental change variables

2.2a. Probability of voting yes with respect to reduction in eutrophic lakes

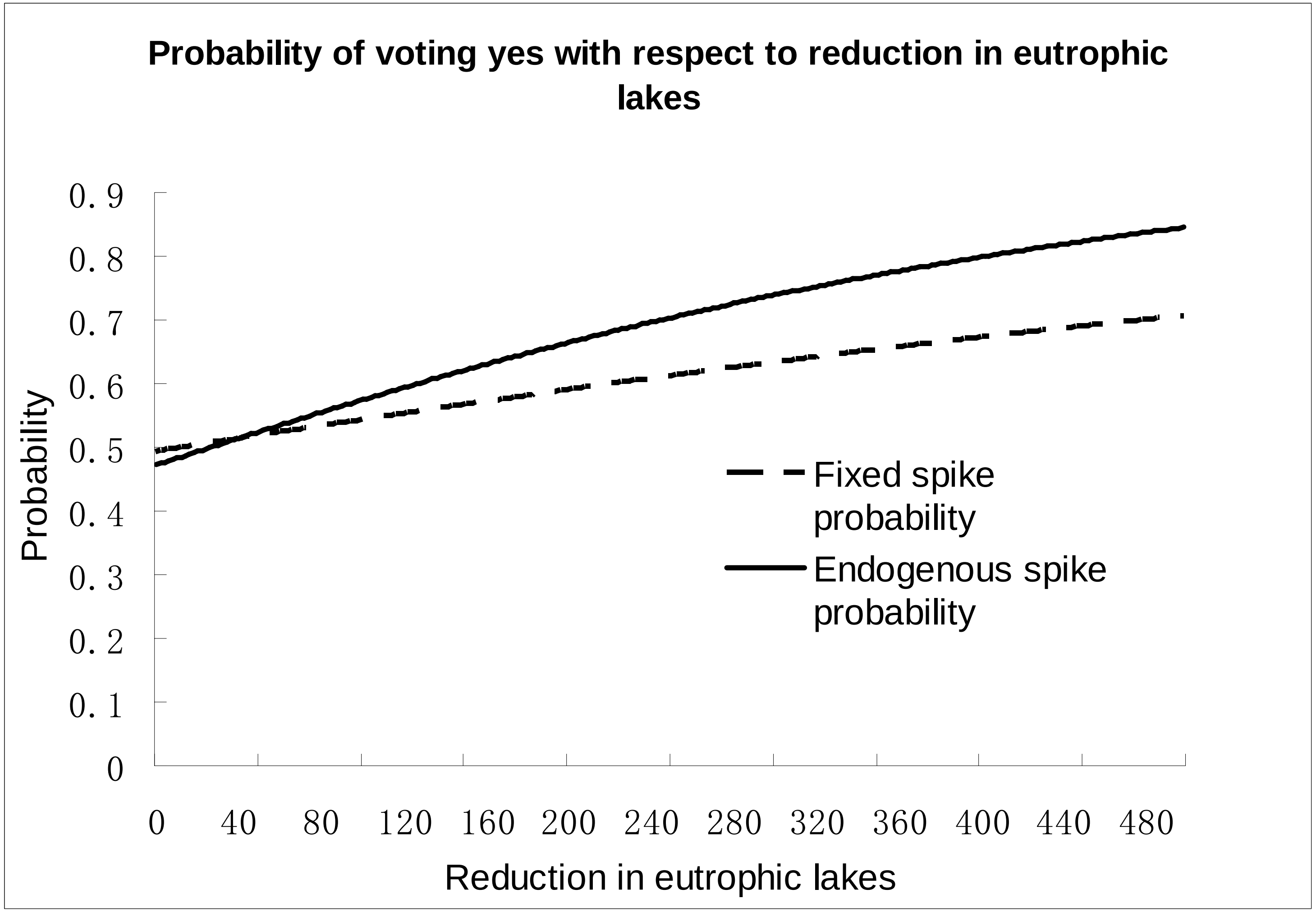


Figure 2.2 (cont'd)

2.2b. Probability of voting yes with respect to reduction in Greenhouse Gas

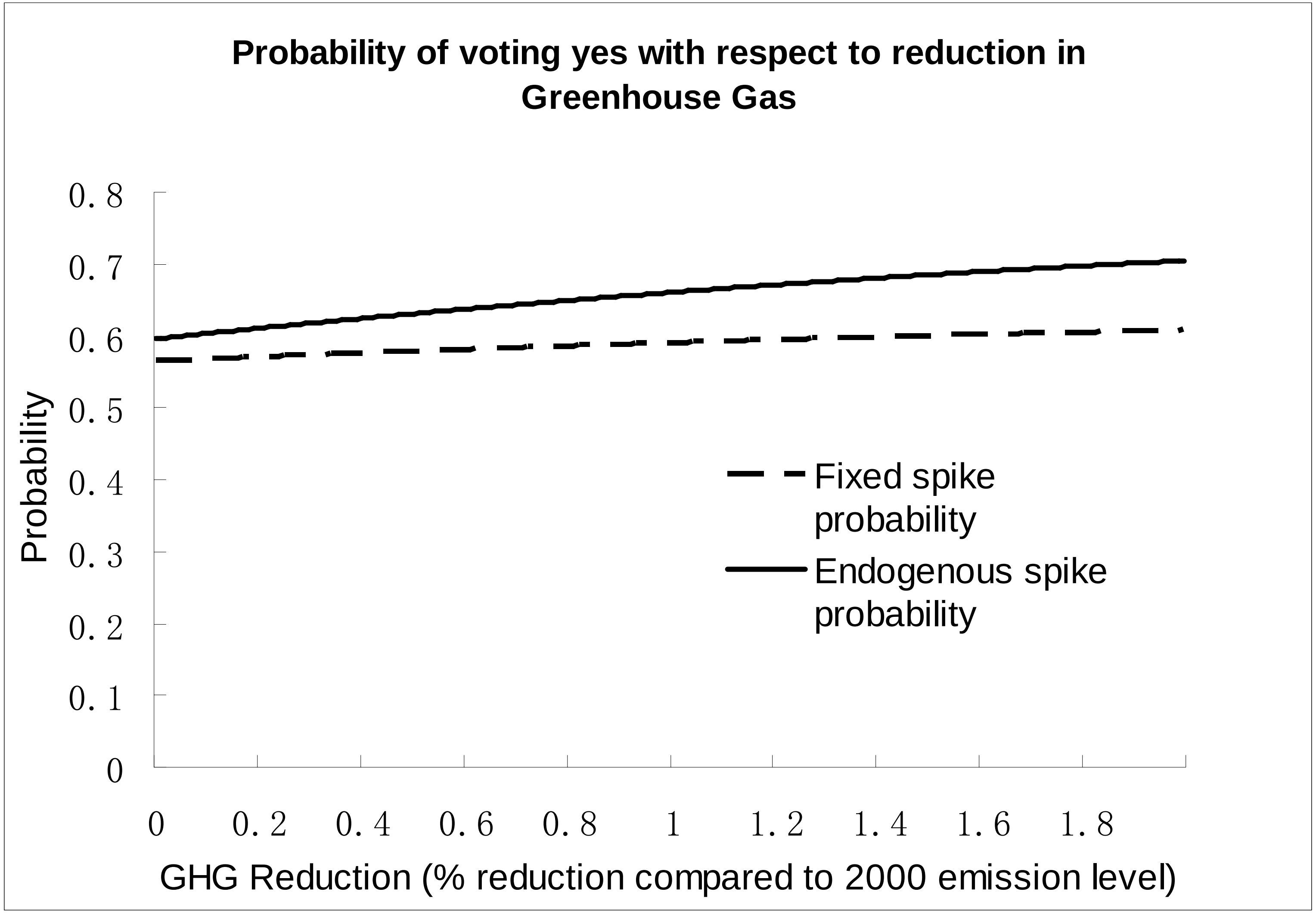


Figure 2.3 Unconditional mean WTP estimates as a function of environmental change variables

2.3a. Mean WTP with respect to reduction in eutrophic lakes

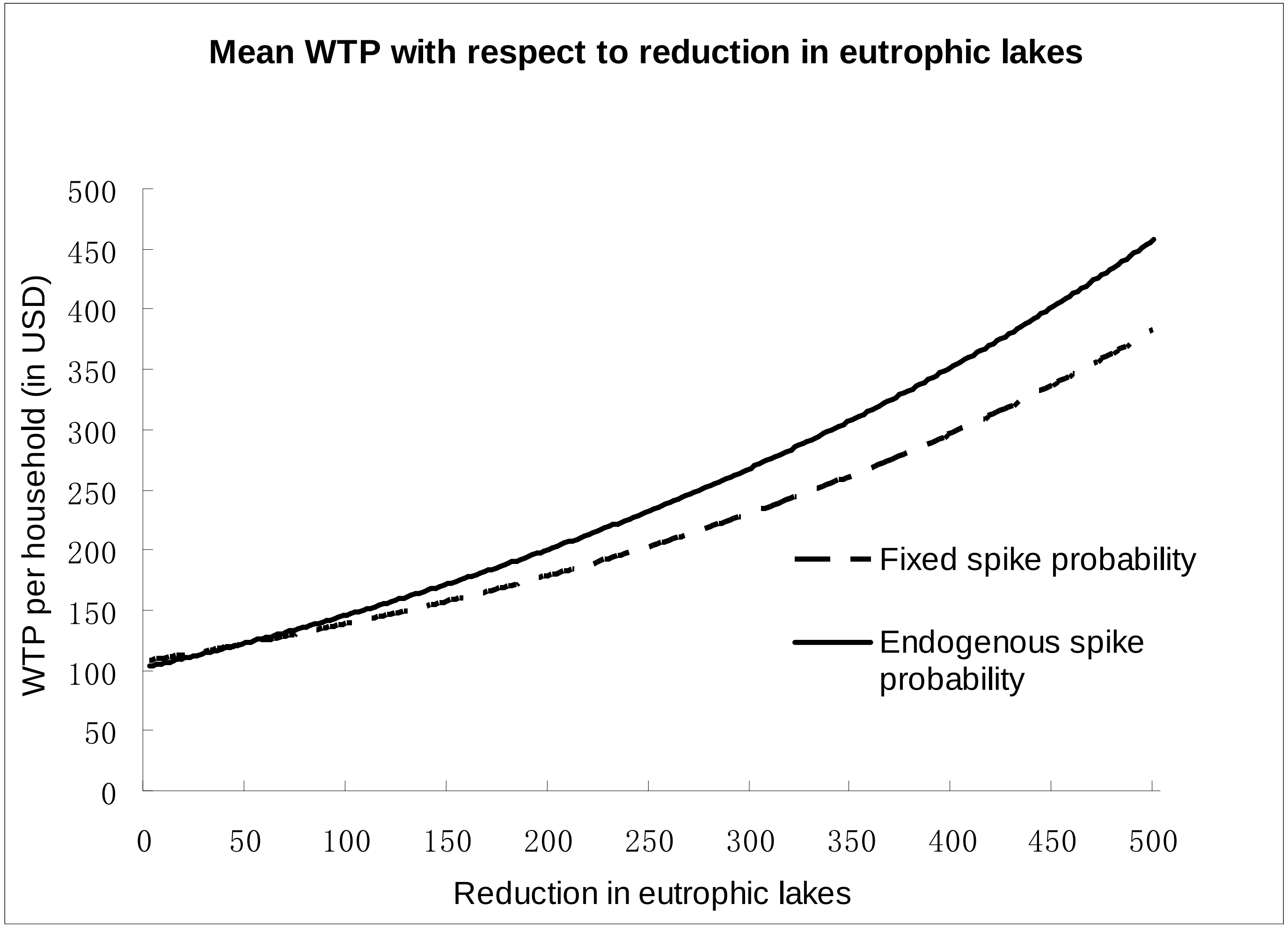
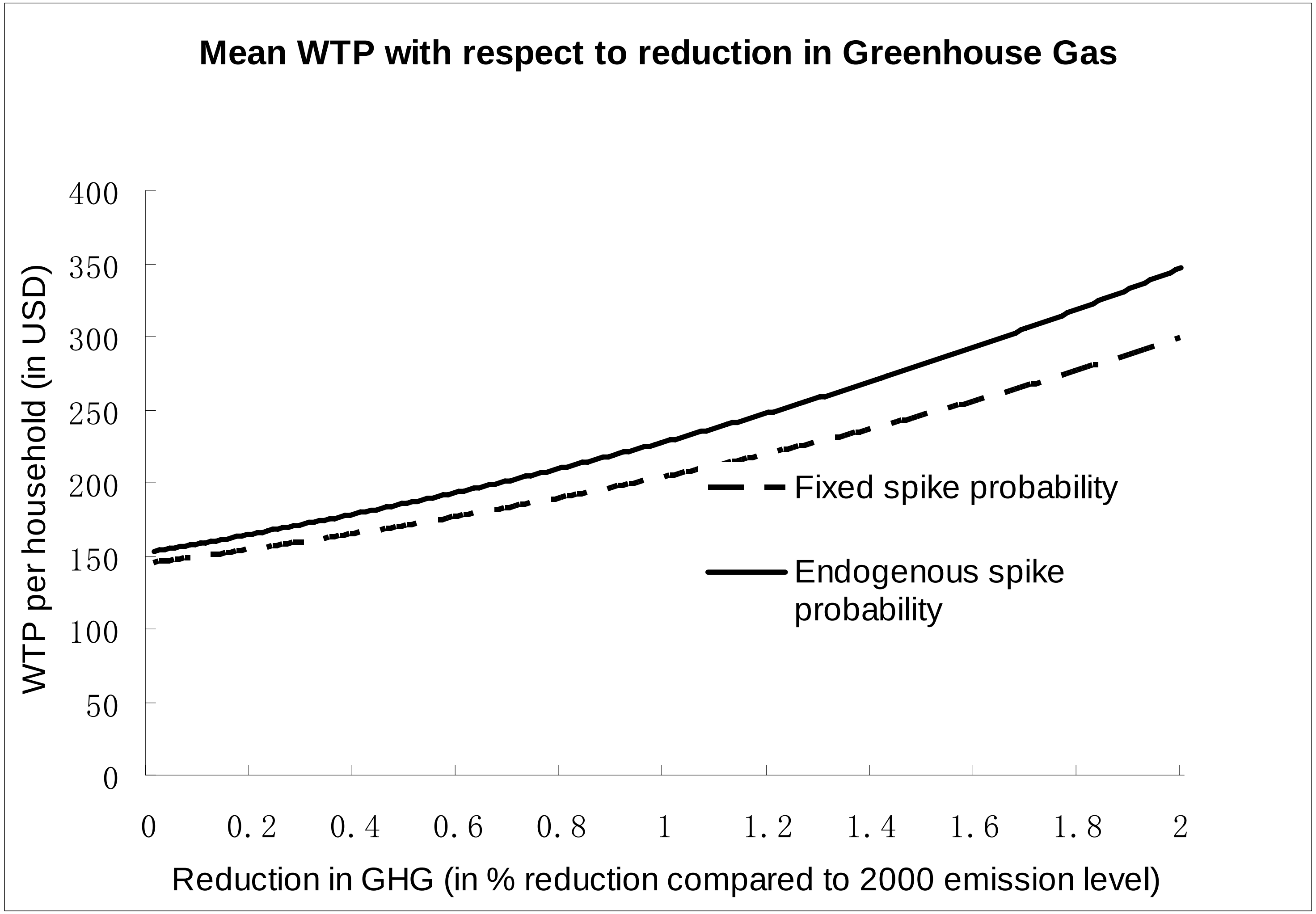


Figure 2.3 (cont'd)

2.2b. Mean WTP with respect to reduction in Greenhouse Gas



8 Conclusions

Ecosystem services from changing agricultural practices were valued by residents. Specifically, our research found that residents were willing to pay for reductions in eutrophic lakes and greenhouse gases. Their willingness to pay depended on the scope of lake and greenhouse gas reduction, attitude towards global warming, age, income, education and whether they are voters. The higher the reduction, the more they were willing to pay for it. Older, higher income, high education people had higher WTP. Voters had higher WTP than non voters. On the other hand, their WTP was not affected by whether the environmental improvements were provided by farmers or not, nor was it affected by the frequencies with which they went on recreational activities to lakes.

Although most respondents cared about lake water quality and were willing to pay for the eutrophic lake reduction, only 40% of the sample said they were concerned about global warming. Their WTP for greenhouse gas reduction differed by their attitude towards global warming. Those concerned about global warming were willing to pay a substantial amount for a unit reduction in GHG while those unconcerned would not pay anything for the reduction.

The probability of having zero WTP, the spike probability, was endogenous. It was determined by the scope of environmental changes, income and attitude towards global warming. Higher income people and those concerned about global warming had lower spike probability. The scope of environmental changes affected both the spike probability and the WTP conditional on WTP being positive. When modeling explicitly the endogenous spike, two scope effects added up. The marginal WTP and the marginal probability of voting yes for a unit increase in eutrophic lake and greenhouse gas reduction were higher than those in the conventional fixed spike case. No other study in the literature has modeled spike probabilities as endogenous functions of the environmental changes provided by a program. Our findings suggest that ignoring the endogenous spike will lead to an underestimation of the benefits of large improvements.

Michigan residents were willing to pay $175 per household every year to get 170 eutrophic lakes reduction and 0.52% GHG reduction from the 2000 level. They were willing to pay $0.45 per household every year to get rid of one eutrophic lake and the 40% that were concerned about global warming were willing to pay $141 per household per year every year to reduce 1% greenhouse gas. The Michigan public had a large WTP for eutrophic lake reduction and greenhouse gas reduction. Even though a substantial portion of them were not concerned about global warming, those who cared about global warming had moderately high WTP for the greenhouse gas reduction.

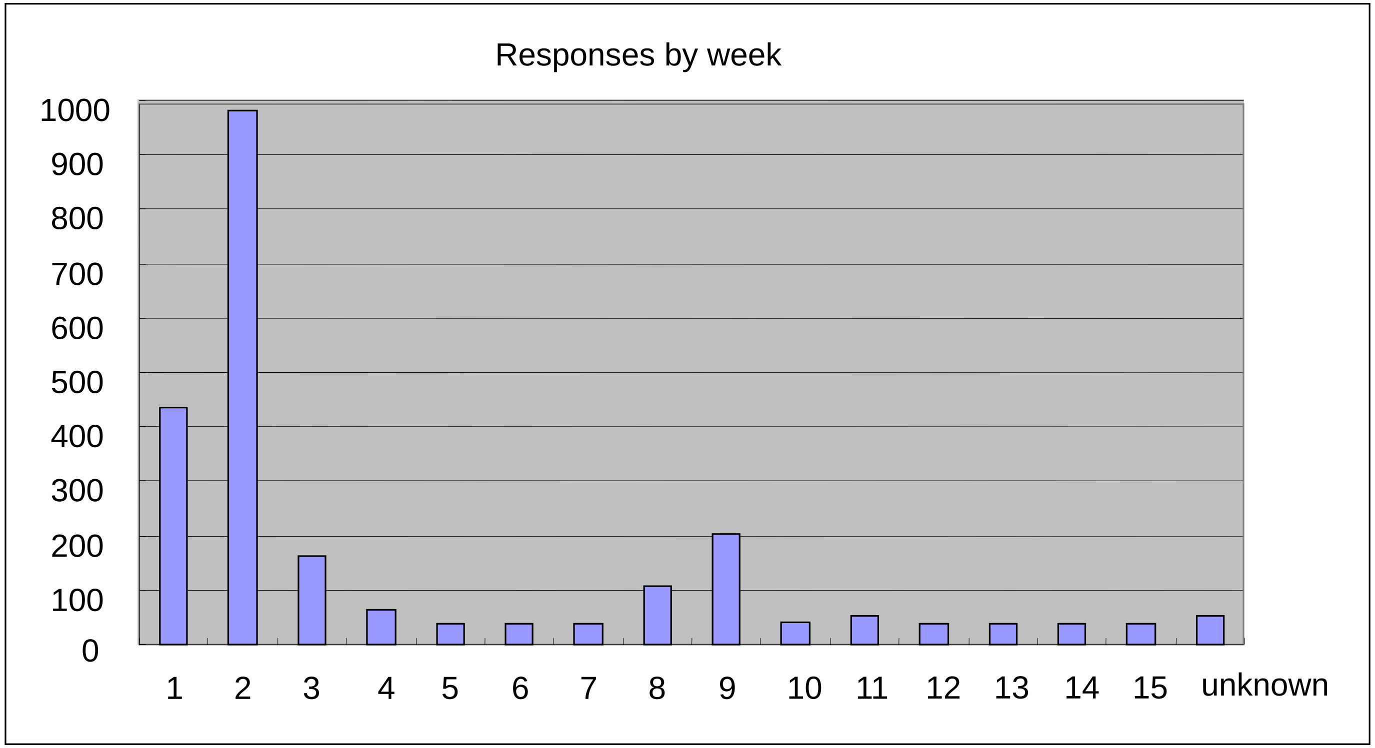
Another finding was that despite the poor economy, an income tax payment vehicle did not generate an excessively high protest rate. Only 10% of the sample was protesting against increased income tax lending support to income tax increase as an appropriate choice of payment vehicle in the contingent valuation survey.

The results of the study estimated the public's demand for two important ecosystem services from agriculture. These can be coupled with estimates of farmers' willingness to supply these services by adopting low-input cropping practices to see if a "market" for these services could exist.

APPENDICES

Appendix 2.1 Responses in survey period (by week)

Figure 2.4 Responses in survey period (by week)



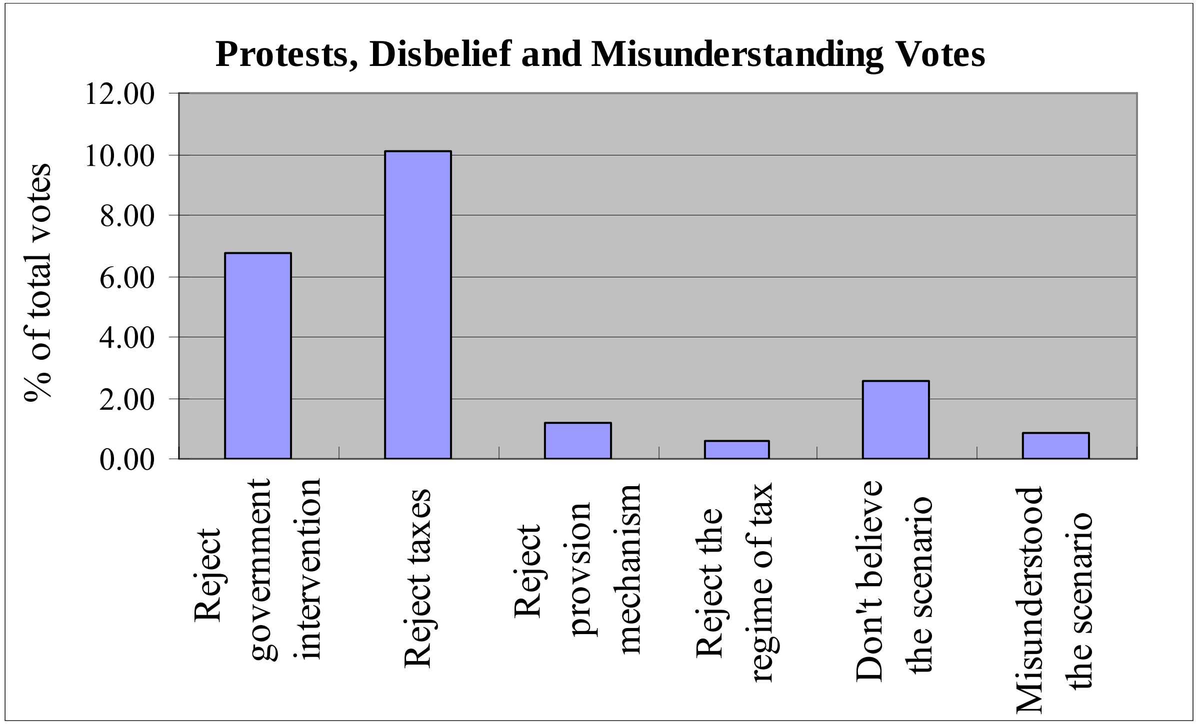
Note: Week 1 started from Aug 3- Aug 9, 2009

Appendix 2.2 Protests, disbelief and misunderstanding votes

Table 2.4 Protests, disbelief and misunderstanding votes

Reasons of rejection	Government intervention	Taxes	Provision mechanism	Regime of tax	Don't believe the scenario	Misunderstood the scenario
% of total votes	6.74	10.07	1.19	0.56	2.55	0.87

Figure 2.5 Protests, disbelief and misunderstanding votes as a percentage of total vote



Appendix 2.3 Content analysis process

Preliminary themes to start with

Set preliminary themes to start with. According to the research interests, the preliminary themes were about protests, disbeliefs and misunderstanding votes.

Training stage

Start the 1st round training of two undergraduate student coders. Each person had the preliminary themes in hand. Each did the same 100 comments independently (i.e., without discussing them with one another), to come up with other preliminary themes. The preliminary themes are pretty narrow and specific.

The supervisor reviewed the themes, re-grouped and reconciled them. Then the new theme lists were developed. It was to be based on in later coding. The group had a meeting and discussed the problems of the first round coding and the theme list.

In the 2nd round training, each coder coded another 300 comments based on the master list. Each coder was given different sets of comments this time. Every time new themes came up, new themes were added.

The supervisor re-grouped and reconciled the new themes that came up in the 2nd round. The group met again to discuss the problems and the updated the theme list.

Self coding stage

1. Coders were assigned same amount of the comments and coded them based on the updated theme list.

2. Each time new theme came up the theme list was updated and circulated within the group so that others knew about the change. The supervisor would reconciled and keep track of the updated theme list. When the whole set of comments was coded once, the theme list

was finalized.

3. Coders shifted data and redid the coding a second time based on the final theme list so that all comments were coded twice.

Appendix 2.4 Themes developed from comments

Table 2.5 Themes names, descriptions and example quotes

Theme Name	**Description**	**Example**
GHG only	They mention GHG alone	It is good to have land management for both the economy and GHG
lakes only	They mention lakes or water quality alone	Not enough done on water- it is the first step
Good for the environment	Respondents said 1.the program will do good to the environment or 2. the environment is important	Land stewardship will work as the problem is mostly the actions of man - water is more valuable than gold. For our kids
cost effective	Respondents feel that the cost is reasonable compared to the improvements that are made.	best plan for both lakes and GHG reductions to get an increased tax rate
recreational use	Respondents mention the program will improve fishing, boating, swimming and any other uses or they want to improve the quality of these activities	I use these lakes and need to help in upkeep.
future generation consideration/Moral obligation	Respondents want a better environment for their future generations/or have a moral obligation to improve the environment	The future of any three sons and their families is my main concern!!!

Table 2.5 (cont'd)

help the economy	Respondents consider the program would help boost the economy	The potential to create Michigan jobs for Michiganders
reductions too small	They vote 'no' and mentioned that 1.reductions are too small, insignificant or 2. they want more reductions	In this program I would like to see a larger reduction of lakes with excess nutrients.
Good start/better than none	They vote 'yes' but mentioned that 1.changes are small or 2.better than none or 3.good to start to do something	Minimal cost. Would help a little – a starting point
benefit not worth cost	Respondents think it is not cost effective	too small results assuming everyone in state is paying 200
can't afford it	Respondents cannot afford the cost although think it is good	I pay enough income taxes. I have no extra money now
complain about zero reduction	Respondents don't like zero reduction in either GHG or lakes	The increase of GHG that nearly fulfills the needed reduction. I was not happy with the zero reduction in eutrophic lakes, but would vote yes to obtain some benefit

Table 2.5 (cont'd)

don't believe in GW	respondents don't believe GW or don't think it is a problem	Global warming is not that big of an issue, from all the facts that I've found out about of my own research of the scientists what I
Need more information about program	Will not vote for program because the respondent wants to know more about technical details about environmental program.	you have to explain what type of land management practices are to be implemented
Rejects premise of environmental improvement	Respondents don't think that people should do anything to change the environment	Let Nature take its course
Irrelevant	Comments are irrelevant to voting.	stop trash coming from Canada
Other substitutes	Respondents think about other programs that can substitute the programs	I believe with education we can achieve these goals

Table 2.5 (cont'd)

Other issues more important	Believe that other issues, i.e. healthcare or employment, are more important than GW/lakes	1. Increased taxes. 2. Other issues taking precedence; i.e economy, having a job, being able to pay mortgage and monthly bills. 3. The health care system. 4. Hunger, homeless in our own state. 5. issues need addressed now: child abuse, animal welfare
Health concerns	Respondents mention health concerns as a reason for voting for the program.	Believe in health reason.
environmental improvement not a concern	Respondents don't care about the environment at all	I don't want to pay anymore taxes! It just is not important to me.
don't care GHG	Respondents mentioned they do not care about greenhouse gas but they might believe global warming is true	GHG taken out of factor
Bad for the economy/Economy is bad	Respondents think the economy is too bad to afford the program or the cost would harm the economy	The hard economy
Polluters pay	Polluters (big corporations, farmers, land owners) should pay, not the public	Most farming is Big Business - corporate owned. I in no way think it is appropriate for government subsidies @ taxpayer expense.

Table 2.5 (cont'd)

Disagree with government regulation / waste	1. Reject government regulation or 2. mention that tax money will be wasted by the government	To much money wasted by govt. Money being spent on something else
Reject provision mechanism	Reject the idea of paying farmers/land owners to reduce pollution	The government (federal or state) has no right to spend my tax dollars for farmers or lake property owners
rejection of tax	opposed to raising taxes to fund the program	I can't justify being taxed a penny more when wage increases don't even batch inflation or are non existent. 2 we are already overtaxed now for everything. I won't vote to pay more.
Reject the regime of program or payment	Respondents 1. reject it is federal tax or 2. prefer local or state taxes to fed tax	I believe land management should be done at the county and state level only. A increased state income tax only drives more businesses our of Michigan. The leviathan (federal government) should not be fed.

Table 2.5 (cont'd)

Don't believe the scenario	They don't think 1) the program would reduce the amount of lakes and GHG given by the tables or 2)the money would go to the program or 3)the cost remain the same overtime or 4)the money would be used only in Michigan	Increased taxes – money never seems to end up where the government says it goes. The program would never reduce that many lakes. The improvement would be a much smaller fraction even if it works.
clear misunderstanding	Respondents clearly have misunderstanding on the scenario	Even though we are reducing 6% it may be a valuable investment in land air, lake quality for only $30 (the actually we gave in his questionnaire was $100)
possible misunderstanding	Some of respondent's comments suggest that they might have misunderstandings but not sure if they did misunderstand the scenario	The increase of GHG that nearly fulfills the needed reduction. I was not happy with the zero reduction in eutrophic lakes, but would vote yes to obtain some benefit (note: reduction in GHG did not "nearly fulfills the needed reduction". It reduces only 1.2% of the needed reduction at the maximum. However, his comments can be interpreted as "fulfills nearly all the reduction that we can achieve from changing land management practices"

Table 2.5 (cont'd)

fund from existing budget	Respondent wants to fund the program by cutting expenses of other parts in the budget	I pay enough in taxes as it is. Attempt to fit this into the state budged first I believe if the government can manage / use the federal income (instead of giving it to banks) or spend on wars) Tax more appropriately. We should not need to pay increased amount of federal income ax to cover this cost. Again- use of money already in system. No to rise taxes.
Users pay	Respondent thinks that those who enjoy the benefit of the improvement should pay, instead of the general population	Tax the user of the additional nutrients. 2. does not make sense for any $ to be spent for user boaters on lake and homeowners on lakes. Who fertilize and add nutrients to the lake?

Appendix 2.5 Survey return statistics

Table 2.6 Survey return categories and quantities

Category	Quantity
Returned and answered	2215
Refused	49
Bad address	480
Deceased	40
Moved out of Michigan	40
Total sample size	6000

Response rate= 2215/ (6000-480-40-40) = 40.72%

Appendix 2.6 Questionnaire

MICHIGAN STATE
UNIVERSITY

Environmental Improvements in Michigan

A SURVEY OF YOUR OPINIONS

This survey aims to understand Michigan citizens' views on various environmental improvements. There are no right or wrong answers. We need *your* views.

Your opinions matter!

By completing this survey, you are helping to inform the design of future policies that better reflect the views and concerns of Michigan citizens.

Introduction to the survey

We would like to know your opinions on several proposed land stewardship programs. Scientists have concluded that by changing land management practices, these programs would improve the following aspects of the environment:

- Lake water quality
- Global warming

ON EACH OF THE FOLLOWING PAGES, PLEASE READ THE TEXT IN THE SHADED BOX FIRST, AND THEN ANSWER THE QUESTIONS.

Lake water quality

Lakes need nutrients that run off from the land. However, **high levels of nutrients in lake water may cause excess growth of plants living in water**. Large quantities of aquatic weeds and water grass can take over the shoreline and float on the water surface.

High nutrient levels can also cause algal blooms. Algal blooms are population explosions by microscopic organisms called algae. When algal blooms happen, large amounts of algae and plants float on the surface of the lakes. Algae use up oxygen in the water, which can **kill fish**. The water can smell bad and become cloudy, colored green, yellow, brown, or red.

Excess plant growth and algal blooms may interfere with recreational activities such as fishing, boating and swimming. Lake scenery is altered. Some toxic algae pose **health risks** to people.

There are about 11,000 inland lakes in Michigan. **About 3400 of them (31%) contain high nutrient levels that promote excess plant growth and are at high risk of algal blooms.**

Land management can significantly affect nutrient input into lakes. Scientists report that in some areas, about half of the nutrients added to the nearby lakes comes from fertilizer runoff from land.

1. **Have you ever seen an algal bloom in a lake?**
   - ☐ No
   - ☐ Yes ⇒ **If yes**

   2. Has the presence of algal blooms affected your recreational activities in or around Michigan lakes?
   - ☐ No
   - ☐ Yes

3. **Have you ever seen excess plant growth in a lake?**
   - ☐ No
   - ☐ Yes ⇒ **If yes**

   4. Has the presence of excess plant growth affected your recreational activities in or around Michigan lakes?
   - ☐ No
   - ☐ Yes

5. **Compared to what you previously thought, how serious of a problem are the consequences of high nutrient levels in Michigan lakes?**
   - ☐ More serious than I thought
   - ☐ About the same as I thought
   - ☐ Less serious than I thought

6. **Which best describes your level of agreement with the following statement "nutrients in lakes are likely to affect me"?**
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Neutral
   - ☐ Disagree
   - ☐ Strongly disagree

Global warming

The global temperature has increased by more than one degree Fahrenheit during the past 100 years. Scientists believe that global warming is increasing.

Several gases cause global warming by holding in heat like a greenhouse. These gases are referred to as "greenhouse gases."

Global warming has many effects. Ice in the North and South Poles is melting. Sea levels are expected to rise. Some low areas are expected to become flooded and submerged in water. Floods, tornadoes, hurricanes and snow storms are expected to happen more frequently. Tropical diseases are expected to break out in more areas. Some animals and plants are expected to **become extinct**.

To keep the long term global temperature increase under 6 degrees, scientists have concluded that greenhouse gas emissions in 2050 should be reduced by 30% from the 2000 emission level. If Michigan were to meet this goal, it would have to reduce 56.7 million tons of greenhouse gases (which is equal to the annual greenhouse gases from driving 10.5 million cars).

Land management can significantly affect greenhouse gas emission. Scientists estimate that land management contributes to 10% of global greenhouse gas emission.

7. How concerned are you about global warming?

- ☐ Very concerned
- ☐ Somewhat concerned
- ☐ Somewhat unconcerned
- ☐ Not at all concerned

8. Compared to what you previously thought, how serious of a problem are the consequences of global warming?

- ☐ More serious than I thought
- ☐ About the same as I thought
- ☐ Less serious than I thought

Please indicate your level of agreement with the following statements.

		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
9.	**Global warming is a problem <u>for me now</u>**	☐	☐	☐	☐	☐
10.	**Global warming will be a problem <u>for me in the future</u>**	☐	☐	☐	☐	☐
11.	**Global warming will be a problem <u>for future generations</u>**	☐	☐	☐	☐	☐

How the environment may be improved by changing land management practices

Land management can significantly affect lake water quality and global warming. For example, changing land management practices can reduce the amount of nutrients entering lakes. In addition, changing fertilizer application methods on land can slow down global warming.

Scientists have evaluated a program to change some land management practices in Michigan and have determined that the following environmental improvements could be achieved. **The actual amount of the improvements would vary depending on the level of investment in the program.**

Table 1: How much could this type of land management program improve the environment?

	Now	*MAXIMUM improvement that this type of land management program could bring*	*After*
Number of lakes with excess nutrients	**3,400**	Reduce **400** **(12%)** →	**3,000**
Greenhouse gas (GHG) reduction needed to slow global warming	Need **30%** reduction	Reduce by **1.2** →	Need **28.8%** reduction

12. **Prior to reading this, how aware were you that *land management practices* can significantly affect both lake water quality and greenhouse gas emissions?**
    - ☐ Very aware
    - ☐ Somewhat aware
    - ☐ Not aware
13. **Looking at Table 1 above, the largest improvement that can be achieved by changing *land management practices* would reduce the number of lakes with excess nutrients by 400 (down to 3,000 lakes with excess nutrients). How important would it be to achieve this reduction?**
    - ☐ Very important
    - ☐ Somewhat important
    - ☐ Not important
14. **Looking at Table 1 above, the largest improvement that can be achieved by changing *land management practices* would reduce greenhouse gas emissions by 1.2% in the 30% reduction goal (down to 28.8% reduction needed). How important would it be to achieve this reduction?**
    - ☐ Very important
    - ☐ Somewhat important
    - ☐ Not important

Voting on a potential environmental improvement program

Proposed Land Stewardship Programs

The federal government is considering a land stewardship program that would cover land owners' cost of adopting environmentally friendly land management practices. The program would be voluntary. **The program would contribute to the environmental improvements described previously**.

Program cost

The program will require funds to operate. The cost of the program is divided into two major parts.

- 90% goes to cover land owners' costs of changing land management practices.
- 10% goes to project management and monitoring.

If the program were implemented, you would need to pay an increased amount of federal income tax annually to fund the program. The money raised would only be used for this specific program. Money raised in Michigan would be spent in Michigan.

We need your input

In the pages that follow, we will show you three different land stewardship programs that provide environmental improvements and cost you money. For each of the three programs, please imagine that you are at the voting booth and have to vote on the program. Please answer each question as if you were really voting on it.

In a real vote, only one of the programs would be offered. We show you three different programs because we need your input on all three programs. Although we ask you to vote on three different programs, please vote on each one as if the other programs were not available. In other words, **when you consider each program, please vote as if it is the only one being offered.**

In a real vote, if at least 50% of the people voted for a program, it would be implemented. If the program is implemented, you would have to pay the income tax increase annually. The environmental improvements would be achieved annually for as long as the tax is in effect.

Important reminders before you vote

The land stewardship program is one of the ways that you could pay to get environmental improvements. Some people will consider the program valuable and will vote yes. Others will prefer having the money to save or spend on other things. We ask for your views. There are no "right" answers other than what you believe is the best way to vote.

Land stewardship program A

Please review program A and then answer questions 15-18. Program A has the following environmental improvements and cost:

	Now	***Program A is going to …***	***After***
Number of lakes with excess nutrients	**3,400**	Reduce by **200 (6%)** →	**3,200**
Greenhouse gas (GHG) reduction needed to slow global warming	Need **30%** reduction	Reduce by **1.2** →	Need **28.8%** reduction
Your share of the costs for the program	**$ 0 per year** in increased income tax		**$10 per year** in increased income tax

15. **Would you vote for program A if it increased income taxes and your share of the increased tax was $10 per year?**
    - ☐ Yes
    - ☐ No → **If no**

    16. **Would you vote for this program if it did not cost you anything?**
        - ☐ Yes
        - ☐ No

17. **On a scale of 1 to 10, where 1 means "very uncertain" and 10 means "very certain", how certain are you with your answer in Question 15?**

    1 2 3 4 5 6 7 8 9 10

    Very uncertain — Very certain

18. **What were your top two reasons for your vote in Question 15?**

    ____

Land stewardship program B

Please review program B and then answer questions 19-22. Assume that program A is not being offered. Program B has the following environmental improvements and cost:

	Now	***Program B is going to …***	***After***
Number of lakes with excess nutrients	**3,400**	Reduce by **260 (8%)**	**3,140**
Greenhouse gas (GHG) reduction needed to slow global warming	Need **30%** reduction	Reduce by **1.0**	Need **29.0%** reduction
Your share of the costs for the program	**$ 0 per year** in increased income tax		**$10 per year** in increased income tax

19. Would you vote for program B if it increased income taxes and your share of the increased tax was $10 per year?

☐ Yes

☐ No → **If no**

20. Would you vote for this program if it did not cost you anything?

☐ Yes

☐ No

21. On a scale of 1 to 10, where 1 means "very uncertain" and 10 means "very certain", how certain are you with your answer in Question 19?

1 2 3 4 5 6 7 8 9 10

Very uncertain Very certain

22. What were your top two reasons for your vote in Question 19?

____

Land stewardship program C

Please review program C and then answer questions 23-26. Assume the previous programs are not being offered. Program C has the following environmental improvements and cost:

	Now	***Program C is going to …***	***After***
Number of lakes with excess nutrients	**3,400**	Reduce by **340 (10%)** →	**3,060**
Greenhouse gas (GHG) reduction needed to slow global warming	Need **30%** reduction	Reduce by **0.6** →	Need **29.4%** reduction
Your share of the costs for the program	**$ 0 per year** in increased income tax		**$10 per year** in increased income tax

23. **Would you vote for program C if it increased income taxes and your share of the increased tax was $10 per year?**
    - ☐ Yes
    - ☐ No → **If no**

    24. **Would you vote for this program if it did not cost you anything?**
        - ☐ Yes
        - ☐ No

25. **On a scale of 1 to 10, where 1 means "very uncertain" and 10 means "very certain", how certain are you with your answer in Question 23?**

    1 2 3 4 5 6 7 8 9 10

    Very uncertain — Very certain

26. **What were your top two reasons for your vote in Question 23?**

____

Your opinion about environmental issues

Please indicate your level of agreement with the following statements.

		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
27.	**It's fair that I pay to get better lake water quality.**	☐	☐	☐	☐	☐
28.	**It's fair that I pay to get less greenhouse gas emission.**	☐	☐	☐	☐	☐
29.	**Polluters should pay for their pollution.**	☐	☐	☐	☐	☐
30.	**The government should finance the land stewardship programs from existing funding (leaving less for other programs).**	☐	☐	☐	☐	☐
31.	**My votes on the land stewardship programs would affect whether or not land management practices change.**	☐	☐	☐	☐	☐
32.	**Improved lake water quality benefits me.**	☐	☐	☐	☐	☐
33.	**Improved lake water quality benefits others.**	☐	☐	☐	☐	☐
34.	**Controlled global temperature benefits me.**	☐	☐	☐	☐	☐
35.	**Controlled global temperature benefits others in Michigan.**	☐	☐	☐	☐	☐
36.	**Controlled global temperature benefits others outside Michigan.**	☐	☐	☐	☐	☐
37.	**Whether or not I visit lakes, just knowing that they are clean is important to me.**	☐	☐	☐	☐	☐
38.	**I would pay more for the programs if the money went to foresters.**	☐	☐	☐	☐	☐
39.	**I would pay more for the programs if the money went to farmers.**	☐	☐	☐	☐	☐

Questions about you

40. How long do you expect to continue living in Michigan?

- ☐ Less than 1 year
- ☐ 1-5 years
- ☐ 5-10 years
- ☐ More than 10 years

41. Do you consider yourself a Michigan resident?

☐ Yes ☐ No

42. What is your gender?

☐ Male ☐ Female

43. Including yourself, how many people are there in your household? _____
(including myself)

44. What is your age? _________________

45. Are you a farmer or do you work on a farm?

☐ Yes ☐ No

46. Are you a forester or do you work in forests?

☐ Yes ☐ No

47. Do you belong to any environmental organizations?

☐ Yes ☐ No

48. How much is the annual pretax income of your household (all sources added together)?

- ☐ Less than $10,000
- ☐ $10,000-14,999
- ☐ $15,000-24,999
- ☐ $25,000-34,999
- ☐ $35,000-49,999
- ☐ $50,000-74,999
- ☐ $75,000-99,999
- ☐ $100,000-149,999
- ☐ $150,000- 199,999
- ☐ $200,000 or more

49. What is the highest level of education you have completed?

- ☐ Some high school or less
- ☐ High school diploma
- ☐ Technical training beyond high school
- ☐ Some college (including AA, AS degrees)
- ☐ 4-year college degree
- ☐ Some graduate work
- ☐ Graduate degree

50. How often do you go fishing in inland lakes in Michigan?

- ☐ Never
- ☐ In some years
- ☐ In most years
- ☐ Every year

51. How often do you go swimming in inland lakes in Michigan?

- ☐ Never
- ☐ In some years
- ☐ In most years
- ☐ Every year

52. How often do you go boating in inland lakes in Michigan?

- ☐ Never
- ☐ In some years
- ☐ In most years
- ☐ Every year

53. How often do you hike near inland lakes in Michigan?

- ☐ Never
- ☐ In some years
- ☐ In most years
- ☐ Every year

54. Are you a registered voter?

- ☐ Yes
- ☐ No

55. (Optional) Do you have any comments?

____

____

____

Thank you! This completes the questionnaire.
We appreciate your help and feedback.

If you have questions, please contact Professor Frank A Lupi at 1- 517-432-3883, by email at lupi@msu.edu, or by postal mail at 301B, Agriculture Hall, East Lansing, MI 48824.

Appendix 2.7 Prenotice letter

MICHIGAN STATE
UNIVERSITY

(Address)

Dear (First Name, Middle Initial, Last Name, Jr/Sr/II/VI etc),

In a few days you will receive a questionnaire in the mail about Michigan's environment. When it arrives, I hope that you will take 15 minutes to fill it out and mail it back. I am writing to you now since many people like to receive advance notice.

You are one of a small number of people who are being asked to express their opinions on the issue. It is very important that you reply so that the results best reflect the views and concerns of Michigan residents.

Thank you in advance for your help.

Sincerely,

Frank Lupi
Professor

Appendix 2.8 First round cover letter

MICHIGAN STATE
UNIVERSITY

July 23, 2009

(Address)

Dear (First name, middle name initial, last name),

I would like to ask you about your views on some possible environmental improvements in Michigan. By completing the enclosed questionnaire, you will be helping to shape future policies, programs and research that influence the daily life of people in Michigan.

You are one of a small number of people being consulted for opinions on these matters as part of a scientific sample of Michigan residents. There are no right or wrong opinions. Because people are different, I need *your* opinions for the results to accurately represent the people of Michigan.

So I ask for 15 minutes of your time to complete the attached questionnaire and return it in the prepaid envelope.

Your individual views will be completely confidential and your privacy will be protected to the maximum extent permitted by law. Also, your participation in the survey is voluntary, and you may refuse to answer certain questions. If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 202 Olds Hall, MSU, East Lansing, MI 48824.

I would be most happy to answer any questions you might have. You can call me at 1-517-432-3883 or email me at lupi@msu.edu.

Thank you for your help.

Sincerely,

Frank Lupi
Professor
Enclosure

Appendix 2.9 Second round cover letter

MICHIGAN STATE
UNIVERSITY

September 4, 2009

(Address)

Dear (First name, middle name initial, last name),

Last month, I wrote to ask your views on environmental improvements in Michigan. To my knowledge, I have not yet received your completed questionnaire.

We have undertaken this study to ensure that the design of future environmental policies is informed by the views and concerns of Michigan residents.

I am writing to you again because your input is vital to this study! You are one of the small number of people drawn from a scientific sampling process. In order for the results of this study to accurately represent the opinions of all Michigan residents, it is very important that each person in the sample return their questionnaire.

In the event that your questionnaire has been misplaced, I enclose a replacement.

As I mentioned in the earlier letter, your individual views will be completely confidential and your privacy will be protected to the maximum extent permitted by law. Also, your participation in the survey is voluntary, and you may refuse to answer certain questions. If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 202 Olds Hall, MSU, East Lansing, MI 48824.

I would be most happy to answer any questions you might have. You can call me at 1-517-432-3883 or email me at lupi@msu.edu.

I do hope that you can take a few minutes to complete and return the questionnaire. Thanks in advance for your cooperation.

Sincerely,

Frank Lupi
Professor

Enclosure

Appendix 2.10 First round reminder postcard

Michigan Environmental Survey
Dept. of Agricultural, Food, and Resource Economics
301B Agriculture Hall
Michigan State University
East Lansing, MI 48824-1039

Name
Address

MICHIGAN STATE
UNIVERSITY

Last week a questionnaire about environmental improvements in Michigan was mailed to you.

If you have already replied, thank you very much. If not, please do so today. We have sent the questionnaires to a small but representative sample of Michigan residents. It is very important that you reply so that the results best reflect the views and concerns of Michigan residents.

If by any chance you did not receive the questionnaire, or it was misplaced, please email me at lupi@msu.edu, and I will replace it right away.

Sincerely,

Frank Lupi
Professor

Appendix 2.11 Second round reminder postcard

Michigan Environmental Survey
Dept. of Agricultural, Food, and Resource Economics
301B Agriculture Hall
Michigan State University
East Lansing, MI 48824-1039

Name
Address

MICHIGAN STATE
UNIVERSITY

I recently sent you a survey about environmental improvements in Michigan. **If you have already returned it, *thank you very much.*** If not, please do so today.

You are part of a small sample of people being asked to complete the survey. We need your input to ensure the accuracy of our study.

This is the last time I will be contacting you. I hope that you are able to respond. If you did not receive the survey or need a replacement, please contact me at *lupi@msu.edu* or (517) 432-3883.

Sincerely,

Frank Lupi
Professor

Appendix 2.12 Steps to generate experimental design

1. Determine the attributes and levels.

2. Start with the orthogonal main effect plan generated by SPSS. There will be one combination that contains “no change” levels in both lake and GHG.

3. Sort the combinations in ascending order with price first and farmer second. Add the version numbers to each combination (each version has three combinations and all three combinations should have same farmer and price levels). Add blank combinations if necessary (yellow ones). Then there were 10 versions and 30 combinations in the plan.

4. Change the numbers in lake and GHG in the plan to satisfy the following criteria:

- In every combination, at least one number in lake and GHG is larger than 0.
- Within the same version, one combination does not dominate another.
- The total correlations within all variables as well as the sequence number (the order that the combination is presented in a version, 1st, 2nd or 3rd) are as small as possible.
- If possible, the numbers should evenly cover the whole ranges of lake and GHG.

Sometimes, in one version, one combination is far superior to another (for example, a combination with very high GHG reduction and zero eutrophic lake reduction and the one with no GHG reduction and low eutrophic lake reduction). In this case, separate the version into two versions- one with the superior combination and one with the inferior one(s). The two combinations have the same farmer and price levels. Then add the blank combinations according to the criteria above.

Appendix 2.13 Experimental design plan

Attributes and levels

Table 2.7 Attributes and levels of the contingent valuation design

Attributes	**Levels**				
Agriculture	Farmer	General land management			
Eutrophic lakes reduction	0	68	136	204	408
GHG reduction	0	0.2%	0.4%	0.6%	1.2%
Price Levels	10	30	50	100	200

Experimental design plan

Table 2.8 Experiment design plans for each version of the questionnaire

Questionnaire Version	**Sequence**	**farmer**	**price**	**lake**	**GHG**
A	1	0	10	200	1.2
A	2	0	10	260	1
A	3	0	10	340	0.6
B	1	0	10	70	0.6
B	2	0	10	140	0.4
B	3	0	10	200	0.3
C	1	1	10	0	0.4
C	2	1	10	100	0
C	3	1	10	70	0.3
D	1	0	30	200	0.2
D	2	0	30	140	0.4
D	3	0	30	70	1.2

Table 2.8 (cont'd)

E	1	1	30	100	0.5
E	2	1	30	70	0.6
E	3	1	30	200	0.4
F	1	1	30	100	0.5
F	2	1	30	0	0.6
F	3	1	30	140	0
G	1	1	30	400	0.4
G	2	1	30	300	0.8
G	3	1	30	200	1
H	1	0	50	140	0.2
H	2	0	50	0	0.5
H	3	0	50	70	0.3
I	1	0	50	140	0.6
I	2	0	50	250	0.2
I	3	0	50	200	0.5
J	1	1	50	400	0.2
J	2	1	50	300	0.4
J	3	1	50	200	1
K	1	0	100	200	1
K	2	0	100	300	0.8
K	3	0	100	400	0
L	1	1	100	100	0.5

Table 2.8 (cont'd)

L	2	1	100	200	0.4
L	3	1	100	70	0.6
M	1	0	200	0	0.4
M	2	0	200	200	0
M	3	0	200	70	0.2
N	1	1	200	180	0.8
N	2	1	200	400	0.6
N	3	1	200	120	1.2

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