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Causes of the decline in the loss of vegetated palustrine wetlands in the U.S. 1955 - 2009

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CAUSES OF THE DECLINE IN THE LOSS OF VEGETATED PALUSTRINE WETLANDS IN THE U.S., 1955--2009

By
Roger K. Wiebusch

A Dissertation
Submitted in Partial Fulfillment of the Requirements for the
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Department of Environmental Resources and Policy
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DISSERTATION APPROVAL

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Approved by:

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AN ABSTRACT OF THE DISSERTATION OF

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MAJOR PROFESSOR: Dr. Christopher Lant

By 1980, the United States had lost over 50 percent of its original wetland resources. The U.S. National Wetland Inventory estimates that 95 percent of annual wetland losses since 1955 occurred to palustrine wetlands. The majority of these losses occurred to the three types of palustrine vegetated wetlands: emergent, forested, and shrub. The primary cause for wetland losses from the mid-1950s to the mid-1980s was agricultural conversion supported by federal agricultural policies, especially the Agricultural Conservation Program that provided significant direct and indirect support for wetland conversions. The rate of converting wetland to agriculture has declined since the mid-1950's with a significant decrease occurring between the mid-1970s and mid-1990s.

Statistical analysis using correlation, regression and principal component analysis was performed to identify the major contributory factors in loss rates in the Midwest, Lower Mississippi River Valley and the Southeast United States. The variables considered are: Swampbuster provisions of the Food and Security Act of 1985, Conservation Reserve Program enrolled acreage and rental rates, Wetland Reserve Program and The Clean Water Act Section 404 permits; prices of corn, soybeans and wheat; and the percent of wetlands remaining. The results indicated agricultural policies and Clean Water Act Section 404 permits and wetland loss rates were negatively correlated and prices of corn, soybeans and wheat were positively correlated. The percentage of wetlands remaining, were also positively correlated with loss rates. Taken together, the selected agricultural policies, Section 404 permits, commodity prices and percent of wetland remaining, explain 96 percent of the variance in wetland loss rates and 94 percent of the agricultural losses nationally. These results are consistent, with minor variations, across

geographic wetland strata and wetland types. Regional differences exist in the major type of wetland losses; emergent wetland losses were more prevalent in the agricultural Midwest, with forested wetland losses concentrated in the Lower Mississippi River Valley and the Southeast United States.

The results of this research reflect the intricate relationships between federal legislation, regulatory programs, legal decisions, economic factors, and changes in society's view and understanding of the importance of wetlands and the need to merge conservation programs with agricultural policies. Economic factors exert a significant impact in decision-making of whether to convert or conserve wetland resources. The economic feasibility of installing drainage system to make wetlands farmable depends upon the relationship of capital investment cost and crop prices. Commodity prices impact decisions regarding enrollment into the Conservation Reserve Program and the Wetland Reserve Program; higher commodity prices can make conversion more profitable but low crop prices will make these programs more appealing economically. The Swampbuster provisions are effective in conserving wetlands if the economic penalties are significant to the individual farmer.

The policy, legal and commodity variables were used to create models that explain the inter-relationship between agricultural economic factors, policy impacts and commodity prices. The models indicate how the variables could affect decision-making in determining whether to convert or conserve palustrine vegetated wetlands; increased commodity prices coupled with lower conservation program payments could jeopardize wetland conservation efforts and result in increased wetland loss rates due to increased wetland drainage and conversion.

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I would not have been able to complete this program or my dissertation without the guidance, counsel, mentoring and motivation provided by my advisor Dr. Christopher Lant. His constructive, honest critiques were focused on improving my research writing and analytical skills, who understood my challenges of balancing a full-time career managing a major federal regulatory program over 22 states, family demands and a hundred mile commute in all weather conditions. He always found the time to discuss my progress and submittals to ensure I was on the right track. Dr. Lant is a consummate professional advisor who not only took an interest in my research, made insightful recommendations and also ensured I developed academically.

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Professor McCubbin provided the inspiration for research into the legal cases that shaped federal jurisdiction over wetlands. Her encouragement to understand the dynamic legal environment of different time periods regarding wetland jurisdiction and interpretation of different laws and policies significantly contributed to my research.

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I am deeply indebted to Tom Dahl and Mitch Bergeson of the U.S. Fish and Wildlife Service who agreed to share the data prepared for the periodic national wetland status and trends reports. Tom Dahl authored the five reports used and provided keen insights into the data and its proper interpretation both by telephone, emails and personal visits. Mitch Bergeson provided critical and helpful information and clarification on interpretation of the data.

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CHAPTER ONE

INTRODUCTION

Problem statement

Wetland acreage significantly decreased in the conterminous United States from 1955 to 2009 with palustrine (freshwater) wetland losses accounting for over 98 percent of all wetland losses during this period. These losses have been documented by status and trends reports prepared by the U.S. Fish and Wildlife Service in 1983, 1991, 2000, 2006 and 2011 that identified the majority of wetland losses occurred in the Midwest, Lower Mississippi River Valley and the southeastern states. Although these reports quantified the losses by palustrine wetland type and region, they only speculated on possible causes for changes in wetland loss rates. This study focuses on identifying the most significant regulatory, conservation policy, legal, economic, and geographic factors that contributed to the changes in palustrine wetland loss rates in the conterminous United States from 1955 to 2009.

Wetlands are transitional areas between terrestrial and aquatic ecosystems that occur globally in coastal, estuarine, riparian and isolated inland environments, support diverse ecosystems and provide essential ecological goods and services. The perceived value and importance of wetlands has cycled over time from serving critical support functions and making significant contributions to the success of human societies (Nicholas, 1998; Coles and Coles, 1989; Diamond, 2005) to being an impediment to human settlement, agriculture and development (Prince, 1997; Vileisis, 1997; Dahl, 1990) to the present view that wetlands are important resources that should be protected and restored (Mitsch and Gosselink, 2000; Dahl, 2000; CEQ 2006; Millenium Ecosystem Assessment, 2005). In the conterminous United States, total wetland acreage has decreased from an estimated 221 million acres in colonial times to

110.1 million acres in 2009 (Dahl, 1990, 2011). Over 50 percent of the original resource has been lost due to actions such as conversion to agricultural use, urban and rural development, transportation facilities and fossil fuel exploration and extraction.

Wetland conversion was encouraged by society and federal government policies until the 1970's when the value of wetlands in their natural condition was recognized and federal policies started to change from supporting conversion to encouraging conservation. The importance of wetland resources was officially recognized by Congress in passing the Emergency Wetlands Resources Act of 1986 (Public Law 99-645) to promote wetland conservation and required the U.S. Fish and Wildlife Service to conduct studies and prepare reports on the status and trends of the Nation's wetland resources approximately every 10 years. Four reports have been prepared: mid-1970's to mid-1980's, 1986-1997, 1998 – 2004 and 2005-2009. Before enactment of the Emergency Wetlands Resources Act, a similar report was prepared for the 20-year period of the mid-1950's to mid-1970's. The five reports provide a comprehensive history of wetland losses and loss rates for all wetland types for the period of 1955 – 2009. These reports document steady decreases in total wetland loss rates from the mid-1950's until the mid-1980's when an 80 percent reduction in the loss rate occurred (Dahl, 2000). Wetlands acreage increased through 2004, then decreased from 2005 – 2009 (Figure 1).

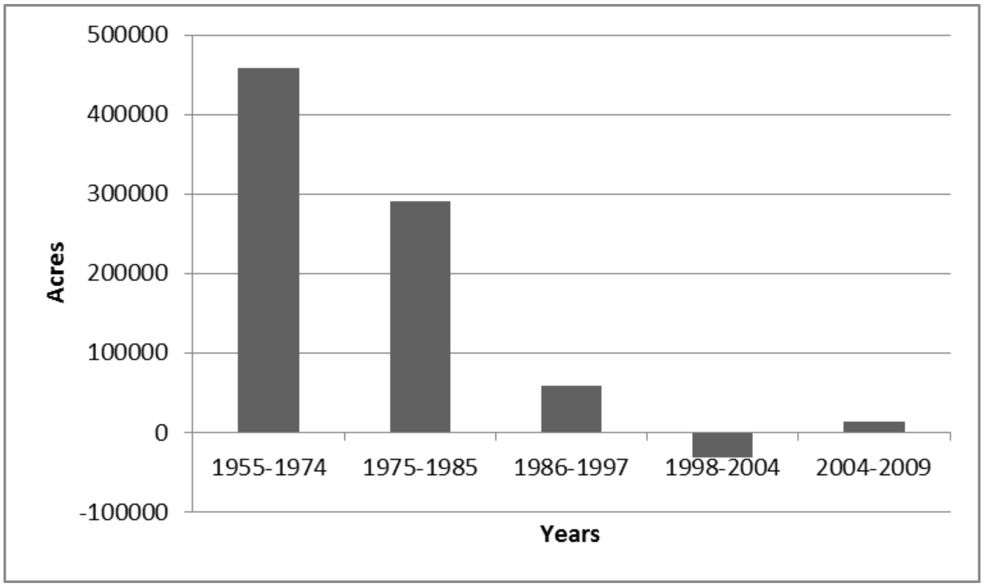


Figure 1. Annual Total Wetland Loss Rate 1955-2009
Source: Dahl and Johnson, 1991; Dahl 2000, 2006, 2011

A review of just the palustrine vegetated wetland loss rates for the same period shows the same general trend in loss rate changes (Figure 2). The values for vegetated loss rates are greater than the overall wetland loss rates due to increases in non-palustrine vegetated wetland acreage.

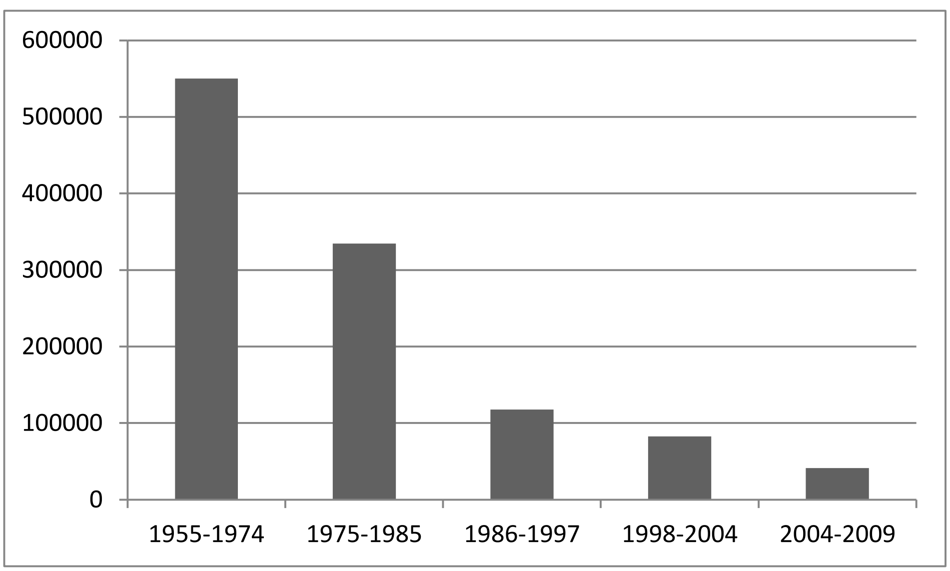


Figure 2. Palustrine Vegetated Wetland Loss Rate 1955-2009
Source: Frayer et al. 1983; Dahl and Johnson, 1991; Dahl 2000, 2006, 2011

National wetland policy is splintered between several agencies that implemented different policies at different times, but have been effective concurrently. Although wetlands are considered to be a valuable resource that provides public benefits, there is no single program and no single lead federal agency tasked with protecting wetlands. As a result there is no clear, singular cause-and-effect relationship between programs that provide some level of wetland protection or conservation and the decline in wetland losses and change in loss rates. Approximately 85 percent of palustrine wetlands are privately owned and a significant percentage of all wetland losses between 1955 – mid-1980's was due to conversion to agricultural use. Speculation on causes for a decline in wetland losses have included the "Swampbuster" provisions of the Food Security Act of 1985 (Dahl and Johnson, 1991; Dahl 2006), elimination of support for wetland drainage (Dahl, 2000), Wetland Reserve Program and Conservation Reserve Program (Dahl, 2006), an increase in public education and awareness about the values of wetlands (Dahl and Johnson, 1991; Dahl, 2000), and the implementation and enforcement of wetland protection measures (Dahl and Johnson, 1991), and there were no wetlands left to drain. Due to the close association of palustrine wetlands to farming operations, commodity prices are another factor that must be considered as a factor in wetland losses and loss rates.

RESEARCH QUESTIONS

The following research questions will be addressed by the study:

1. How have wetland loss rates varied in the U.S., over time from 1955-2009 and by geographic strata?
2. What policy and economic factors account for these variations?

3. How can we utilize these policy and economic factors to gain a better understanding of the process of wetland loss in the U.S.?

HYPOTHESES TESTED

The following hypotheses will be tested:

1. Policy variables of Conservation Reserve Program, Wetland Reserve Program, Swampbuster and Section 404 of the Clean Water Act reduce vegetated wetland loss rates.
2. Agricultural commodity prices are positively related to wetland loss rates.
3. Wetland loss rates are affected by the remaining stock of wetlands available for conversion.
4. The factors that have affected wetland loss rate vary geographically (by Strata), and by wetland type.

CHAPTER TWO

LITERATURE REVIEW

Wetland definition and classification systems

The term ”wetland” was initially used in a federal government publication in *Wetlands of the United States* also known as *Circular 39* (Shaw and Fredine,1956). The publication defined wetlands as lowlands covered with shallow and sometimes temporary water and based the classification system on the value of 20 different wetland types for waterfowl (Table 1).

Table 1. Inland Fresh Areas wetland types

Wetland type	Description	Estimated acres
1	Seasonally flooded basin or flats	23,092,100
2	Inland fresh meadows	7,518,600
3	Inland shallow fresh meadows	3,969,600
4	Inland deep fresh meadows	2,347,300
5	Inland open fresh water	2,596,500
6	Shrub swamps	3,813,500
7	Wooded swamps	16,779,000
8	Bogs	3,347,800
Total		63,464,400

Source: Shaw and Fredine, 1956

In addition to the classification system, the publication discussed the results of previous Department of Agriculture wetland inventories conducted between 1906-1953, which focused on identifying wetlands that had the potential to be drained for conversion to agriculture. The 1906 inventory identified 79 million acres that would qualify as wetlands that could be profitably drained; the 1922 inventory identified 75 million acres that could be drained for agricultural profit. In 1953, the estimate was 53 million acres of drainable wetlands.

In 1979, a significantly revised wetland classification system was published by the U.S. Fish and Wildlife Service, *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al., 1979) for use in the analysis and preparation of reports required to identify the status and trends of wetlands in the United States since the mid-1970's. This system is based on biological and ecological concepts and relationships that include all types of wetlands that are defined in terms of hydrophytes, hydric soils and frequency of inundation. The system also includes deepwater habitats that are usually omitted in wetland classification systems. The Cowardin system was adopted by the U.S. Fish and Wildlife Service and officially replaced Circular 39 as the agency's wetland classification system.

The Cowardin system is a hierarchical system that divides wetlands and deepwater habitats into the five major systems of marine, estuarine, riverine, lacustrine, and palustrine with 10 subclasses and 55 classes. Freshwater wetlands are included in the palustrine system with six classes that replaced the eight freshwater wetland types described in Circular 39 (Table 2).

Table 2. Classes of palustrine wetlands

Palustrine class	Description
Vegetated palustrine wetland types	
Emergent wetland	characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens
Scrub-Shrub	areas dominated by woody vegetation less than 6 m (20 feet) tall.
Forested	characterized by woody vegetation that is 6 m tall or taller
Nonvegetated palustrine wetland types	
Aquatic bed	Dominated by plants that grow principally on or below the surface of the water
Unconsolidated bottom	25% of area covered with particles smaller than stones with a vegetative cover less than 30%; usually permanently flooded, intermittently exposed or semipermanently flooded
Unconsolidated shore	Substrates lack vegetation except for pioneering plants; includes mudflats

Reference: Cowardin et al., 1979

Wetland functions and values

Wetland functions and values are two different concepts. Wetland functions can be described as the biological, physical and chemical processes that occur within the wetland ecosystem that may affect only the wetland or could extend beyond its boundary (Smith et al. 1995; MEA 2005). The Millenium Ecosystem Assessment (2005) defines ecosystem services as the benefits people obtain from ecosystems…which include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious, and other nonmaterial benefits. This definition can be simplified to the consequence of only some ecosystem functions… ecosystem services have relevance only to the extent human

populations benefit from them (Ruhl et al, 2007, p15). There are many wetland functions that satisfy ecosystem service criteria such as nutrient recycling, water supply, groundwater recharge, floodwater storage, waste removal, erosion control, climate control, carbon sequestration, pollution control, oxygen release, food production and raw materials (Mitsch and Gosselink, 2000; Heal, 2000; Carpenter and Turner, 2000; Turner et al., 2000; Hefner et al., 1994; Costanza, 1997; and Millenium Ecosystem Assessment, 2005) (Table 3).

Table 3. Wetland functions

Habitat
Sediment removal
Oxygen production
Nutrient recycling
Flood control
Erosion control
Groundwater recharge
Groundwater discharge
Water supply
Peat production (energy)
Recreation
Aesthetics
Education
Biomass production (carbon sequestration)
Soil formation
Food production
Raw materials
Carbon storage and sequestration
Waste removal
Climate control
Carbon sequestration
Pollution control

Source: Tiner (1984); Woodward and Wui (2001); Wilson and Carpenter, 1999; Mitsch and Gooselink,2000; Barbier (994); Smith (1995); Ruhl et al. (2007); Gleason et al., 2008; MEA, (2005)

Ecosystem services represent a paradox because they are extremely valuable, but it is difficult to assign them a value because they do not pass through a market like other goods and services. They are therefore generally undervalued or given no value or consideration in decisions regarding use of natural resources or capital. Ecosystem services in general and wetland ecosystem services in particular, represent a complex interaction between ecological processes and requirements, geographical landscapes and resources and economic forces and markets (Ruhl et al., 2007). The ecosystem functions of denitrification for example, has not changed in 200 years, but its service value to society has grown tremendously as aquatic ecosystems have become overloaded with nitrates and water supply needs have expanded greatly. Primary productivity of wetlands is among the highest of all ecosystems (Costanza, 1997), resulting in production of oxygen and carbon sequestration, due to photosynthesis, and biomass and detritus critical for associated food webs. Wetlands reduce water erosion in all environments by serving as a buffer between waves, currents and land. Their presence dissipates the force of the water and the plant roots hold soil to prevent its loss. Although these functions occur within a wetland, their impact is felt outside its boundaries.

Environmental quality functions are less obvious but vitally important. Wetlands impact water quality by removing nutrients and sediments. Wetlands are located at the transition between land and water and receive both flood waters and surface runoff and have been shown to reduce nitrate-nitrogen levels by 68 percent and phosphorous levels by 43 percent (Woltemade, 2000), thereby providing a buffer against eutrophication of adjacent or downstream bodies of water. Wetland plants used in sewage treatment systems have been shown to reduce biological and chemical oxygen demand by 90 percent (Verhoeven and Meuleman, 1998). Sediments are effectively removed due to the filter-type environment presented by the plants that reduce water velocity to allow sediments to be deposited in the wetland. Boyer and Polasky (2004) identified annual ecosystem service values provided by urban wetlands to be between $2.99-$1,211/acre; annual economic values to society have been estimated for certain wetland functions in specific areas to be as much as $1M for air pollution benefits from a 2300 acre wetland in Georgia, and $25M from aquifer recharge in a 552,000 acre wetland in Florida (Hefner et al., 2000). .

The Millennium Ecosystem Assessment identified a linkage between ecosystem services and human well-being with four major categories of ecosystem services -provisioning, regulating, cultural, and supporting. The majority of services are non-market. These categories of ecosystem services were linked to human welfare concerns of security, health, social relations, required materials for life, and the freedom of choice to select which ecosystem services society values most. The importance of the linkage between ecosystem services and human well-being is significant even without assigning a specific economic value to a specific service. It is clear that society depends upon the ecosystem services provided, such as nutrient cycling and oxygen production, and society can significantly impact the quantity and quality of these services through over-harvesting or the conversion of a wetland to agricultural fields or a housing development. The linkage concept emphasizes the inter-relationship between, and the value of, ecosystem services produced and human well-being.

Wilson and Carpenter (1999) divided ecosystem goods and services into direct market goods and services and non-market goods and services. When applied to wetlands, the value of direct market goods and services associated with wetlands such as fish, furs and timber can be determined by traditional markets. Both Woodward and Wui (2001) and Wilson and Carpenter (1999) identified methods to establish the value of non-market ecosystem services of wetlands, which included travel cost, contingent valuation, and hedonic models. In addition, Woodward and Wui (2001) included net factor income as a reference to market goods associated with wetlands. The use of contingent valuation and hedonic pricing to assess wetland value has been extensively discussed in the literature by Diamond and Hausman (1994), Portney (1994), Wilson and Carpenter (1999), Lant and Tobin (1989), Lant and Roberts (1990), Doss and Taft (1996), Mahan et al., (2000), Lupi et al.,(1991),Reynolds and Regaldo, (2002), and Shultz and Taff (2004).

Over 80 percent of wetlands are in private ownership so the majority of the economic benefits produced by the wetlands benefit the public rather than the landowner. The quandary faced is whether a landowner will manage a wetland for public benefit or manage the wetland for private profit (Heimlich et al., 1998; Ruhl et al., 2007). The benefits to society are real and can be estimated, but cannot be converted directly into cash for the landowner, whereas selling the land for development or conversion to agriculture will immediately and directly benefit the landowner. The overriding impact of wetland conversion is the potentially irreversible loss of important functions that have economic impacts as lost or diminished ecosystem services (Lant et al, 2008).

The economic value of wetlands has also been estimated by Thibodeau, (1981), Reimond and Hardisky (1978), Farber and Costanza (1987) and Barbier (1994). One way to establish the market-based economic value of a wetland for agricultural purposes is to compare the expected revenue from crop production after conversion to the cost of installing and maintaining a drainage system. An additional consideration is the increased real estate value of the land after conversion to agricultural cropland. Pavelis (1987) determined drainage increased property values at least as much as 30 percent in 1985. The exact increase in value depends on many variables such as the commodity involved, its yield over time, how quickly the fields lose saturation, and their location. Regardless of the variables, installation of drainage systems increases land value in the long-term Decisions regarding the economic value of a wetland should compare the value of the action, such as converting to cropland or selling for development, as determined by market forces, with the functional value (value of ecosystem services provided) of the wetland. This is a difficult and complex decision because the true value of wetlands is not readily apparent to the owner and it is difficult to assess the value of ecosystem services provided by a specific wetland. When properly measured, however, the total economic value of a wetland's ecological functions, its services and its resources may exceed the economic gains of converting the area to an alternative use (Barbier, 1994, p155). Even if the value of a wetland's functions are determined, there is no direct payment to the landowner by ecosystem service recipients for providing those services.

The economic value of a wetland depends upon its use. In its natural state it produces ecosystem services, if converted to agriculture or some form of development, its value depends upon the revenue the wetland area would produce. In an agricultural setting, prior to 1985, the wetland value equated to the crop production and expected commodity price after the costs of drainage are considered. The 1985 Farm Bill added additional economic issues to consider; potential loss of federal farm benefits if a wetland was drained and potential income if the wetland were conserved and enrolled in the Conservation Reserve Program and, after 1990, the Wetland Reserve Program. The conservation provisions of the 1985 Farm Bill established an economic value of an acre of wetland that did not previously exist.

Wetland losses

Estimates of the original acreage of wetlands in the conterminous Unites States vary between 211 to 221 million acres with 221 million acres accepted by the U.S. Fish and Wildlife Service (FWS) as the most accurate estimate (Dahl, 1990). In the United States, half of the original wetland resource has been lost (Dahl, 2011). Human activities that encouraged wetland losses include agricultural policies, urban expansion, transportation infrastructure, and oil and gas exploration. Dahl (1991) identified 22 states that lost 50 percent or more of their original wetlands, with losses in major Midwest farm states exceeding 85 percent (Table 4).

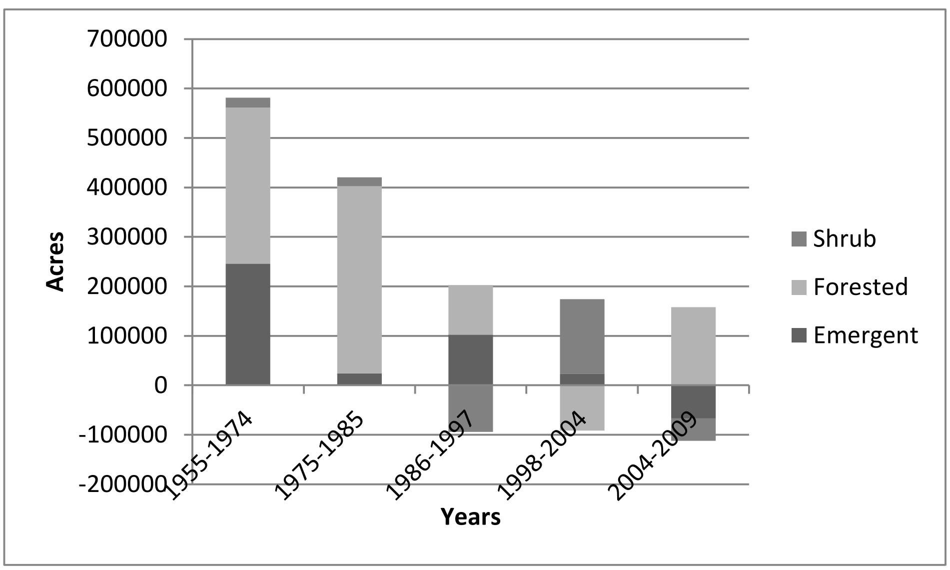
Table 4. Changes in Wetland Acreages in Certain States 1780-1980

State	1780 Acreage	1980 Acreage	Lost Acreage	Percent lost
Alabama	7,567,600	3,783,800	3,783,800	50
Arkansas	9,848,600	2,763,600	7,085,000	72
California	5,000,000	454,000	4,546,000	91
Connecticut	670,000	172,500	497,500	74
Delaware	479,785	223,000	256,785	54
Florida	20,325,013	11,038,300	9,286,713	46
Georgia	6,843,200	5,298,200	1,545,000	23
Illinois	8,212,000	1,254,500	6,957,500	85
Indiana	5,600,000	750,633	4,849,367	87
Iowa	4,000,000	421,900	3,578,100	89
Kansas	841,000	435,400	405,600	48
Kentucky	1,566,000	300,000	1,266,000	81
Louisiana	16,194,500	8,784,200	7,410,300	46
Maryland	1,650,000	440000	1,210,000	73
Michigan	11200000	5,583,400	5,616,600	50
Minnesota	15070000	8,700,000	6,370,000	42
Mississippi	9,872,000	4,067,000	5,805,000	59
Missouri	4,844,000	643,000	4,201,000	87
New Jersey	1,500,000	915,960	584,040	39
New York	2,562,000	1,025,000	1,537,000	60
North Carolina	11089500	5,689,500	5,400,000	49
North Dakota	4927500	2,490,000	2,437,500	49
Ohio	5000000	482,800	4,517,200	90
Oklahoma	2,842,600	949,700	1,892,900	67
Pennsylvania	1,127,000	499,014	627,986	56
Tennessee	1,937,000	787,000	1,150,000	59
Texas	15,999,700	7,612,412	8,387,288	52
Virginia	1,849,000	1,074,613	774,387	42
Wisconsin	9,800,000	5,331,392	4,468,608	46
Total	188,417,998	81,970,824	106,447,174	57

Source: Dahl, 1990

Generally, losses in emergent wetland acreage have been higher in the Midwest states, as well as Florida, California and Texas; losses in forested wetland acreages have been highest in the Southeast states (Dahl and Johnson, 1991; Hefner et al., 1994) and losses in shrub wetlands have occurred at various locations, especially in the Lower Mississippi Valley. Emergent wetland gains and losses reflected responses to agricultural conservation programs compared to crop prices, especially corn. Acres were enrolled when the prices were low, but withdrawn when prices increased. Timber harvests and silviculture impacted forested wetland gains and losses. Changes in palustrine vegetated wetland loss rates varied between report periods and between different wetland types (Table 5). Loss rates for all palustrine wetland types dominated between 1955-1985, when gains first occurred to emergent vegetation followed by gains in forested wetlands in the 1998-2004 period, and gains to both shrub and emergent wetlands between 2004-2009. Palustrine vegetated wetland loss rates exceeded wetland gains, however, for the entire period.

Table 5. Palustrine vegetated wetland loss rates, 1955-2009.



Source: Frayer et al., 1983; Dahl and Johnson, 1991, Dahl, 2000, 2006 and 2011

Status and trends of palustrine vegetated wetlands

The status of the nation's wetlands are monitored and reported by two federal agencies. The Emergency Wetland Resources Act of 1986 requires the U.S. Fish and Wildlife Service (FWS) to report to Congress on the status and trends of the nation's wetland resources approximately every 10 years. The Natural Resource Conservation Service (NRCS) is required to report at five-year intervals on the status of soil, water, and related resources, which include wetlands, by the Rural Development Act of 1972, Soil and Water Resources Conservation Act of 1977, the Food Security Act of 1985, and the Food, Agriculture, Conservation, and Trade Act of 1990. Although both agencies currently use Cowardin (1979) as the wetland classification system for the reports, there are significant differences between the legislative mandates of each agency in preparing the reports, sampling methods, and handling the data and its analysis. As a result, the two reports are not directly comparable or interchangeable (Dahl, 2011). The FWS data that support the status and trends were used in this study. Status and trends reports have been published by the FWS in 1983, 1991, 2000, 2006 and 2011 (Table 2). The studies followed the same methodology, used the same basic sample plots, but added some additional plots in the latter reports to increase statistical reliability. Wetland assessment and evaluation methods changed as technology advanced and field verification was employed to ensure report accuracy. The reports do not differentiate between private or publically owned wetlands and identify the wetland acreage lost or converted since the previous report. When viewed together, the reports present an historical assessment of the status and trends of the nation's wetlands over a 50-year period, and provide a database of wetland gains, losses and conversions by wetland type, state and physiographic region.

The reports reflect two types of actions that impact wetland acreage changes; wetland conversions and wetland loss. Wetland conversion is when one type of palustrine wetland (emergent, forested or shrub) converts to a different type of palustrine wetland such as shrub changing to forested. This change may be successional or due to human actions. Although the wetland type changes, the area is still a type of vegetated wetland. Wetland loss refers to actions that change the area from a wetland into a non-wetland such as draining or filling -- actions that adversely impact natural wetland hydrology. This study identified both wetland conversions and losses, with losses being the most significant factor in both the research questions and hypotheses.

Where did all the wetlands go?

Wetlands have been drained, filled or otherwise converted to other uses for a variety of reasons including agriculture, transportation, settlement and development, energy exploration and mining, navigation improvements and flood protection (Mitsch and Gosselink; Turner, et al., 2000). Wetland filling and drainage began in colonial America when inland wetlands were destroyed and converted to provide basic needs of subsistence, settlement and access. Efforts eventually focused on the economic opportunities provided by wetland conversion for agricultural lands and timber harvests particularly in Virginia, South Carolina, Georgia, and Louisiana. The common perception formed in eastern colonies that wetlands were wastelands, public health hazards, and impediments to progress and development was carried westward with expansion of the country and resulted in large wetland areas being converted to non-wetlands. The two major forces that facilitated wetland losses were agriculture and development, with agricultural conversion being supported by legislative and legal actions and technological advances in wetland drainage equipment.

Heimlich (1998) reviewed the history of wetland losses from Euro-American settlement until 1992. His assessment determined the annual wetland conversion rate was 814,000 to

887,000 acres from settlement to 1954; 458,000 acres from 1954 to 1974; 290,000 acres from 1974 to 1982 and 79,000 acres from 1982-1992, with agricultural conversions responsible for 95 percent of the conversions from 1954-1974 then decreasing to 53 percent between 1974 to 1982, then reversing the loss trend between 1982-1992 when agricultural lands became a source for wetland additions. Federal policies were identified as the cause for both wetland losses and gains. These figures are close to those identified by the U.S. Fish and Wildlife Service in the status and trends reports; 458,000 acres from 1955-1974; 290,000 acres from 1974-1985; 58,500 acres from 1986-1997; an increase of 32,000 acres from 1998-2004 and a loss of 13,800 acres from 2005-2009.

Swamp Land Acts

In the early 19th century, Congress realized there were vast areas of wetlands that were federally-owned, but possessed the potential to be sold and reclaimed as farmland. Starting in 1826 repeated attempts were made to introduce national legislation to measure the extent and map the location of swamp and overflowed lands that might be handed over to the states (Prince, 1997, p143). Bogue (1951, p170) emphasized that the basis for the political debates was that wetlands were thought to spread disease and death among the people, retarded settlement, and prevented the sale of contiguous federal land. Wetlands were considered to be a problem in both the lower Mississippi River basin and Midwest states. Significant floods in the first part of the 19th century finally prompted Congress to take action and passed the Swamp Land Act of 1849 that ceded unsold federal wetlands within Louisiana to the state for reclamation. The theory behind the Act was that states would be interested in promoting and organizing local drainage enterprises, that malarial swamps would be made healthy, drained land would be brought into cultivation, and the value of adjoining areas of public domain would be enhanced to the benefit of the U.S. Treasury (Prince, 1997, p143). The Swamp Land Act of 1849 transferred 9,384,626 acres of wetlands to the State of Louisiana (Prince, 1997). This first Swamp Land Act was followed by Swamp Land Acts in 1850 and 1859 with the same purpose, but directed at different states.

The Swamp Land Acts established federal support for wetland conversion by ceding approximately 65 million acres of wetlands to 15 states for reclamation (Prince, 1997; Heimlich et al., 1998) (Table 6). The goal of these Acts was to cede unproductive and unusable swamplands and overflowed lands to the states for sale to generate money to reclaim the land for farming and development. The United States was an agrarian nation and needed farms and productive farmland to support the growing population. In the mid-nineteenth century, industrialization was growing, but farming was still the basis of the national economy. The idea of reclaiming wetlands to increase farmland was a national priority and obligation as reflected in the bill's final wording that identified as swamp land "all swamp and overflow lands made unfit thereby for cultivation" (Vileisis, 1997, p73).

Table 6. Lands Ceded to States by Swamp Land Acts of 1849, 1850 and 1860

State	Swamp Land acres	Indemnity Acres	Total acres	Swamp Land Act
Alabama	418,634	20,920	439,554	1850
Arkansas	7,686,335	0	7,686,335	1850
California	2,159,304	0	2,159,304	1850
Florida	20,202,328	94,673	20,297,001	1850
Illinois	1,457,399	2,309	1,459,708	1850
Indiana	1,254,271	4,880	1,259,151	1850
Iowa	874,094	321,977	1,196,071	1850
Louisiana	9,384,626	32,631	9,417,257	1849
Michigan	5,655,816	24,039	5,679,855	1850
Minnesota	4,663,007	0	4,663,007	1860
Mississippi	3,286,306	56,782	3,343,088	1850
Missouri	3,346,936	81,017	3,427,953	1850
Ohio	26,252	0	26,252	1850
Oregon	264,069	0	264,069	1860
Wisconsin	3,251,684	105,048	3,356,732	1850
Total	63,931,684	744,386	64,676,070	

Indemnity acres were compensatory acres awarded due to conflicts over ownership or land type of originally identified swamp land.
Source: Prince, 1997

The nation's population was increasing and states wanted to attract settlers with the potential of cheap available land to create farms. Transferring land from the federal to state governments increased state control over swamplands within each state, and the revenue from land sales would flow to the states rather than the federal government. The basic problems remained however; the lands were wet, undesirable for existing farmers or new settlers, their agricultural value was suspect, and it was very expensive to drain the land.

The Acts did not achieve the anticipated goal of wetland reclamation. Land was sold to speculators, given to railroads to induce expansion, and became privately owned without the land being reclaimed. These Acts reflected the popular and political view of the time that wetlands lacked value, were a public health nuisance, and signaled the intention of the Federal Government to become directly involved in land reclamation and associated drainage enterprises (Pavelis, 1987, p5). Overall, the Acts did not achieve their intended purpose. The money received by the states was spent on infrastructure improvements, education, debt reduction, railroad benefits and inducements and associated lawsuits.

The Swamp Land Acts of 1850 and 1860 ceded 17,182,522 acres of wetlands to the Midwest states of Ohio, Indiana, Illinois, Iowa, Michigan, Minnesota and Wisconsin, 27 percent of the entire area of wetlands transferred (Prince, 1997). From 1857 – 1863, the majority of the swampland ceded to Illinois was sold to investors, many of whom were non-residents, but the nature of the wetlands differed. In 1868 the House of Representatives Committee on Public Lands was informed that half the swamp land grant given to Illinois, Indiana, Iowa, Ohio, Minnesota, and the Dakotas was in the hands of speculators (Prince 1997, p147).

Railroads and wetland losses

The Midwest contained extensive wet prairies that served as significant impediments for settlement. Major wetlands were the Black Swamp in Ohio, the Grand Prairie in Illinois and the prairie pothole region of Minnesota, Iowa and the Dakotas. Railroad development and expansion supported by government land offers played a significant role in the conversion of these wetlands and the stimulation for wetland conversions to agriculture. Many areas of the Midwest prairies contained poorly drained soils that held the water and were inundated for various periods of the year.

The Black Swamp extended southwest from the western end of Lake Erie in Ohio to Eastern Indiana and served to isolate southeast Michigan. The potential value of the Black Swamp was recognized in 1838 when it was described as consisting of a basin of hard clay upon which is bedded a thick stratum of the most fertile black loam (Kaatz, 1951, p15). Before the forested wetlands of the Black Swamp could be drained they had to be cleared. This was accommodated by the developing railroads that required an abundance of timber for fuel and ties, and provided a means of transportation for selling lumber, personal transportation, and access to markets. A significant economic impetus for clearing wetlands was the economic value of the trees to support the railroad's demand for lumber, which reached one million cords for fuel alone in 1860 (Kaatz, 1951). Timber was also converted to charcoal for use in smelting factories with one location requiring lumber from 1000 acres per year. Drainage and lumbering significantly contributed to the conversion of the Black Swamp into fertile farmland capable of producing significant corn crops. Within a few decades, the Black Swamp was transformed from a useless, obstructive morass into one of the most productive agricultural regions in Ohio and the Corn Belt (Kaatz, 1951, p32). Other significant wetlands in Ohio were also drained (Table 7).

Table 7. Major wetlands drained in Ohio

Historic Wetlands	Area in Acres	Date Drained	Source
Black Swamp	3,072,000	1859 - 1885	Ohio DNR, 1988
Pickaway Plains	4,800	1821	Gordon, 1969
Scioto Marsh	16,000	1859, 1883	Gordon, 1969
Hardin County Marshes	9,000	1860	Howe, 1900
Hog Creek Marsh	8,000	1868 - 1874	Gordon, 1969
Cranberry Marsh	1,000	Unknown	Gordon, 1969
Lake Erie Marshes	300,000	1936 - 1974	Bednarik, 1984
Dungan's Prairie	Unknown	1827	Middleton, 1917
Total	3,410,800		

Source: Dahl and Allord, 1996

In Illinois, the Grand Prairie was an extensive area extending from central Illinois into Indiana and was one of the largest contiguous areas of tallgrass/wet prairie east of the Mississippi River (Urban, 2005, p648). The Grand Prairie presented significant impediments to settlement due to its physical characteristics as well as the psychological impact it had on potential settlers. It was viewed as "a dangerous, disease-ridden swamp not fertile enough to support crops" (Urban, pg 648). Settlement was hampered by four factors: the tough tallgrass prairie sod that required extensive labor or draft teams to prepare the land for cultivation, health concerns over malaria, the threat of prairie fires, hordes of biting insects and the perception that the soil was unproductive. The wet prairies isolated the upland and drier prairie areas as there were few roads and bridges to provide passage and the roads that did exist became unusable in wet conditions (Urban, 2005, p652).

The potential value of the Grand Prairie as an agricultural area was recognized by Congress in the mid-1850's, when they acted to subsidize the construction of railroads through the area. The problems presented to growth and development were due to its isolating effect; the wet prairie soils made transportation difficult and prevented the flow of necessary goods into the area to create change and prevented the export of goods from the area. The final agreement was reached in 1850 when Congress gave the Illinois Central Railroad a land grant of 2,589,498 acres along the rail line from Chicago to Cairo, Illinois. The railroad received the land in a six mile strips along the rail line with the "even numbered sections assigned to the company, odd numbered sections in the private domain to be sold for at least double government's minimum price, that is not less than $2.50 per acre" (Prince, 1997, p176) with the railroad agreeing to sell its sections at the same price. Over the next 10 years, similar land grants totaling almost 25 million acres were awarded to railroads that crossed Iowa and Illinois (Prince, 1997). The amount of land granted to the railroads decreased the amount of public land available for settlers to create farms.

The railroads had a significant impact on wetland conversion. They afforded access to previously inaccessible areas, provided the goods to improve the land, a means of transporting commodities produced, accelerated the destruction of forested wetlands for wood supplies, but also facilitated the purchase of the lands by speculators rather than settlers, for later sale at higher profits. As a result, the cost of an acre of unimproved wet prairie adjacent to a rail line cost significantly more than an acre several miles from a rail line (Prince, 1997). The higher cost of the land, plus the additional cost required for draining the wet prairie to make it suitable for cultivation, prevented small and poorer settlers from purchasing the land and encouraged land speculation. In 1870, in the three prairie states of Indiana, Illinois and Iowa alone, speculators held not less than 20,500,000 acres (Prince, 1997, p201).

Drainage, Technology and Tiles

In the latter half of the 1800's, there were several factors that significantly affected wetland losses: implementation of improved methods to drain wetlands, creation of drainage districts and technological improvements in drainage equipment. These factors changed the value of wetlands from having no value to being very valuable for agriculture.

The early and simplest method for removing excess water and drying soil was to construct ditches to drain the water into a waterway. Ditching was labor-intensive and only provided a temporary solution since the ditches required constant maintenance to keep them clear, open, and functioning. If the land was not adjacent to a natural stream, the landowner needed to obtain permission from adjacent landowners to cross their property. To address this issue, Midwest states enacted ditch laws. Indiana passed the first ditch law in the Midwest in 1832 that directed township justices of the peace to appoint twelve respectable landowners to ascertain whether proposed ditches were 'necessary and proper (Vileisis, 1997, p83). Illinois passed a law in 1845 that authorized landowners of adjacent farmlands to form field committees to oversee the construction of cooperative ditches, fences and dikes (Vileisis, 1997, p83). Michigan passed ditch laws in 1857 (Prince, 1997); Ohio in 1859 (Kaatz, 1955). Minnesota passed a drainage act in 1858 whose stated purpose was to regulate and encourage the drainage of lands (Wilson, 2000). A process for dispute resolution was identified in later acts in 1866 and

1876 that focused on disputes over landowners objecting to drainage ditches crossing their land (Wilson, 2000). In Illinois, the Illinois Central Railroad encouraged and supported drainage activities because, if the wet prairie lands they received in grants were drained, they could sell them at a higher price and drained land would support agricultural communities which would ensure future freight business.

Ditching was an effective and simple way to remove excess water to improve crop yield, but it was expensive and time-consuming. In order to lower costs, different ditching machines were developed, with the first steam-powered machine introduced in 1883. Although steam-operated ditchers reduced the labor force, they required extensive supplies of coal, with some as much as two tons a day.

Underground drainage tile was initially introduced and used in the United States in Geneva, New York in 1835. The underground tile system was introduced into the Midwest in Indiana in 1850 (Prince, 1997; Vileisis, 1997, Urban, 2005) and in Illinois in 1858 (Bogue, 1951). By 1870 the preferred method of draining wet areas in Illinois was by subsurface tiles (Urban, 2005). Tiling was an expensive proposition and there were few tile factories in the Midwest. In the Black Swamp area of Ohio, the demand for tile was so great that the number of tile factories increased from 5 in 1870 to 50 by 1879. Tiling became popular and tiles were in such high demand that, by 1882, 90 percent of all subsurface tile factories in the United States were located in Indiana, Illinois and Ohio (Prince, 1997, p213) (Table 8).

Table 8. Tile factories in operation in the United States, 1 January 1882

State	Number of factories
Indiana	486
Illinois	320
Ohio	230
Michigan	63
Iowa	18
Wisconsin	13
New York	8
Pennsylvania	2
Total in U.S.	1,140

Source: Prince, 1997, and S.H. McCrory, Historical notes of land drainage in The United States, Proc. Amer. Soc. Civil Engineers 53 (1927) 1629

Installation of tile-like ditching could be labor-intensive. Just as ditching stimulating the invention of the ditching machine, the need to install tile also resulted in tile-installation machines. Initially, horsepower provided the energy to remove soil to lay tile, but by the 1880's steam-powered machines replaced horses and oxen. These machines created a trench at the desired depth for the manual installation of the clay tiles, hollow tubes of various diameters that would allow water to seep in and then carry it away to an appropriate outlet such as a canal or stream. The value of tile drains was they would be installed at a certain level to drain the water from the soil above them to make a drier environment for the crop root systems. In spring, high groundwater would stunt root growth and the plants would wilt in late summer. Drained soils enable plants to develop deep root systems that are beneficial throughout the growing season (Prince, 1997).

There are several reasons for a landowner to go to the effort and expense of installing a tile drainage system. Drained land increased in value. For example, in Illinois in the 1870's, undrained land was valued at $3 - $12 per acre but drained land was $18 - $40 per acre (Bogue, 1951). Drained land was highly productive for crops, especially corn, which increased the harvest and farm income and the diversity of cash crops increased (Hewes and Frandon, 1952). Drainage of large areas enabled the owner to rent the farm to tenant farmers or divide the land into small farms to sell at a higher price as improved land. Land improved by drainage could command higher rent due to the increased productivity of the land. Rent was based either on the owner receiving a percentage of the crop, such one-third to one-half the grain crop, or $2 - $6 per acre cash rent. In addition to sharing the crop profit, the tenant was responsible for providing the seed and labor (Hicks, 1946).

Drained land afforded greater options for crops and allowed corn to become a viable option over wheat and hay that enabled farmers on drained lands to survive economic cycles of depressed prices (Prince, 1997). Corn became the primary crop in much of the drained wet prairie region since its productivity was twice that of other crops and its yield was more dependable. By 1879, the highest proportion of land growing corn and the highest yields gathered were from former wet prairies (Prince, 1997, p24). This is why this region of wet prairies, described as useless and unfit for agriculture, became known as the Corn Belt. In Illinois, the corn crop accounted for 60 percent of the total value of all cereals in 1890 (Destler, 1947, p105). Draining the wet areas was economically justified by the potential productivity of the converted wet prairies. Drained areas commanded higher prices since the land increased corn productivity that increased farm rent. In addition, drainage eliminated wet soil conditions that supported mosquitoes and malaria giving the perception of a healthier environment. @

Drainage Districts

McCorvie and Lant (1993) identified the importance of drainage districts in facilitating large-scale wetland drainage in the Midwest from 1850-1930. Wetlands were often the last of the public lands to be sold due to their marginal quality for farming and high cost associated with converting a wetland area to productive farmland. The value of these lands increased significantly, however, due to a combination of legislation that made the land available at a reasonable cost, improved drainage technology and the formation of drainage districts to collectively finance, construct, and manage drainage on the massive scale necessary to bring large areas of wet soils into agricultural production (McCorvie and Lant, 1993, p25). The combination of these factors resulted in 71 percent of the wetlands in the seven Midwestern states of Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio and Wisconsin being drained between 1850-1930. Drainage districts were successful because they had taxing authority to raise money to fund collective drainage projects that were too expensive for individuals, they coordinated the drainage system network to effectively remove water over a large area, and they had legal powers such as eminent domain to procure land for the common good of the district. The formation of drainage districts contributed significantly to the loss of Midwest wetlands.

A significant factor that contributed to the ability and decision to drain wetlands was ownership. Landowners, individually and collectively as members of drainage districts, decided it was in their best interests to drain wetlands to increase farmland, production and profit. There were no governmental regulations to hamper private landowners from implementing their personal vision of how to shape their land to increase their income. Factors that motivated Midwest drainage identified by McCorvie and Lant (1993) are increased population, market accessibility, demand for crops, and support of urban expansion. Productivity on drained land increased corn yield in Illinois by 50 percent and the value of drained farmland increased as much as 500 percent (Vileisis, 1997; McCorvie and Lant, 1993; Pavelis, 1987). The high productivity of drained wetlands was a strong motivation for draining wetlands in the eight Midwest states of Illinois, Indiana, Iowa, Michigan, Minnesota, North Dakota, South Dakota, and Wisconsin (Diedrick, 1981). Farming on drained wetlands yielded 10-30 more bushels per acre than corn grown on non-wetland soils.

McCorvie and Lant (1993) discussed the impacts of, and factors involved in, the creation of drainage districts in the Midwest between 1850-1930. The key factors identified as pivotal in these endeavors were: 1) legal standing of the created drainage district; 2) possessing the legal power of eminent domain; and 3) the power to tax. These three factors enabled the drainage districts to control and implement drainage activities over large areas and require the cooperation of multiple landowners who were part of the district. The creation of these organizations intensified the focus of drainage activities. Taxes could be assessed against real estate, rights-of-way, and easements in the districts in proportion to the amount of benefits each landowner was expected to receive (McCorvie and Lant, 1993, p22). The drainage districts provided the oversight necessary to coordinate the multitude of tile and drainage systems constructed to ensure they were properly connected and achieved the overall purpose. The empowerment of drainage districts to financially impact landowners also came with a stipulation that the proposed improvement was clearly to the benefit of the public at large, not merely to the advantage of a section or private interest (Vileisus, 1997, p207) and that the establishment of drainage districts must be of benefit to the public health, utility, and welfare, and the cost of the drainage must not exceed the estimated benefits to the properties affected (McCorvie and Lant, 1993, p31). In 1888, the Michigan Supreme Court ruled that the power of drainage districts to tax was proper and in the interest of public health (Vileisis, 1997, p207) and in 1890, the Minnesota Supreme Court made a similar ruling that supported drainage districts because they facilitated wetland drainage.

Most drainage districts flourished and were responsible for the organized drainage of significant wetland areas and are responsible for the development of the Corn Belt from the wet prairies of the Midwest. The acreage included in drainage districts in seven Midwestern states (Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio and Wisconsin) increased substantially from 756,081 before 1869 to 16,792,947 in 1919 with 60 percent of the acreage in drainage districts occurring between 1900 and 1919.

Not all drainage districts were successful, however. The northern Midwestern states of Minnesota, Wisconsin and Michigan possessed bogs rather than wet prairies, presenting different challenges for drainage and post-drainage farming. Prince (1995 and 1997) described the events that led to the collapse of drainage districts in central Wisconsin that possessed abundant forests, bogs and peatlands. The clear cutting of the forests, availability of cheap land due to the Swamp Land Act and the development of wheat as a major crop enticed immigration. By 1900, the success of drainage in the wet prairies stimulated the idea that the northern bogs could also be drained to create valuable farmland, and drainage districts were established in central Wisconsin that included over 300,000 acres by 1907 (Prince, 1995). Peatland did not respond to drainage the same as the wet prairies; as water was drained the peat shrank, the ditches became shallower, outlets were no longer adequate and the ditch sides collapsed when the dry peat decomposed. The soils were acidic, not fertile as in the Grand Prairie, and the only solution to improve fertility was to add fertilizer, which was economically prohibitive when added to extra costs of having to reconstruct the ditches. These problems, plus low crop prices and peat fires, combined to drive many farmers out of the districts, leaving those that stayed with exorbitant costs associated with the drainage district that could not be paid. As a result, by 1930 most drainage districts in central

Wisconsin were either dissolved or reduced in size (Prince, 1997, p270) and the lands reverted to the government due to tax forfeiture laws.

Wetland drainage started slow in the mid-1800's, increased during the late 1800's and peaked in the period of 1900 – 1919, then tapered off during the 1930's and 1940's and increased during the 1950's (McCorvie and Lant, 1993; Prince, 1997). By 1959 over 51 million acres were part of established drainage districts; 97 percent of that acreage was entered by 1930 (Table 9).

Table 9. Wetland acres and drainage districts in 1959.

State	Original wetland acres (Dahl, 1990)	Acres in drainage districts, 1930	Acres in drainage districts, 1959	Percent of acreages in district by 1930
Illinois	8,212,000	5,032,682	5,661,468	89
Indiana	5,600,000	10,214,014	10,411,018	98
Iowa	4,000,000	6,131,649	6,207,017	99
Michigan	11,200,000	9,170,851	9,197,216	100
Minnesota	15,070,000	10,574,683	10,945,063	97
Ohio	5,000,000	7,372,051	7,440,854	99
Wisconsin	9,800,000	1,299,616	1,406,851	92
Total	58,882,22	49,795,546	51,269,487	97

Source: McCorvie and Lant, 1993; Dahl, 1990

Regional drainage activity

Wetland conversions did not occur uniformly or randomly across the country, but were concentrated in certain areas. Historically, the general path of wetland conversion in the conterminous United States followed settlement patterns from the coastal northeast to the southeast, to the Midwest, California and the Lower Mississippi River Valley. The major stimulant for converting wetlands was to create or increase agricultural land. But a determining factor in success of the conversions was the nature of the wetland. Wet prairies of the Midwest required effective drainage methods and establishment of drainage districts that possessed the legal and taxing authority to implement large-scale drainage efforts. Floodplain wetlands of the Lower Mississippi River and Central Valley of California required drainage systems but also required construction of protective levees to prevent floods from periodically inundating reclaimed wetlands. Differences in the magnitude, cost and complexity of draining activities varied between regions with the Lower Mississippi Valley and Central Valley of California benefitting from federal involvement, but conversions of the wet prairies were dependent upon landowner initiatives.

The initial use of the wet prairies in Illinois was for cattle grazing since it required little capital outlay and no improvements since the area served as open rangeland. In their natural condition, wet prairies served as major areas for cattle ranches from 1855-1880 (Bogue, 1951). Many large ranches existed within the Grand Prairie using the wetlands as permanent pastures rather than going to the expense of trying to drain them for crops. By the late 1800's the wet prairies were still regarded as unfit for cultivation unless the water could be removed, so much of the area was retained in an undeveloped state for use by livestock or as investments by land speculators. Bogue and Bogue (1957) studied land speculation in Illinois during this period and identified a profit of between 6.4 to 18.9 percent on investments in wet prairie land from 1835 – 1880.

Although the wet prairies generated financial benefits through speculation, tenant farming and open range cattle ranching, the real potential for economic value of the land was as agricultural cropland. In order to increase land value and productivity, however, efficient and cost-effective methods had to be devised to remove water from the land. The Swamp Land Acts failed to serve as the stimulant for wetland drainage even though prices were as low as $.10 per acre. The land didn't sell because it was so costly to drain (Prince, 1997). Draining activity was the responsibility of the individual landowner and not the government, so converting the wet prairies into agricultural land was not achieved until the cost of drainage made conversion profitable.

California possessed significant wetland areas and suffered the same problems of other states; wetland areas were undesirable and hard to sell to new settlers and they were not viewed as valuable in their natural condition. The Central Valley of California is approximately 400 miles long and 60 miles wide located between the Sierra Nevada and Coastal Ranges, with the principal rivers being the Sacramento in the north and the San Joaquin River in the southern part. It contained over four million acres of wetlands. The two rivers meet to form the Sacramento-San Joaquin delta before they empty into San Francisco Bay. The delta was originally a vast complex of canals, sloughs and freshwater tidal marshes supported by annual flooding of the Sacramento River following the mountain snowmelt.

California received about two million acres of swampland in the Swamp Land Act of 1850. In order to comply with the Act, the state established local districts to sell the land at one dollar per acre and constructed levees to protect reclaimed wetland from flooding. The work was unsuccessful, however, and flooding continued exacerbated by upstream hydraulic mining activities that dumped huge sediment loads into the rivers that raised streambeds causing rivers to overtop the levees and flood previously drained lands. There was no successful overall management of levee construction and drainage until the late 19th century when the Corps of Engineers and the Bureau of Reclamation were directed to design, and construct a flood control and irrigation plan. By 1920, 70 percent of the original wetland resources were drained.

The wetlands of the Lower Mississippi Valley were decimated by conversion to agricultural land and harvesting of cypress timber from the extensive floodplain forests. Levees were constructed that physically destroyed some wetlands and severed the connection between the river and other wetlands. The federal government recognized the need for a coordinated and extensive levee system to support multiple purposes of navigation and flood control.

Construction of the levee system was assigned to the Army Corps of Engineers, but individual landowners benefitted from the protection provided by the levees and enabled large areas of floodplain wetlands to be drained and converted to agricultural land.

The majority of wetland conversions prior to the mid-1950's occurred in the Midwest, but between the mid-1950's, and the mid-1970's drainage focus changed to the Southeastern, Delta and Gulf states. According to Heimlich et al. (1998) wetland conversion in the Southeastern states accounted for 60 percent of all conversions while the Delta and Gulf Coast contributed 30 percent of wetland conversions with 75 percent of those occurring in North Carolina. The majority of the Delta and Gulf Coast conversions were due to loss of coastal wetlands in Louisiana and conversions for agriculture in Texas and Mississippi. Dahl and Johnson (1991) identified the majority of forested wetland losses occurred in the southeastern states while emergent wetland losses occurred in the Midwest, Florida, California and Texas. The increase in wetland conversions in the Delta states were attributed to agricultural expansion in Louisiana, Mississippi and Arkansas while the southeast losses were attributed to urban development and agricultural expansion.

Why convert wetlands

Over 80 percent of all wetlands are on private land (Heimlich et al., 1998), but federal government policies and regulations exert a significant influence upon whether the wetlands are conserved or converted. A major determinant for the fate of many wetlands remains an economic incentive based on whether a wetland has more value as a natural area or converted to some other use. A difference in decision-making between the mid-1800's and today is the additional economic considerations created by conservation- focused government farm policies.

These include Swampbuster, which links wetland preservation with federal farm subsidies, and conservation land retirement programs, such as the Conservation Reserve Program and Wetland Reserve Program, that pay landowners to conserve and restore wetland resources for specified lengths of time.

Initial federal policy that promoted reclamation of wetlands was established by the Swamp Land Acts of the mid-1800s. This view towards the lack of value of wetlands was emphasized in federal farm policies in the Farm Bills from 1933-1985, which provided economic and technical support to drain wetlands for agricultural use. A significant amount of palustrine vegetated wetland acreage was converted to agricultural land over the past 150 years due to surface draining, installation of subsurface tiles, and facilitated by formation of drainage districts. Wetland losses due to agricultural conversions are well documented by the FWS status and trend reports from the mid-1950's and 2009 (Table 10). The majority of wetland conversions occurred prior to the enactment of the Food Security Act of 1985.

Table 10. Palustrine vegetated wetlands lost or gained due to agriculture decisions.

Years	Annual Loss rate All wetlands (acres)	Percent loss due to agriculture conversion	Palustrine wetland acres lost
Mid-1950's-mid-1970's	458,000	87	398,460
Mid-1970's-mid-1980's	290,000	54	156,600
1986-1997	58,5000	26	15,210
1998-2004	-32,000 (Gain)	-11	-70,770 (Gain)
2005-2009	13,800	1	46,300

Source: Frayer et al., 1983; Dahl and Johnson, 1991, Dahl, 2000, 2006 and 2011

Rural and urban development and transportation projects have significantly contributed to wetland losses (Crosson and Frederick, 1999). As the impact of agricultural conversions lessened, the impact of development increased, with transportation projects such as road-building of paramount importance. Urban expansion necessitated the need for more highways and bridges, increasing wetland losses. Urban and rural development surpassed agricultural conversions as a major contributing factor for freshwater wetland losses starting in the mid-1980s (Figure 3).

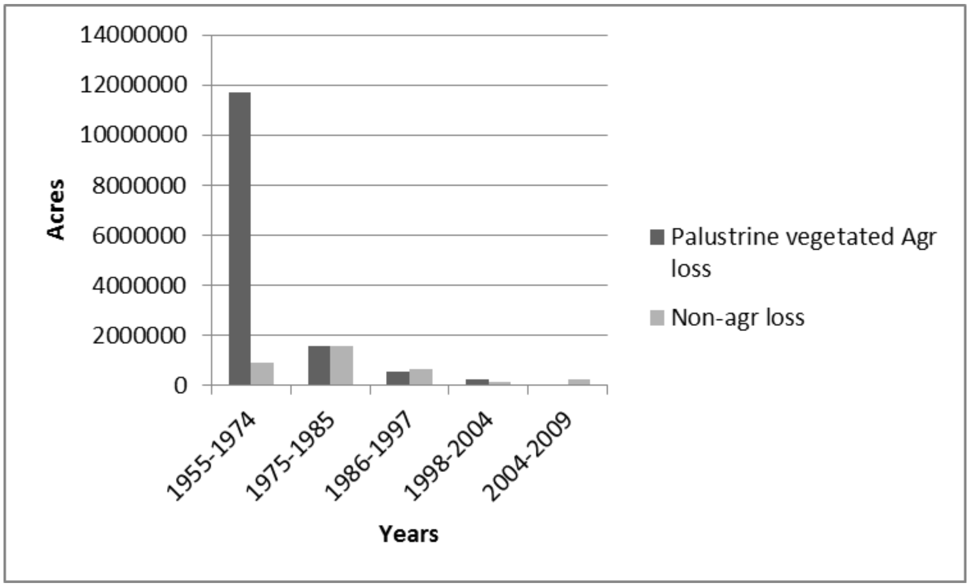


Figure 3. Acres of palustrine vegetated wetlands lost due to agricultural conversion and development, 1955 – 2009
Source: Frayer et al. 1983; Dahl and Johnson, 1991; Dahl 2000, 2006, 2011

A change in public perception of wetlands became evident starting in the 1970's with enactment of many environmental control laws that reflected society's overall concern about environmental quality (Tiner, 1984) and increased concern over natural resources such as wetlands. A combination of federal regulations and laws such as Section 404 of the Clean Water Act permits for fill and dredging wetlands, legal decisions that expanded regulatory jurisdiction of the Section 404 program, Executive Order 11990, Protection of Wetlands, which mandated federal actions minimally impact wetlands, the National Environmental Policy Act, which requires an environmental assessment be conducted before federally conducted or permitted projects are approved, and the Endangered Species Act were enacted in the 1970's. These were followed by significant federal farm policies that emphasized wetland conservation in the 1980's and 1990's.

Over the last 200 years, society and the federal government have vigorously supported and encouraged the conversion of wetlands to farmland as evidenced by the passage of the Swamp Land Acts, implementation of drainage systems on wet soils, technological advances in machinery designed to drain wetlands faster, the establishment of drainage districts to facilitate drainage of massive areas, and the construction of flood control and water management projects that directly eliminated wetlands and indirectly supported wetland conversions.

Agricultural policies and wetland loss rate

In 1933, the Federal Government initiated emergency agricultural programs in response to the national economic depression. The purposes of these programs were to increase commodity prices and farm income while reducing commodity surpluses. The Agricultural Adjustment Act of 1933, Soil Conservation and Domestic Allotment act of 1936 and the Agricultural Adjustment Act of 1938 set the tone for subsequent legislation and policies aimed at influencing the agricultural sector through direct payments to farmers and price supports. To achieve these goals, the Government tried to increase commodity prices by restricting acreage under cultivation through allotments, set-aside programs of crop acreage and paid diversions. Although these programs were enacted prior to the study period and focused on improvements to the agricultural sector, they encouraged and supported significant wetland losses, set the tone for wetland conversions to agricultural use and provided direct and indirect support for drainage activities that extended into the 1980's. The Department of Agriculture (USDA) created public policies that strongly influenced the land use decisions and management of private land until the mid-1980's; these decisions significantly contributed to the annual wetland loss rate of 458,000 acres between the mid-1950's and the mid-1970's and 290,000 acres from the mid-1970's to the mid-1980's. Agricultural policies have been dynamic in response to national and global economic, social and political conditions but ignored the impact they had on wetland resources. Contradictory USDA programs simultaneously stressed reducing commodity production, paid farmers to idle productive farmland, while supporting wetland drainage to create additional farmland that was used to take advantage of subsidy programs. The farm programs provided the opportunity for farmers to increase their income at the expense of wetland resources. Farm subsidies were based on acreage; as acreage increased, so did the amount of the subsidies received. This relationship provided a strong economic stimulant for farmers to increase acreage by converting wetlands to cropland. Simply put, more acreage increased the amount of subsidies received. It made good economic sense for farmers to convert wetlands to cropland.

Agricultural programs

The basic philosophy of Federal farm policies since 1933, has been to improve the economic position of farmers through a variety of price support programs and direct payments to farmers. These programs and policies reduced the risk levels of farming by guaranteeing minimum commodity prices, which encouraged overproduction and stimulated the conversion of wetlands to cropland, even if the productive quality of the new cropland was marginal. Not all farming environments were the same and not all subsidy programs applied to all crops, but they did include corn and wheat initially with the later addition of soybeans. Farm Bills specified the program crops and qualification criteria for benefits, and farmers determined if they satisfied the program criteria for benefits. Basic farm policy changed with the enactment of the Food Security Act of 1985, which introduced substantial conservation requirements, restrictions on wetland conversion, and economic incentives and disincentives for wetland conversions and contributed to the significant decrease in wetland loss rates. Significant federal agricultural policies that economically impacted farming include:

1. Nonrecourse loans: Used to establish and ensure the price a farmer will receive for a commodity. The USDA lends money to farmers based on the established loan rate of the particular crop. The loan rate is established by Farm Bills and the crops serve as loan collateral. The crop is stored and if the market price is higher than the loan rate, the farmer could sell the commodity, repay the loan, interest and storage costs and keep any profit; if the market price is below the loan rate, the farmer can forfeit the crop to the Government to repay the loan or sell the crop at the market price. This program encourages increased crop production because the minimum price per bushel is known so increased production results in increased income (Edwards, 2009).
2. Price supports/Deficiency payments: Target prices are established for specific crops based on the assumption that it is equal to the minimum cost of crop production. This ensures the farmer should not lose money during crop production, and the farmer knows in advance the value a commodity will have regardless of the actual market price. The target prices are established in the periodic Farm Bills. If the market price falls below the target price for a sufficient time period, the Government will pay the farmer the difference between the target price and the selling price in a deficiency payment (a direct payment to the farmer). This program only applied to participating farmers and payment ceilings were established at different levels and times to limit the amount of money any one farmer could receive.

3. Acreage allotments: Farmers were limited in the amount of acreage that could be enrolled into certain commodity programs (crops eligible for price supports) such as corn and wheat. Based on planting history, farmers were allotted acreage (a base), for specific crops. Prior to 1985, the base could be increased by dropping out of the program for one year while a new history of crop production was developed. This could be achieved by increasing productive acreage of a crop by converting wetlands to cropland. Conversely, if the USDA determined less production of a crop was required due to market conditions, then 50 percent of the reduced area had to be planted in a cover crop, which forced the farmer to remove land from crop production. It was possible to use the recently converted cropland for this purpose especially if the land was only marginally productive. A farmer could convert a wetland to increase its crop base to increase income then idle the converted land to maintain eligibility for program subsidies. Farmers would also certify crop yields for program crops, which would be used in determining deficiency payments.
4. Disaster payments and crop insurance. Farming success must deal with natural challenges due to weather. Too much or too little rain, rain at the wrong times of the growing season, hail, floods, and tornados all create conditions that could reduce or eliminate crop production. To combat these natural events, disaster payments initially, and then crop insurance later, were included in Farm Bills to economically compensate farmers for crop losses through no fault of their own. Wetlands that were recently converted to cropland can be problematic by either being too dry or too wet; either condition could reduce production and increase crop losses. These converted lands would also be subject to compensation through disaster payments. Both

disaster relief and crop insurance minimize economic risks of farming converted wetlands and encourage farmers to convert wetlands even if they are marginally productive, since crop losses are covered by disaster payments. Crop insurance replaced disaster payments in 1980.

5. The Farmers Home Administration was created as a bank for farmers that could not obtain loans from other sources. The Farmers Home Administration provides low interest loans that could be used for farming operations and cropland expansion including wetland conversions. The ability for farmers to obtain low interest loans to increase farming operations facilitated the conversion of wetlands.

Prior to 1985, farmers could take advantage of all the above programs to increase acreage under production in order to increase profitability. Price supports and deficiency payments encouraged farmers to plant more acreage than was justified if the subsidies were not present, and provided economic incentives to convert wetlands. Subsidy programs increased income stability by ensuring the price for a commodity regardless of the demand, provided the potential for increased income by expanding acreage that would qualify for program support, and reduced economic risks of farming by subsidizing crop insurance premiums that increased from 30 to 62 percent (Faber, 2012). Crop insurance protected the farmer from crop losses even when the crops were planted in areas that would be too wet to harvest. These benefits encouraged the conversion of wetlands and other marginally productive land to farmland, and were significant contributors to increased wetland loss rates. Wetlands presented problems to efficient farming operations in a number of ways, including their location, which could disrupt farming operations, endanger equipment, and require installation of drainage systems to reduce soil saturation levels.

Converting wetlands by draining, leveling or filling could improve efficiency of farming operations as well as increase crop production subject to federal program benefits.

Until 1985, there were no effective federal restrictions on wetland conversions so farmers could decide whether it was economically beneficial to drain wetlands based on potential increased income. Although USDA policies encouraged conservation practices, they were not focused on conserving wetlands. Farmers used the subsidies and support programs to increase their income at the expense of wetlands. A significant program that enabled and facilitated farmers to drain and convert wetlands was the Agricultural Conservation Program.

Agricultural Conservation Program (ACP)

A key link between farm policies and wetland loss rates was the Agricultural Conservation Program (ACP) that provided technical and financial support for wetland drainage and other farm projects. The ACP was created by the Soil Conservation and Domestic Allotment Act of 1936 (SCDA), which combined parts of the Agricultural Adjustment Act of 1933, and the Soil Conservation Act of 1935. The Act combined programs aimed at boosting commodity prices and implementing soil conservation practices and paid farmers to plant soil-conserving grasses instead of soil-depleting crops such as corn. The program for paying farmers to plant and maintain soil-conserving crops became the Agriculture Conservation Program (ACP) and developed into the main conservation program for USDA. The Agricultural Adjustment Act of 1938 emphasized and increased the role of the ACP by stating the purpose of the program was to provide financial assistance to farmers who implemented soil restoration, conservation, erosion control practices and changes in the use of their land. The original financial authority of the ACP was limited to pay for labor, materials and payments for planting cover crops. The 1938 Act, however, significantly expanded ACP financial assistance to include any type of vegetative, mechanical or structural conservation practice. The limits of financial assistance increased over time and included cost-share programs between the farmer and USDA to install conservation actions including drainage systems to convert wetlands to agricultural land. Participation in cost-sharing to install drainage depended upon the farmer's need, coinciding with the priorities of the county committee. The ACP was a diverse program that was managed by several USDA agencies including the Agricultural Adjustment Administration, Commodity Stabilization Service, Agricultural Stabilization and Conservation Service (ASCS) and Farm Service Agency. In 1951, technical assistance aspects of the program were consolidated in the Soil Conservation Service and financial assistance was consolidated in the ASCS. The ACP program was terminated in 1996.

From 1940-1985, the ACP provided over $77 billion in financial assistance, including cost-sharing, to install surface and underground drainage systems on 57 million acres of farmland (USDA, 1987). The average annual ACP funding from 1935-1994, was $200 - $300 million (Pavelis, 2011). The ACP was a powerful program for planning and funding changes in the agricultural environment. Although the ACP was a federal program, local county committees made decisions on which type of projects would be implemented. The ACP funds were apportioned to the states and the states divided the funds among the counties that were administered by local county committees. Decisions on the type of actions to implement and the amount of money to spend on structural and non-structural actions were at the discretion of these county committees with advice and input from governmental agencies. This type of decision-making ensured that funds were spent on projects that had the highest priority for the local farming community. Wetland drainage was a popular use of ACP support that peaked in 1947, with the total drainage of six million acres, with an average of 1.2 million acres drained per year (See Table 11).

Table 11. Total acres drained by ACP program 1940-1985

Year	Total Acres drained	Year	Total Acres drained
1940	57	1963	1,302,328
1941	1,502	1964	1,176,618
1942	11,036	1965	1,283,386
1943	254,335	1966	822,155
1944	2,455,457	1967	1,221,112
1945	2,165,514	1968	1,110,410
1946	4,031,263	1969	1,150,015
1947	5,597,023	1970	1.067,444
1948	3,292,153	1971	598,045
1949	3,718,813	1972	654,260
1950	2,970,695	1973	746,355
1951	2,390,269	1974	0
1952	1,857,812	1975	567,021
1953	1,513,357	1976	537,331
1954	1,306,582	1977	603,186
1955	1,362,453	1978	458,041
1956	1,260,872	1979	380,639
1957	1,069,449	1980	40,797
1958	1,636,502	1981	7,194
1959	1,597,511	1982	3,272
1960	1,657,788	1983	1,236
1961	1,520,136	1984	65
1962	1,482,351	1985	696
		Total	56,923,740
		Average	1,237,473

Source: Agricultural Conservation Program 45-year Statistical Summary 1936-1980; ASCS, USDA, 1981

ACP-funded drainage was not conducted uniformly throughout the country; in some areas open drainage ditches were more effective and appropriate than underground drainage systems. This reflects the local control and priorities for ACP projects and indicates drainage needs and priorities varied regionally. Approximately 79 percent of all open ditch drainage acreage occurred in 16 states between 1940-1983, with 65 percent occurring in 11 Midwest and Lower Mississippi Valley states. There were similar findings from 1956-1983, with the overall percentage of ditches installed in the 16 states remaining about the same but the percentage within the Midwest and Lower Mississippi Valley states decreased about four percent (See Table 12). The 16 states included in Table 11 lost an average of 61 percent of their original wetland acreage; the 11 Midwest amd Lower Mississippi River Valley states lost an average of 65 percent of their original wetland acreage. ACP funded drainage contributed to the wetland losses.

Table 12. Acres drained by ACP-funded open ditches 1940-1983.

State	Acres drained by ACP-funded open ditches 1940-1983	Percent of all ACP-funded open ditch acreage 1940-1983	Acres drained by ACP-funded open ditches in 1956-1983	Percent of all ACP-funded open ditch acreage 1956-1983	Percent of original wetlands lost by 1980
Arkansas	3,524,078	8.0	1,464,492	9.2	72
California	1,099,051	2.5	421,674	2.7	91
Florida	1,042,457	2.4	309616	2.0	46
Illinois	997,498	2.3	453,635	2.9	85
Indiana	977,125	2.2	553,307	3.5	87
Iowa	865,123	2.0	335,624	2.1	89
Louisiana	4,081,436	9.3	1,080,615	6.9	46
Michigan	2,720,264	6.2	295,546	1.9	50
Minnesota	3,898,467	8.9	1,496,090	9.5	42
Mississippi	4,896,641	11.2	1,860,456	11.8	59
Missouri	2,921,875	6.7	1,278,942	8.1	87
North Carolina	1,411,809	3.2	657,152	4.1	49
North Dakota	1,763,920	4.0	444,393	2.8	49
South Carolina	1,573,946	3.6	891,450	5.7	27
Texas	1,271,493	2.9	395,816	2.5	52
Wisconsin	1,639,762	3.7	313,368	2.0	46
Total	34,684,945	79.2	12,252,176	77.8	
Average	2,167,809		765,761		61
U.S. Total acres	43792726		15,758,178		

Source: Agricultural Conservation Program 45-year Statistical Summary 1936-1980; ASCS, USDA, 1981. Wetland losses in the conterminous United States 1780s to 1980s, DOI, USFWS, 1990.

Installation of underground drainage systems, like the open drainage ditches, varied regionally with 87 percent of all underground drainage installed in 12 states from 1940-1985, and 69 percent installed in seven Midwestern states. There was less underground drainage installed between 1956-1985 than the prior period, with lower percentages in all states and the seven Midwestern states (See Table 13). The 12 states included in Table 13 lost an average of 65 percent of their original wetland acreage; the 7 Midwest amd Lower Mississippi River Valley states lost an average of 70 percent of their original wetland acreage. ACP funded drainage contributed to the wetland losses.

Table 13. Acres drained by ACP funded underground drainage systems 1940-1985

State	Acres drained by ACP funded underground drainage 1940-1985	Percent of all ACP funded underground drainage 1940-1985	Acres drained by ACP funded underground drainage 1956-1985	Percent of all ACP funded underground drainage 1956-1985	Percent of original wetlands in 1980
California	579,713	5.0	381,905	5.5	91
Illinois	339,629	2.9	32,505	0.5	85
Indiana	1,409,877	12.0	842,552	12.2	87
Iowa	1,847,539	15.8	1,014,326	14.7	89
Michigan	1,323,467	11.3	772,000	11.2	50
Minnesota	1,054,377	9.0	652,622	9.5	42
New York	358,351	3.1	249,865	3.6	60
North Carolina	369,106	3.1	227,870	3.3	49
Ohio	1,856,269	15.8	947,625	13.8	90
Oregon	375,547	3.2	222,652	3.2	38
Pennsylvania	378,079	3.2	272,795	4.0	56
Wisconsin	282,449	2.4	81,703	1.1	46
Total	10,174,403		5,698,420		
Average	847,867	86.8	474,868	82.7	65
U.S. Total acres	11,718,368		6,888,558		

Source: Agricultural Conservation Program 45-year Statistical Summary 1936-1980; ASCS, USDA, 1981 Wetland losses in the conterminous United States 1780s to 1980s, DOI, USFWS, 1990.

Overall, open ditch drainage systems were more plentiful than underground systems, with the majority of underground systems being favored in the Midwest. The ACP provided the means for farmers to leverage agricultural programs for personal benefit with wetland losses being acceptable collateral damage. Program benefits were linked to commodity production that was linked to productive acreage, especially prior to 1985. A way to increase acreage and thus benefits was to convert wetlands to cropland. Approximately 87 percent of wetland losses between the mid-1950's and the mid-1970's, and 54 percent of the wetland losses between the mid-1970's to mid-1980's, were attributed to agricultural conversion (Dahl and Johnson, 1991).

Major forces in wetland conversions have been federal farm programs that subsidized farming with programs such as price support payments, subsidized crop insurance and marketing assistance; the annual cost of these subsidies was between $15 billion - $35 billion (Edwards, 2009). The amount of financial support available for farming was significant and farmers could increase the amount of financial benefits by increasing acreage, which was accomplished by converting wetlands and other marginal areas to cropland. The financial attraction provided by federal subsidies was simply too large to ignore. The economic impact of the subsidies is reflected in the comparison of average farm and non-farm household income. In 2007, the average farm household income was about $86,000, and the average non-farm household had an income of $68,000 (Edwards, 2009). Subsidies were a significant income stream for farmers. From 1956 – 2009, the United States annual budget for farm subsidies increased from $1336 million to $14,584 million, with a maximum value of $33 billion in 2000 (See Figure 4).

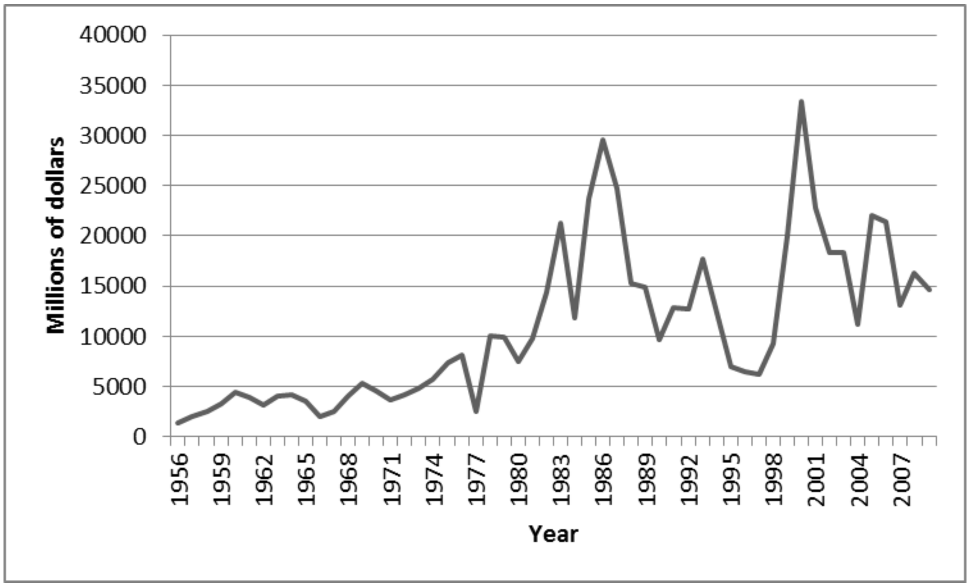


Figure 4. U.S. Budget for Farm Income Stabilization 1956-2009.
Source: Budgets of the United States Government 1956-2009

The distribution of farm subsidies is not equally shared between all sizes of farms. Since 1935, the average size of farms has significantly increased (See Figure 5) with farming operation concentrated in fewer farms. The majority of subsidies are paid to a small number of very large farm operations, with the 10 percent of largest farm operations receiving 72 percent of all subsidy payments (Edwards, 2007).

Figure 5. Average size of farms 1945-2007
Source: U.S. Agriculture Census published from 1935-2007

The USDA budget is large and attempts by different administrations to implement significant changes in farm policies that would reduce the subsidies and the USDA budget have been unsuccessful. Since the inception of farm subsidies in the 1930's, there has been strong Congressional support for maintaining and increasing subsidy programs by representatives of the agricultural states due to the number of farmers impacted. However, the number of farms has significantly decreased from a high of approximately 6.8 million in 1935 to 2.2 million farms in 2007 (see Figure 6), but he size of farms has increased.

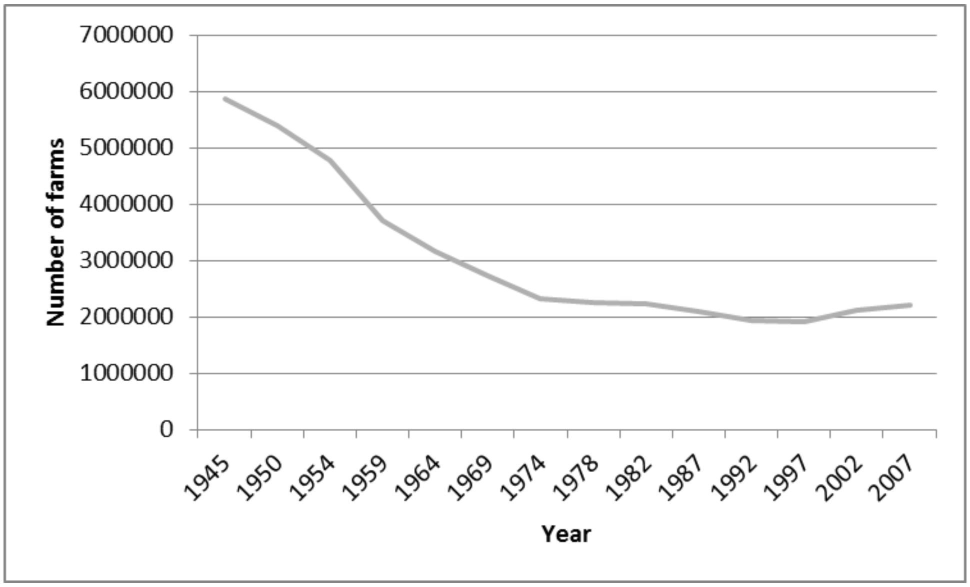


Figure 6. Change in number of farms from 1945 to 2007.
Source: U.S. Agriculture Census published from 1935-2007

Subsidies motivate overproduction by farmers, which reduces commodity prices, which stimulates politicians to create new or increase existing subsidies. Congressional actions increased subsidies in the 1996, 2002 and 2008 Farm Bills. The 1996 Farm Bill forecast subsidies to cost $47 billion dollars but they actually cost $121 billion, the 2002 Farm Bill increased subsidy payments by 74 percent over 10 years and the 2008 Farm Bill extended existing and created additional subsidy program (Edwards, 2009). The agricultural lobby remains strong due to the diversity of programs contained in Farm Bills; in addition to subsidies directed at core farming operations, the Bills include food stamps, which have backing from urban interests and conservation provisions such as the Conservation Reserve Program that are supported by conservation groups.

The support and priority of the county committees to use ACP for wetland drainage is reflected in Tables 11-13 and wetland loss rates. The states listed in Table 2 lost an average of 61 percent of their original wetland resources and an average wetland loss rate for the states having the highest acreage drained by open ditches is 61 percent; the states listed in Table 3 have lost an average of 65 percent of their original wetland resources (Dahl, 1990). The relationship between wetland losses and drainage acreage is significant. Wetland conversions to agricultural land have been a standard practice since the 1800's and are responsible for creating highly productive farmland, but there was a tendency to create too much, to drain all available wetland to increase cropland. This philosophy of farm management resulted in the farm crisis of the 1980's. Agriculture was a booming business in the 1970's, and many farmers, in order to take advantage of the conditions, became overextended financially by expanding land under cultivation by converting wetlands, and increasing commodity production. However, due to the surpluses, prices dropped (corn fell from $3.02/bushel to $2.02: wheat fell from $4.09 to $2.33/bushel) and total farm income decreased 42 percent from 1973 to 1977 (USDA, 1984). The loss of wetlands decreased the ecosystem services provided to society in general and local communities. For example, additional land being farmed meant more agrichemicals were applied to the land and there were fewer wetlands to absorb the chemicals before they entered surface or ground water systems. If the county committee selected drainage as a priority use for ACP funding, a farmer would receive technical assistance for project planning from the SCS and the ASCS. Financial assistance would be provided by the ACP as a cost-sharing program with the government paying up to 75 percent of the cost of certain soil and water improvements, crop management, and other actions deemed necessary to make farm operations more efficient. Farmers in the Midwest and Lower Mississippi Valley states had greater support for ACP-funded drainage systems than farmers in other regions. ACP was a significant contributor to wetland loss rates.

Food Security Act of 1985 - Swampbuster

Farm bills have been the legislative vehicle for establishing national farm policy and programs since the mid-1930's. These bills have exerted a major influence on agricultural production, benefits, philosophy, and landscape changes. The Food Security Act of 1985 (P.L. 99-198) significantly differed from previous farm bills by establishing environmental programs as an integral part of the agriculture program. A significant part of the bill that affected wetland loss was Title XII, Subtitle C-Wetland Conservation, the "Swampbuster" provision that created economic disincentives for wetland conversions to productive cropland (Margheim,1988). Farmers that produced a crop on a wetland area that was converted after December 23, 1985, lost eligibility in that year for U.S. Department of Agriculture benefits such as price support or payments, crop insurance, agriculture disaster payments, a farm storage facility loan, and certain agricultural insured or guaranteed loans (Zinn and Copeland, 1996, p3). The Swampbuster program was amended but retained in the 1990 farm bill.

Enactment of the Farm Security Act followed published reports by both the Fish and Wildlife Service (Frayer et al., 1983) and the Natural Resource Conservation Service that indicated an annual wetland loss rate of 458,000 acres between the mid-1950's and mid-1970's, with over 11 million acres lost due to agricultural activities. There were another 5.2 million acres of wetland considered highly susceptible for conversion. If a reduction of wetland losses was to be achieved, a change to agricultural policy was required. Since 80 percent of freshwater wetlands are privately owned, mainly in agricultural areas, a voluntary program with financial disincentives rather than a regulatory program was crafted that also reduced federal subsidies providing financial incentives to convert wetland to cropland (USDI, 1994, p103).

The act was passed on December 23, 1985; the Interim Rules were published in the Federal Register on June 27, 1986 with the Final Rules published on September 17, 1987. During the 21-month span, the impacts and administration of Swampbuster were tested in pilot programs conducted in six states, public comments were reviewed and the implementation rules were reshaped to be as effective as possible to achieve the desired goal. The potential of Swampbuster was addressed in a variety of articles soon after passage of the bill. Risley and Budzik (1988) were optimistic that the program could be a very beneficial and positive tool for reshaping farm policies, but cautioned that little wetland protection resulted from Executive Order 11990. Wetland delineation problems needed to be addressed, as did the focus and effectiveness of U.S. Department of Agriculture personnel in carrying out a program that was contrary to long-term agency philosophy and actions. Jones (1988) also identified the potential benefits of Swampbuster, but like Risley and Budzik had concerns over its administration by the Agricultural Stabilization and Conservation Service and Soil Conservation Service, two Agencies that have historically provided support, technical assistance and cost-sharing for wetland drainage (p30). Swampbuster did not penalize landowners for draining wetlands unless the land is cropped, so conversions for other reasons could proceed without penalty. Only farmers that participated in programs subsidized by the U.S. Department of Agriculture would be affected and enforcement emphasis would be uncertain due to the biased pro-production outlook of those tasked with enforcement. Margheim (1988) reviewed the implementation and administrative process from enactment to final rulemaking and identified potential problems based on definitions critical to implementation, including commencement, minimal effect, ineligibility, converted wetland, maintenance and improvement and third party. Overall his assessment was optimistic and positive, believing the act would preserve benefits of the current voluntary system, are sustainable in the long run, and provide for consistency (p28). Cook (1989) looked to the future and identified the need to increase enforcement provisions of the act to apply restrictions to wetlands regardless of whether a crop was planted. McElfish and Adler (1990) assessed the first two years of program implementation and determined it was not clear whether the objective of the act had been achieved and agreed with the shortcomings identified by Jones. Based on Agricultural Stabilization and Conservation Service, Soil Conservation Service, and Environmental Protection Agency data, the act had not prevented a minimum loss of over 82,500 acres of wetlands between December 1985 –January 1990, the punitive aspect of benefit denials was exceedingly low, with only 26 landowners being denied benefits by April 1989, and there were 31 states in which no violations were reported. On the positive side, McElfish and Adler (1990) identified wetland loss reductions occurred in six out of seven counties surveyed. Overall wetland losses had decreased, but cautioned the cause could also have been due to a decline in crop prices, not just Swampbuster. They felt the program had significant weaknesses associated with evaluating the concept of commenced exemption, lack of enforcement, and an inefficient and biased appeal process.

The trigger for potential Swampbuster violations was converting a wetland for crops after December 23, 1985, so it was critical to clearly define a wetland. Swampbuster legislation defined wetlands but created four wetland classification types unique to the program: wetland, converted wetland, prior converted wetland and farmed wetland (Table 14).

Table 14. Food Security Act of 1985 Wetland Classification

Code	Classification	Comments
W	Wetlands	Wetland areas; no additional drainage allowed
PC	Prior converted croplands	Wetlands converted prior to Dec 23, 1985; no longer meets wetland criteria. Additional Drainage and drainage maintenance allowed.
CW	Converted wetlands	Wetlands converted after Dec 23, 1985 to increase production. No additional drainage and no drainage maintenance allowed.
FW	Farmed wetlands	Wetlands manipulated and used for cropping prior to Dec 23, 1985 that still meet wetland criteria. No additional drainage but may maintain existing drainage. May be farmed.
AW	Artificial wetlands	Exempt from FSA
Source: Implementation of the "Swampbuster" provisions of the Food Security Act of 1985 A Report by the Environmental law Institute, 1990; Agricultural Wetlands: Current Programs and Legislative Proposals; CRS Report for Congress, 96-35 ENR, Zinn and Copeland, 1996		

The concept of Swampbuster was to deny federal agriculture benefits to land owners who: 1) converted a wetland to cropland after December 23, 1985 and 2) used the converted wetland for crop production. Program scope, definitions, agency policies and program exemptions combined to weaken the program's potential for reducing wetland losses.

Swampbuster only impacted farmers who participated in federal farm programs and only restricted wetland conversions and cropping of wetlands to produce commodity crops such as corn, wheat, or soybeans, rather than all crops. A wetland could be converted without loss of benefits if an annual crop was planted or if the conversion was for nonagricultural purposes such as construction of roads or buildings (USDI, 1994). Program eligibility was determined annually, so a person could crop a wetland when commodity prices were high and lose benefits for that year, but not crop a wetland in other years when commodity prices were low and qualify for benefits. Land owners could select when to comply with Swampbuster based on economics rather than environmental or conservation concerns.

Swampbuster exemptions and agency policies lessened the impact of program noncompliance by allowing landowners to apparently violate program provisions but still qualify for farm benefits. Significant were the commenced conversion, third party, farmed wetland, minimal effects and good faith exemptions (USDI, 1994; ELI, 1990). The commenced conversion exemption allowed landowners who had made significant financial commitments to convert a wetland prior to enactment of the Food Security Act, to continue the activity without penalty. The concept and implementation differed, however. As interpreted by the agency, “commenced” could be properly interpreted as not only actually having started work, but also to have contemplated conversion or made a financial commitment for drainage work. There was a “hardship” provision that applied whereby a landowner did not need to prove the conversion occurred prior to December 23, 1985 if the landowner would suffer “undue economic hardship” due to the financial obligations that were made (McElfish and Adler, 1990). The exemption could apply to individual acreage or entire drainage districts. The commenced exemption was used successfully. By March 1989, the Department of Agriculture approved over 78% of the 5,259 requests received for commenced exemptions (ELI, 1990). The “third party” exemption pertained to situations where a wetland was converted as a result of actions of a third party over which the landowner had no control, such as a development on adjacent land that affected wetland hydrology. The “good faith” exemption applied when a landowner took action based on the advice of a county or state committee. If a landowner questioned whether conversion of a wet area would be a violation of Swampbuster, and the program experts advised in error that it was not a violation, then the landowner would not lose benefits and the action was not required to be corrected. The farmed wetland exemption allowed cropping on wetlands if natural conditions and not human actions created suitable farming conditions. The minimal effects exemption allowed wetland conversion, if the activity individually or cumulatively had a minimal impact on hydrological or biological characteristics of the wetland and the purpose for the conversion was not to increase crop production. This exemption required formal mitigation agreements with the U.S. Fish and Wildlife Service. By October 1989, 171 minimal effects determinations were approved that converted 2,648 acres of wetlands. The average size per exemption varied from 2.4 acres to almost 36 acres (ELI, 1990). Determination of violations was not centralized within one agency but was delegated to the agencies that administered the different programs. The agencies determined if actions by a land owner violated Swampbuster and thus restricted application of their programs.

The Soil Conservation Service classified agricultural lands for program enforcement as shown in Table 11. These classifications are unique to the Food Security Act enforcement. The Agricultural Stabilization and Conservation Service determined if Swampbuster provisions had been violated or if exemptions applied, with the advice of "local county and state committees" (ELI, 1990, p5**)** whose members were active farmers who participated in federal agricultural programs. The Farmers Home Administration determined whether a loan was used to convert a wetland for crop production and the Federal Crop Insurance Corporation was responsible for denying insurance for crops produced on a cropped wetland.

An agency's decision regarding Swampbuster noncompliance could only be appealed by the landowner who was adversely impacted due to lost benefits. Although the purpose of Swampbuster was to reduce the loss of agricultural wetlands, there was no appeal process available to federal or state natural resource agencies that disagreed with a U.S. Department of Agriculture agency decision to allow wetland conversions. A successful appeal meant a wetland was converted.

The Swampbuster provisions of the Food Security Act were amended by the farm bills of 1990, 1996, 2002 and 2008. The Food, Agriculture, Conservation, and Trade Act of 1990 (Farm Bill), clarified the definition of a wetland, determined a violation was considered to have occurred when a wetland was converted for planting regardless of the crop. It minimized penalties by authorizing partial loss of benefits rather than complete loss for certain situations and allowed conversion of wetlands to agricultural use if the loss was mitigated by restoring another wetland area. It also provided for a graduated, rather than a total loss, of benefits based on the severity of the conversion and if it was conducted under the "good faith" exemption (Cohen et al., 1991). The Federal Agriculture Improvement and Reform Act of 1996 (1) amended the Swampbuster program by providing greater flexibility for mitigating wetland conversions, (2) increased mitigation options focused on maintaining wetland functions and values, (3) encouraged the use of "minimal effect" determinations, (4) established that any wetland conversions authorized by Section 404 permits for agriculture production were accepted without penalty under Swampbuster, and (5) revised "abandonment" to allow prior converted wetlands to be converted to wetlands and then converted back to crop production without being considered a violation. The Secretary of Agriculture could waive penalties for ineligibility and grant time to restore a wetland or identify which programs would be impacted by violations and the penalty amount (www.usda.gov/programs/farmbill/1996/Sum96FB.html). The Farm Security and Rural Investment Act of 2002 established that the Secretary of Agriculture could not delegate compliance decisions to private entities and the Secretary could waive ineligibility and allow a year for violators to restore wetlands if the violation resulted from acting in "good faith" without an intention to violate the program provisions. The Food, Conservation, and Energy Act of 2008 provided little substantial change to the program other than identifying roles of the Natural Resource Conservation Service in determining "good faith" exemption situations.

Swampbuster provisions have not eliminated agricultural wetland conversions but they have contributed to overall decreases in wetland loss rates **(**Dahl and Johnson, 1991; Dahl, 2000;

Dahl, 2006**;** USDI, 1994**;** USDI, 2003**;** Heimlich et al., 1998**).** Although statistics vary between the U.S. Fish and Wildlife Service and the Natural Resource Conservation Service, both agency reports reflected a consistent decreasing trend in spite of program amendments that lessened compliance penalties and the scope of the act by not preventing wetland conversions on agricultural lands. Following the initial act, subsequent amendments have provided greater leeway for landowners rather than tougher standards. This is most effectively illustrated by reviewing violation statistics from 1987 to 1994 (Economic Research Service, 1997). In 1987, 12 violations were identified that denied $0.1 million in benefits. Violations increased for the next four years, peaking in 1991, when there were 165 violations that denied $2 million in benefits**.** Since then the violations and amount of lost benefits have decreased, perhaps indicating compliance with the program has been achieved. The data could also be interpreted, however, that compliance actions and lost benefits have decreased due to not actively pursuing potential violations.

Food Security Act of 1985 - Conservation Reserve Program

The Conservation Reserve Program (CRP) is a voluntary long-term cropland retirement program authorized in Title XII of the Food Security Act of 1985. The program was created to address the agricultural excesses generated from the agriculture expansion in the 1970's, when there were highly favorable export markets and it was advantageous to increase the amount of farmland and crop production. This situation brought increased and often marginally productive acreage into production, which also generated significant increases in erosion rates (Zinn, 1997). The agricultural boom ended in the 1980's, having created a situation of too much production capacity but insufficient markets. In addition there was a farm credit crisis that reduced the value of farmland and existing federal programs were not able to adequately address the farmer's economic situation (Zinn, 1997). The Conservation Reserve Program was designed to address these problems by taking highly erodible land out of production, which would reduce crop surpluses, and increase commodity prices, while providing increased economic stability to farmers by providing rent for land removed from crop production for a 10-year period. The CRP was enacted at a time of economic stress in the agriculture sector and provided farmers with an opportunity for a stable and reliable income while reducing commodity surpluses (Osborn, et al., 1995).

The primary purpose of the CRP as initially established was to reduce soil erosion on highly erodible farmland. The program evolved, however, to include environmental improvements in water and soil quality, creation of wildlife habitat and wetland conservation. Land enrolled into the CRP replaced crops with cover vegetation such as grass and trees. The initial enrollment goal of CRP was 40-45 million acres by the end of 1990. Farmers selected for the program received an annual rental payment per acre for the contract period plus 50 percent of the cost of establishing cover vegetation such as grass and trees on the enrolled acreage. Enrollment sign-up periods were held, during which farmers submitted proposals for land to be enrolled, the desired rental price and the crop base that would be affected if the land was accepted into the program. Bids were reviewed by the Farm Service Agency and the U.S. Department of Agriculture determined the acceptable rental rates by region and usually bids that did not exceed the rental rate limit were accepted. In addition to meeting the rental rate ceiling, it was not permissible to enroll more than 25 percent of the agricultural land in any one county due to the detrimental economic impact that could result.

Wetlands were impacted as program criteria changed from strictly erodible farmland to include filter strips in 1988 and cropped wetlands in 1989 (Osborne, et al., 1995). The Food, Agriculture, Conservation, and Trade Act of 1990 amended the Conservation Reserve Program and excluded enrollment of farmed wetlands but maintained the eligibility of prior converted wetlands. Enrollment started in 1986 with rental contracts established for 10-year periods. Between 1986 – 1989, about 34 million acres were enrolled, the enrollment ceiling was revised to 38 million acres in 1992, decreased to 36.4 million acres in 1996, but then increased to 39.2 million acres in 2002 (AREI, USDA Land Retirement Programs, Chpt 5.2). No funding was provided for enrolling acreage in 1994 – 1995. By the end of 2004, there were over 34.7 million acres enrolled in the program with almost 1.9 million acres enrolled as wetland restoration and farmable wetlands (USDA, FSA CRP summary and enrollment, 2004).

Post-1985 Agricultural policies

The Food Security Act of 1985 (1985 Farm Bill) significantly changed farm policies by emphasizing wetland conservation rather than conversion and making it more difficult for farmers to convert wetlands to cropland due to the Swampbuster provisions and the establishment of the Conservation Reserve Program (CRP), which provided an economic option for using wetlands for income. These two provisions established an economic value for wetland acreage based on the annual rental rate a farmer would receive for enrolling wetlands into the CRP and the value of federal benefits that would be lost if wetlands were converted to productive cropland. The Act also increased the length of time required to increase acreage bases. Prior to 1985, a farmer could drop out of the Federal programs for a year to increase their base acreage by converting wetlands to cropland, often with the assistance of ACP, then reenter the program with greater acreage and receive increased benefits based on a new crop production history. The new policy required an absence of five years from federal programs to increase base, but it became more difficult to add cropland at the expense of wetlands due to Swampbuster provisions. The 1985 Farm Bill impacted farmers that relied upon federal benefits but did not impact farmers that did not participate in federal programs; they could continue to convert wetlands without economic penalty. Between 1995-2012, the federal farm program paid a total of $292.5 billion in the following subsidies: commodity program $177.6 billion; crop insurance $53.6 billion; $38.9 billion in conservation; and $22.5 billion in disaster subsidies. About 62 percent of all farmers do not collect subsidy payments, but 10 percent received about 75 percent of all payments (http://farm.ewg.org).

The programs established by the 1985 Farm Bill presented a different level of economic analysis for determining farm operations. Prior to 1985, the economic issues for wetland conversion included the cost of conversion (reduced if there was ACP cost- sharing), temporary loss of program benefits for a year while converted land was brought into production to increase base acreage, increased program benefits after a year due to increased crop base, and associated additional costs of planting and harvesting. Post-1985 economic issues were the loss of benefits if a wetland were converted, cost of conversion without ACP assistance, and the net income increase once the additional acreage was in production. The loss of crop insurance subsidy would be significant since the farmer only pays about a third of the cost (Edwards, 2009). There was less value in converting very marginal land, but more potential value in conserving the land and enrolling in CRP. Draining wet soil areas in the post-1985 era became more difficult to justify due to the potential of losing all federal benefits that would have to be compensated by sufficiently high commodity prices.

The wetland loss rates from the mid-1970's, through the 1980's, steadily and drastically decreased. The causal factors are not solely Farm Bill policies but also reflect the depressed economic conditions that plagued farming from the early 1980's. Based on a robust period in the early 1970's, fueled by global grain failures and high export prices, farmers extended themselves financially to take advantage of the good economic conditions and were encouraged to plant fencerow to fencerow by Secretary of Agriculture Butz. However, the good times did not last; overproduction and decreased commodity prices reduced farm income by 42 percent between1973-1977 (ERS, 1984), property values decreased, and farms faced foreclosure. Adverse economic conditions were increased when the United States suspended agricultural exports to the Soviet Union in 1980. To combat these economic problems, Congress increased commodity target prices, maintained nonrecourse loans, disaster payments and acreage allotments. In general, the agricultural sector suffered economically. It was a period when neither funds nor desire to convert wetlands were feasible, so wetland conversions decreased as did loss rates. There is a substantial link between the condition of the farm economy and wetland loss rates. The establishment of the CRP in the midst of the farm economic crisis should not be considered coincidental. The CRP was a way to infuse needed money into the farming community at a time when it was needed. The additional environmental benefits of conserving wetlands and the economic benefit of reducing productive cropland were significant beneficial effects.

The Food, Agricultural, Conservation, and Trade Act of 1990 (1990 Farm Bill) established the Wetland Reserve Program (WRP) that provided the farmer another opportunity to conserve wetlands for pay. The WRP was previously discussed in detail but it provided long-term (30-year or permanent) easements for enrolled wetlands. Again it presented the farmer with another economic option of deciding how to best manage the farm. All aspects of the 1985 Farm Bill were still in effect, and Swampbuster provisions were amended to increase clarity to remove confusion over the type of actions that would trigger loss of benefits. As a result, wetland conversion became more difficult and costly, and was not generally a feasible option for increasing base acreage. The Act also prohibited farmers from participating in any commodity program if they dropped out of a program to increase acreage base. For example, if a farmer grew corn and wheat and dropped out of the corn program to increase the corn base acres, the farmer would be excluded from participating in the wheat program as well. Each succeeding Farm Bill placed greater importance on wetland conservation and made it more difficult to increase base acreage. These Acts changed the way a farmer managed the farm. The farmer could no longer drain a wetland, wait the required year to develop a new planting history, rejoin the crop program, and decide whether to farm the converted wetland or idle the land for set-aside or conservation planting requirements. The economic value or impact of wetlands had to be considered in decision-making. As a result, less wetland acreage was converted and more was conserved, as evidenced by the 80 percent decrease in the national wetland loss rate between 1986-1997.

The Federal Agricultural Improvement and Reform Act of 1996 (1996 Farm Bill) changed commodity programs again by initiating de-coupled program payments to farmers based on the past participation in programs and not income support payments such as deficiency payments that would be linked to specific crops and prices. The impact on commodity programs did not impact actions regarding wetland conversion or conservation since both the CRP and WRP continued, but the Act weakened Swampbuster provisions. The changes enabled former violators to return to program eligibility without loss of benefits and increase base acreage. The Farm Bills of 2002 and 2008 changed commodity policies but continued Swampbuster provisions, CRP and WRP.

Food, Agriculture, Conservation, and Trade Act of 1990 - Wetland Reserve Program

The Wetland Reserve Program was created by the Food, Agriculture, Conservation, and Trade Act of 1990 as an incentive-based voluntary program to restore farmed wetlands that had been converted prior to December 23, 1985. Program responsibility was originally delegated to the Agricultural Stabilization and Conservation Service, but due to U.S. Department of Agriculture reorganization, program oversight became the responsibility of the Natural Resource Conservation Service in 1994. The program is available in all 50 states and possessions of the United States and provides “technical and financial assistance to eligible landowners to restore, enhance, and protect wetlands” (USDA, 2009). The program provides a scale of financial incentives to land owners based on the length of wetland easement or cost-share agreement. The land owner retains control over the property and can use it for activities that are “compatible with the purpose of the wetland conservation easement, including timber production and harvesting, haying, and grazing, provided the objectives of the WRP easement continue to be fulfilled (USDA, 1996, p21). The Wetland Reserve Program has been reauthorized in subsequent farm bills in 1996, 2002 and 2008. Initially, the act only provided for permanent easements, but more flexible options of a 30-year easement and cost-share agreements were provide in the 1996 farm bill. According to the U.S. Department of Agriculture (2009), the current program options provided are:

1. Permanent easement where land is placed in a perpetual easement and the landowner is paid either the fair value cost of the land, the price set by a program cap or the amount offered by the land owner. The U.S. Department of Agriculture pays up to 100 percent of the cost of restoring the wetland.

2. 30-year easement which includes the same use restrictions as a permanent easement but the land owner is paid 75 percent of what would be earned from a permanent easement and the U.S. Department of Agriculture only pays 75 percent of the restoration costs.

3. Restoration cost-share agreement is an agreement for a minimum of 10 years that converts a farmed wetland to a natural wetland. The U.S. Department of Agriculture pays up to 75 percent of the restoration costs with no easement placed on the property.

The Wetland Reserve Program has application eligibility restrictions for both landowners and acreage. In order to be eligible for consideration, the owner has to own the land for at least 12 months before the 2008 farm bill, but this was changed to seven years by the Food, Conservation, and Energy Act of 2008 with some exceptions and the owner's adjustable gross income must be below $2.5 million for the preceding three tax years. Eligible land must be a wetland that has been farmed under natural conditions, a prior converted cropland, a farmed wetland pasture, farmland that became a wetland due to flooding, rangeland, pasture, or production forestland where the hydrology has been significantly degraded and can be restored, riparian areas that link protected wetlands, lands adjacent to protected wetlands that contribute significantly to wetland functions and values, previously restored wetlands, or non-cropped wetlands previously enrolled in the Water Bank Act (www.nrcs.usda.gov/Programs/wrp/WRPfact.html; Heimlich, 1994; USDA, 2009). Land owners have to apply for specific acreage for acceptance into the program. Not all applications are approved and not all lands are accepted. Every opportunity to enroll wetland acreage has resulted in more applications and acreage than were accepted. The obligation for enrolled acreage to follow original agreements transcends changes in land ownership. Each farm bill and Congressional authorization has the potential to change the criteria of the program as well as providing different levels of funding for easements and cost-share agreements. The Conservation Reserve Program and the Wetland Reserve Program had restrictions that prohibited more than 25 percent of the farm land in any county to be actively enrolled in the programs. This restriction was reduced to ten percent for the Wetland Reserve Program in the 2008 farm bill. Through FY 2007 the program has approved over 10,000 contracts, of which 74 percent are for permanent easements at a national average cost per acre of $1,302, 14 percent in 30-year easements with an average annual per acre cost of $667 and 12 percent restoration cost-share agreements with an annual per acre cost of $293. As of 2009, the Wetland Reserve Program enrolled approximately two million acres at a total cost of over $2 billion (USDA, 2009).

The original goal of the Wetland Reserve Program in the Food, Agriculture, Conservation, and Trade Act of 1990 was to restore one million acres of wetlands that had been converted to agriculture by 2000. This goal was later amended to 975,000 acres (Crosson and Frederick, 1999). The Wetland Reserve Program was initially implemented as a test in nine states (California, Iowa, Louisiana, Minnesota, Mississippi, Missouri, New York, North Carolina and Wisconsin) in 1992. It proved to be a very popular program that generated applications from 2,337 landowners for 462,078 acres but only 49,888 acres were accepted for enrollment at a cost of $46,000 or $923 per acre with the majority of the acreage located in Mississippi and Louisiana (USDA, 1996). The breakdown of the average costs of the initial program acreage was, "an average of $742 of the $923 per acre total cost went to easement purchase; restoration, technical assistance, and settlement fees averaged $52, $124, and $4 per acre, respectively" (USDA, 1996).

The program was not funded in FY93 but in 1994, $66.7 million was authorized to enroll 75,000 acres (USDA, 1996) and the Wetland Reserve Program was extended to include the additional eleven states of Arkansas, Illinois, Indiana, Kansas, Nebraska, Oregon, South Dakota, Tennessee, Texas, Virginia, and Washington. This opportunity to enroll resulted in 5,775 land owners proposing 590,020 acres for enrollment; 40 percent of the acreage was located in Mississippi, Louisiana, and Arkansas. The cost of accepted acreage was $39 million and the average cost per acre was $889 (USDA, 1994). In 1995, about 3700 landowners submitted applications totaling 572,500 acres of which about 118,000 acres were accepted at an average cost per acre of $790.

The Federal Agriculture Improvement and Reform Act of 1996 reauthorized the Wetland Reserve Program through 2002 with the same goal of 975,000 acres, provided $77 million to enroll 100,000 acres, required new enrollments to be equally divided between all three options and made the Wetland Reserve Program an entitlement (CRS, 1996**;** USDA, 1996). By September 1996 a total of 315,175 acres from 1,769 landowners was enrolled in the Wetland Reserve Program with an average easement cost per acre of $600 (USDA 1996-97; 1996). In 1998, enrollments increased to 745,000 acres and by 2000, acreage was 785,000 with 40 percent located within Mississippi, Louisiana, and Arkansas with permanent easement making up the majority of enrollments with cost-sharing agreements composing five percent of the total (Congressional Research Service 2000).

The Farm Security and Rural Investment Act of 2002 reauthorized the Wetland Reserve Program through 2007 and increased the enrollment cap to 2.275 million acres with a maximum annual enrollment of 250,000 acres (Congressional Research Service, 2003). By the end of FY 2002 there were 1.275 million acres in the WRP with 35 percent in Louisiana, Mississippi and Arkansas. By the end of FY 2005, total enrollment increased to 1.744 million acres

(Congressional Research Service, 2006). In FY 2006 an additional 105,382 acres were enrolled followed by 95,393 in FY 2006 and 75,750 acres in FY 2008 (NRCS email, 2009).

The Food Conservation and Energy Act of 2008 increased the Wetland Reserve Program acreage ceiling to 3.041 million acres and made changes in eligibility rules previously identified and added a Wetland Reserve Enhancement Program designed to allow tribal and some non-government organizations to work with the Natural Resource Conservation Service in identifying suitable land for acceptance into the Wetland Reserve Program and created a pilot program to allow grazing as an acceptable use of Wetland Reserve Program acreage, provided it did not interfere with program goals.

Over the last 16 years, the Wetland Reserve Program has significantly increased the restored wetland acreage that has contributed to the national goals of "no net loss" and increasing wetland resources. The program has been responsible for over 2 million acres of restored wetlands and is authorized to save over three million acres and possibly more based on the historical trend of farm bills reauthorizing the program and increasing the acreage ceiling. It is anticipated that the Wetland Reserve Program will continue to be part of the agricultural conservation program in the future based on the positive findings of a Natural Resource Conservation Service benefit-cost analysis that identified "substantial net economic benefits" produced by the Wetland Reserve Program (USDA, 2009).

Wetlands have been an under-appreciated natural resource since colonial times and have been reduced to approximately 50 percent of their original acreage largely due to conversion to agricultural land. The rate of conversion has been dependent upon financial support, technological improvements in drainage technology, commodity prices and farm policies. It is only over the past 45 years that environmental and conservation policies have been enacted to support wetland conservation, restoration and creation.

Commodity prices and farm policies have supported wetland conversions in order to maximize land under cultivation and farm income. These forces controlled wetland loss rates, since over 80 percent of wetlands are privately owned, and there was no federal policy or program that protected all wetlands from all adverse actions. The 1985 Farm Bill changed the way the agricultural sector impacted wetlands by including Swampbuster provisions that provided economic disincentives to convert wetlands and the Conservation Reserve Program that provided economic incentives to conserve wetlands. These two programs revolutionized farm policies and led to the creation in 1990 of the Wetland Reserve Program that provided economic support to conserve wetlands. These Farm Bill policies provided an economic value to wetlands that would increase farm income while improving environmental quality.

Post-1990 Farm Bills

The Farm Bills of 1996, 2002 and 2008, affected commodity programs more significantly than wetland conservation policies. Some changes clarified actions that would trigger loss of benefits under Swampbuster and prohibited farmers from participating in any commodity program if they dropped out of a program to increase acreage base. . All post-1985 Farm Bills placed greater importance on wetland conservation and made it more difficult to increase base acreage, significantly changing the way a farmer managed the farm. A farmer could no longer drain a wetland, wait the required year to develop a new planting history, rejoin the crop program and decide whether to farm the converted wetland or idle the land for set-aside or conservation planting requirements. The economic value or impact of wetlands had to be considered in decision-making. As a result, less wetland acreage was converted and more was conserved, as evidenced by the 80 percent decrease in the national wetland loss rate between 1986-1997.

Farmers Home Administration

Another USDA agency that whose policies have impacted wetland loss rates is the Farmers Home Administration (FmHA), which makes and guarantees loans at below market rates to farmers with limited resources. The loans are typically for farm ownership and operating costs but have been used to fund wetland conversions. However, FmHA policies changed to reflect the wetland conservation. In 1984, FmHA embraced Executive Order 11990 (Protection of Wetlands) and prohibited making loans that would directly or indirectly impact wetlands, and their loans stipulate that any loan would be cancelled if it supported wetland alterations. Loan applicants must certify they comply with Swampbuster provisions and the loans will not be used for wetland conversion actions. FmHA has also included wetland restrictions in its property disposal actions in order to comply with the agency's responsibility to protect and enhance wetlands. Before any property is sold, a conservation easement is placed on the land if there are wetlands present and the property value is reduced by the value of the easement. Inclusion of these restrictions on how FmHA loans could be used supported wetland conservation and contributed to a decrease in wetland loss rates.

Internal Revenue Service tax policies

Tax laws provided support and incentives to drain wetlands. Beneficial tax provisions allowed farmers to deduct costs for land clearing up to a certain limit and costs for soil and water conservation actions including land draining and ditching. The Tax Reform Act of 1986 eliminated the special provisions that promoted conversion of wetlands. The Act also rewarded wetland conservation actions by qualifying the value of land donations and easements to conservation organizations as charitable contributions. The Alternate Minimum Tax (AMT) also impacted donations of wetlands. Until 1993, the value of donated land was the original price of the property but under normal tax codes the value of the property would be its fair market value which would be higher than the original property cost so the value of the charitable deduction would be lower. Wealthier land owners who wanted to donate a wetland would be impacted so they would not donate the property at a lesser value. The Revenue Reconciliation Act of 1993 revised the law so the higher value of a property could be used as a charitable deduction.

Clean Water Act of 1972 and associated legal decisions

The Federal Water Pollution Control Act Amendments of 1972, also known as the Clean Water Act (CWA) was intended to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" by eliminating or at least exercising control over point and nonpoint sources of pollution. A significant part of the CWA was Section 404, which required federal approval prior to depositing dredged or fill material into "navigable waters of the United States." The Section 404 permit program, administered jointly by the Environmental Protection Agency and the Corps of Engineers, became controversial in both its jurisdiction and application. Jurisdiction of the 404 program has been the subject of numerous court decisions since 1974 that strived to clarify CWA jurisdiction; in order to address public and political concerns over regulated activities, the 1977 Amendments to the CWA exempted certain activities including normal farming practices from Section 404 permits.

The regulatory impact of Section 404 upon wetlands has depended upon the definition of the phrase "navigable waters of the United States." The Corps of Engineers felt the traditional definition of navigable waters used in issuing permits under Section 10 of the Rivers and Harbor Act of 1899 was correct, but the following legal decisions established a different interpretation of jurisdiction of the CWA:

United States v. Holland (1974): The United States sued a developer to stop filling a mangrove swamp in Florida. The District Court determined that Congress is not limited by the ‘navigable waters‘ test in its authority to control pollution under the commerce clause and placing fill on land that was periodically inundated by tidal waters constituted discharges entering waters of the United States. This decision broadened the definition of navigable waters and the scope of Section 404 jurisdiction to include wetlands adjacent to navigable waters.

N*atural Resources Defense Council v. Callaway (1975)*: The U.S. District Court, District of Columbia determined the jurisdiction of the CWA must be broadly interpreted. Congress defined the term ‘navigable waters' to mean ‘the waters of the United States, including the territorial seas,' which asserted federal jurisdiction over the nation's waters to the maximum extent permissible under the Commerce Clause of the Constitution. In addition to the jurisdictional decision, the court also ordered the Corps to develop regulations to reflect the broader jurisdictional scope of the CWA.

United States v. Riverside Bayview Homes Inc. (1985): This case challenged the jurisdiction of CWA. Action was brought by the Corps to stop the discharge of fill into 80 acres of marshy area adjacent to a navigable waterway. The issue to be determined was whether the land had to be subject to periodic flooding to be subject to Section 404 jurisdiction. The Corps felt the land qualified as an adjacent wetland per their revised 1975 definition of waters of the United States. The trial court found for the Corps, but on appeal, the Sixth Circuit reversed the finding because they found the land did not qualify as a wetland since it was not flooded frequently enough to support wetland vegetation. The court felt a narrow interpretation of the law was required to prevent "taking" of private property without just compensation. The Supreme Court disagreed with the "takings" position of the lower court and their finding that the land involved did not qualify as a wetland. The Court determined the Corps could regulate adjacent wetlands; the land did not require frequent flooding from adjacent navigable water to qualify as a wetland.

<u>Tulloch Rule Cases (1993-2008):</u>

North Carolina Wildlife Federation v. Tulloch (1993), American Mining Congress v U.S. Army Corps of Engineers (1997, Natural Association of Home Builders v. U,S, Army Corps of Engineers (2007): The Tulloch Rule addresses when the redeposit of dredge material is regulated under Section 404 of the Clean Water Act. It required three attempts by the Corps of Engineers (Corps) and the Environmental Protection Agency (EPA) to write an appropriate and legally acceptable rule. Before 1993, the Corps defined discharge of dredged material as any addition of dredged material into waters of the United States, and excluded de minimis incidental soil movement that occurred during normal dredging operations. This definition basically eliminated permits that only involved excavation activities.

The Corps' exclusion of redeposit of dredge material was challenged in 1993 by *North Carolina Wildlife Federation v. Tulloch*. The issue was an 1800-acre development that contained 700 acres of wetlands that the developer took precautions to prevent any deposition of dredged material other than incidental fallback and ensured only de minimis amounts of excavated material were redeposited into the wetlands. The North Carolina Wildlife Federation filed suit alleging the developer destroyed the wetland without the required Section 404 permit. The settlement required the Corps to revise their regulations regarding incidental fallback. The new rule became known as the Tulloch Rule, deleting the de minimis exception to Section 404 permits and defined discharge of dredge material to mean any addition of dredged material, including redeposition of dredged material into the waters of the United States. It defined discharge of dredged material to be any addition, including redeposit of dredged material, which is incidental to any activity such as mechanized land clearing, ditching, or channelization. Including incidental fallback as a permitted action, the Corps extended Section 404 jurisdiction to all excavation activities carried on within waters of the United States. The Rule contained a de minimis exception for incidental additions of fill material, but it was very restrictive in scope and did not apply to most mechanized activities or to work in the water.

The courts invalidated the Tulloch Rule in *American Mining Congress v. U.S. Army Corps of Engineers* in 1997. The ruling determined the Corps exceeded their statutory authority by regulating all forms of redeposited material and incidental fallback. Judge Silberman identified two situations where redeposited material could be regulated under Section 404: the distance from where the material was originally removed and the location where deposited and the length of time between removal and redeposit. In 1999, an interim rule was published with a final rule published in 2001.

The 2001 Rule became known as Tulloch II; it excluded incidental fallback from the definition of dredged material, but defined incidental fallback as the redeposit of small volumes of material that is incidental to excavation activities when the material falls back to the same place where it was removed. The new Rule also defined the following activities as automatically requiring a permit unless project-specific evidence shows only incidental fallback is involved: mechanized earth-moving equipment to conduct land clearing activities, channelization, in-stream mining, or other earth moving activities in waters of the United States. This Rule was challenged in court.

In 2007, in *National Association of Home Builders v. U.S. Army Corps of Engineers*, the Court invalidated the two provisions of Tulloch II, and the definition of incidental fallback because it included a volume requirement and there was no restriction on how long the material could be held before being redeposited. In addition, the court noted that not all types of earth-moving mechanized equipment may be regulated, so the Corps could not require project-specific evidence over projects outside their jurisdiction.

The Corps revised the Rule again – Tulloch III was issued on December 30, 2008. The Corps returned to their original definition of dredge material, eliminated the definition of incidental feedback and their presumption that activities using earth-moving equipment automatically requires a Section 404 permit. The definition of discharge of dredge material is any addition of dredged material, including excavated material, into waters of the United States, which is incidental to any activity, including mechanized land clearing, ditching, channelization, or other excavation.

The issue of whether redeposit of dredged material requires a Section 404 permit is left to the discretion of the Corps in evaluating a project on a case-by-case basis. Probably the standard that will be used is that set by Judge Silberman; the deciding factors should be the location where the material was taken and the location where redeposited and how long the material was held before being dropped back into the water.

Solid Waste Agency of Northern Cook County v. United States Army Corps of Engineers (2001): This case concerned whether Section 404 jurisdiction included isolated, non-navigable intrastate wetlands based on the Corps' 1986 Migratory Bird Rule. The court determined the Migratory Bird Rule could not be used to assert jurisdiction over isolated, intrastate non-navigable waters and retreated back to the traditional definition of navigable waters as the appropriate measure for jurisdiction under the Clean Water Act. In order for a wetland to be within Clean Water Act jurisdiction, there had to be a significant nexus between the wetland and navigable water. This finding generated uncertainty over the extent of jurisdictional wetlands and resulted in revised program guidance.

Rapanos v United States & Carabell v. United States (2006): The Rapanos case involved the unauthorized filling of 54 acres of wetland in 1989 near man-made ditches that emptied into Saginaw Bay a navigable water of the United States located 20 miles from the Rapanos property. A lower court held that jurisdiction applied because the wetlands were adjacent to "waters of the United States" based on hydrological connections to the drains. The Carabell case involved unauthorized filling of a 19-acre wetland that was separated from a drainage ditch by an impermeable berm but was still considered within the jurisdiction of the CWA. The CWA defines navigable waters as "the waters of the United States, including the territorial seas," but the Corps, based on earlier court decisions, interpreted the term to include the traditional navigable waters but also other defined waters, tributaries of such waters and wetlands adjacent to such waters and tributaries, with "adjacent wetlands" defined as being those that border, are contiguous to or border waters of the United States, even if separated from jurisdictional waters by man-made structures such as dikes. In a 4-1-4 split, the important question regarding jurisdiction of CWA over wetlands in these areas was not clarified, but resulted in more confusion. In a Supreme Court decision that does not result in a majority opinion "controlling legal principles may be derived from those principles espoused by five or more justices. Thus, regulatory jurisdiction under CWA exists over a body of water if either the plurality's or Justice Kennedy's standard is satisfied" (CoE/EPA; 2008). Justices Scalia, Thomas, Roberts and Alito (the plurality) favored a conservative and traditional interpretation of navigable waters of the United States and thus a restricted scope of CWA jurisdiction. Their position was that waters of the United States should include "only those relatively permanent, standing or continuously flowing bodies of water forming geographic features that are described in ordinary parlance as streams, oceans, rivers and lakes' (Rapanos, 2006). They felt the important characteristic of jurisdiction was the permanency of the body of water and for wetlands it required a physical connection to a relatively permanent "water of the United States," not just a hydrological connection. In reaction to the Supreme Court decision, the Corps determined the CWA applies to:

1. Traditional navigable waters
2. Wetlands adjacent to traditional navigable waters
3. Non-navigable tributaries of traditional navigable waters that are relatively permanent where the tributaries typically flow year-round or have continuous flow at least seasonally (typically 3 months)
4. Wetlands that directly abut tributaries

The Corps will determine jurisdiction based on a fact-specific analysis to determine whether there is a significant nexus with traditional navigable water:

1. Non-navigable tributaries that are not relatively permanent.
2. Wetlands adjacent to non-navigable tributaries that are not relatively permanent
3. Wetlands adjacent to but do not directly abut a relatively permanent non-navigable tributary

The Corps will generally not exercise jurisdiction over the following:

1. Swales or erosional features
2. Ditches excavated wholly in and draining only uplands that do not carry a relative permanent flow of water.

As required by Court decisions, the Corps will determine if a nexus exists by conducting a nexus analysis to determine flow and function characteristics of the tributary and adjacent wetlands to determine if they affect the chemical or biological integrity of downstream traditional waters; a significant nexus will also consider hydrologic and ecological impacts.

The 1977 Clean Water Act Amendments revised the CWA by adding exemptions from the requirements of Section 404 for certain activities; the most significant being Section 404 (f) (1) that exempted normal farming, silviculture, forestry and ranching operations. The exempted farming activities included plowing, seeding, cultivating, minor drainage and harvesting, as well as discharges from the maintenance of dikes, dams, levees, and similar structures, construction or maintenance of stock or farm ponds or irrigation ditches. The exceptions generated concern that they would weaken the protection provided by Section 404 over agricultural wetlands which suffered the greatest losses through the mid-1980’s.

The decade following the 1977 Amendments continued to cause regulatory problems that must be considered based on the context of the times:

1985: The Farm Bill initiated Swampbuster provisions that provided economic disincentives for converting wetlands and the Conservation Reserve Program provided economic incentives for retiring sensitive farmland that included wetlands.

1986: The Corps issued the Migratory Bird Rule that extended Section 404 jurisdiction to wetlands, including isolated wetlands, based on use by migratory birds.

1987: The Corps published wetland delineation manual that provided guidance on how to identify and delineate wetlands at a time when other federal agencies were using different references.

1988: President Bush announced the "no net loss" policy for wetlands

1989: A revised delineation manual jointly prepared by the Corps, EPA, Fish and Wildlife Service and the Soil Conservation Service was published that generated objections from many sectors because it expanded the definition of wetlands to include previously non-regulated areas.

1990: Memorandum jointly issued by Corps and EPA to provide guidance in the interpretation and application of Section 404(f) permits exemptions to" normal farming" activities. In order for the farming exemptions to be approved, they needed to be part of an established and ongoing operation even if they occurred in a wetland, provided the actions were not designed to convert the wetland. Activities conducted for wetland conversion do not qualify as exemptions. The evaluation of whether an activity is a normal farming operation is based on whether the activity must be part of an ongoing farm operation. Planting different crops as part of a crop rotation is exempt; and resumption of planting in areas that were fallow as part of a crop rotation cycle is also exempted. However if the land was fallow for so long that it returned to wetland conditions and required draining for planting, then it is not exempt. The actual actions conducted are critical and there are differences between plowing wet soils and grading the soils to eliminate or reduce its hydrologic characteristics. The minor drainage exemption is directed at existing functioning drainage systems and not the introduction of new systems that change the water regime of existing wetlands. Section 404(f)(2) is the "recapture" section that applies to drainage actions that are not exempt. Two conditions must be met. The first is that the activity is a new use and the second is whether the action changes or reduces the flow of a water of the United States. Regulatory Guidance Letter 90-07 issued to clarify the meaning of "normal circumstances" with respect to cropped wetlands and farmed wetlands (wetland classifications unique to Swampbuster provisions of the 1985 Farm Bill) in order to provide consistent interpretation between Section 404 and the Soil Conservation Service. Prior converted croplands are former wetlands that were converted to cropland prior to December 23, 1985 and are not subject to Section 404, whereas farmed wetlands are wetlands that were manipulated for farm operations prior to December 23, 1985 but retain wetland characteristics so they would revert to a wetland if farming operations ceased and they would be subject to Section 404. 1990 Farm Bill initiated the Wetland Reserve Program to conserve wetlands on agricultural land.

1991: Proposed revisions to the 1989 wetland delineation manual were proposed, but they were determined to be objectionable and Congress prohibited its use by the Corps without prior approval by landowners. The Corps reverted to using the 1987 manual.

1993: Tulloch Rule law suits initiated to contest Section 404 jurisdiction on incidental fallback in dredging as previously explained.

1996: Corps and EPA jointly issued Regulatory Letter 96-02 that provided guidance on administering Section 404(f) exemptions with an emphasis on the difference between "deep-ripping" and plowing; plowing is a normal farming process but deep-ripping can be the initial step in wetland conversions.

2001: SWANCC case ultimately rules that isolated, non-navigable, intra-state waters are not subject to Section 404 and a nexus to a navigable water is required per previous discussion.

2006: Rapanos/Carabell case as previously described.

2014: The Corps, EPA and the Department of Agriculture (Natural Resource Conservation Service (NRCS)) signed a Memorandum of Understanding Concerning Implementation of the Section 404(f)(1)(A) Exemption for Certain Agricultural Conservation Practice Standards (MOU). The MOU identified NRCS standard conservation practices as normal farming exemptions and NRCS as the primary federal contact with landowners regarding normal farming practices.

Overall, the interpretation and implementation of exemptions to Section 404 jurisdiction has been dynamic; wetland delineation manuals changed, court decisions revised jurisdiction, general Section 404 permits were instituted, the 1985 and 1990 Farm Bill introduced wetland conservation provisions, wetland classifications unique to Swampbuster were created, and program administration and coordination increased from two to four agencies, each with a different focus. The regulatory, legal, environmental and economic conditions associated with the exemptions have not been constant and their impact upon the farmer and farm operations required regular evaluation and re-evaluation.

The program is composed of standard and nationwide or general permits. The standard permits are for specific actions that require public review, comment and environmental assessment, whereas the nationwide permits are for a general type of well-defined actions that are interpreted to have minor impacts and omit the public review and assessment requirement. The nationwide permit provides blanket authorizations for certain activities in certain sized wetlands. Over 39 nationwide permits (Heimlich, 2003) were developed to reduce process time and provide improved public service (Heimlich, 2003; Zinn and Copeland, 1996). Nationwide permit 26 was used to justify filling 42,000 acres of valuable wetlands between 1991-1995 (USDI, 1988), which prompted a review and revision to its applicability. In addition to nationwide permits, there are a number of normal agricultural activities that are exempt from Section 404 permit requirements such as drainage ditches and draining activities and farm maintenance work. As a result, the agricultural sector generates relatively few permit applications. In 1997, only about seven percent of the total Section 404 permit applications received applied to agricultural activities and over 87 percent were approved by nationwide permits (Heimlich et al, 1998). Both nationwide permits and permit exemptions contributed to wetland conversions on agricultural property. The only type of actions that require permits under Section 404 are dredge and fill activities.

Section 404 permits that authorize filling wetlands require mitigation in the form of restoring or creating new wetlands. In FY98, the Corps of Engineers imposed a wetland compensation rate of one and a half acres for every acre filled (Heimlich, 2003). Permitting the filling of wetlands, but requiring mitigation by restoring or creating new wetlands, serves to increase wetland acreage. The Section 404 permit program does not effectively prevent the filling of wetlands since most applications are approved either individually or as a nationwide permit and most agricultural activities affecting wetlands are exempt from permitting. The major impact of the Section 404 permit program has been on non-agricultural activities and development.

A number of authors have discussed issues pertaining to the Section 404 permit program. Heimlich (1998) discussed the different wetland delineation systems used by federal agencies for their specific programs, the difference between scientific and jurisdictional wetlands, differences between program jurisdiction and wetland delineation and impacts on property rights. Wiebe et al. (1995) reviewed the Section 404 program and identified the low denial rate (less than one percent in 1998), but a mitigation ratio of 1.5 acres of wetland for every acre converted. Wiebe et al. (1996) reviewed the possible economic impacts that could result from changes to wetland delineation in Section 404 permit and Swampbuster programs. Gnam (1992) discussed the controversial definition of wetlands and identified 30 bills introduced in the 102nd Congress aimed at revising Section 404 jurisdiction, wetland definitions or increasing protection for wetlands. Anderson and Magleby (1997) identified the low rejection rate for Section 404 permit applications (less than one percent) in FY 1994, the high number of general permits issued (50,000), with only three percent of enforcement cases for reported violations litigated. Downing et al. (2003) discussed the legal decisions that shaped changes in program jurisdiction and Crosson and Frederick (1999) discussed program expansion.

A review of 1981 permit statistics shows a less than three percent permit denial rate (OTA, 1984). In a 1993 Government Accounting Office report, the Corps of Engineers stated they received about 15,000 individual permits annually, 67 percent are approved, 30 percent are withdrawn or qualify for general permits and three percent are denied. In addition, the Corps of Engineers approves about 40,000 applications through Nationwide Permits (GAO, 1993). Heimlich (2003) summarized the results of Section 404 permit applications in FY 1998, showing an increase in the approval percentage and decrease in the denial rate. According to the data, 95 percent of the 73,450 applications received were approved, five percent were withdrawn and less than one percent were denied.

The Corps of Engineers has limited authority under the Clean Water Act to prevent wetland conversions or destruction. There are a number of activities that will harm or destroy wetlands that are not regulated by the Clean Water Act that were identified by William R. Gianelli, Assistant Secretary of the Army (Civil Works), before the House Committee on Merchant Marine and Fisheries on Section 404 of Clean Water Act on August 10, 1982: "It is important to point out that wetlands subject to section 404 can be destroyed in a number of ways without any requirement for a Corps permit. They can be destroyed by excavating, draining, flooding, clearing, or even shading without the need of a Corps permit as long as the activities do not include the discharge of dredged or fill. So it is clear that section 404 does not serve as the Nation's comprehensive protection law" (OTA, 1984, p167). The Section 404 permit program has had a significant impact on wetland resources by protecting some existing wetlands, but mainly by requiring the restoration or creation of new and additional wetlands to mitigate the loss of wetlands authorized to be filled by permits.

Wetland Mitigation Banking

Over the last decade wetland mitigation banking has developed into a major part of the current Section 404 permit program as compensatory mitigation for unavoidable wetland losses (Federal Register 2008). In order to meet the national goal of no net loss of wetlands, the Corps of Engineers and the Environmental Protection Agency issued a Memorandum of Agreement in 1990 that established a "mitigation sequence" to avoid, minimize and then compensate (mitigate) wetland losses (http://www.epa.gov/owow/wetlands/pdf/CMitigation, 11/17/2010).

Once mitigation is identified as the only possible action, then compensation must be implemented by restoring an existing wetland, enhancement of an existing wetland's functions, creation of a new wetland or preserving an existing wetland (Federal Register 2008). A wetland mitigation bank is a site where a wetland has been restored, enhanced or preserved for the purpose of providing compensatory mitigation for wetland impacts. They are privately owned and operated for profit. When using a mitigation bank, the permittee passes all responsibility for satisfying mitigation requirements to a third party.

Wetland projects that require mitigation are evaluated and assigned a number of debits -- a unit of measure associated with the amount of functions adversely impacted by the project. The debits must be matched to a number of credits in the mitigation bank --the amount of units required to compensate for the wetland debits. The Corps of Engineers determines the appropriate amount of debits and credits on a case-by-case basis. Usually, the mitigation bank is required to be in the same watershed as the project. The Corps of Engineers' wetland compensation requirements have produced positive results; between 2001-2005 Section 404 permits impacted 20,754 acres of wetlands that resulted in 56,693 acres of mitigated wetlands. In Fiscal Year 2005 the mean acreage of wetlands impacted by permit actions was 23,000 acres while the mean compensated acreage was 50,000 acres (Federal Register 2008). Use of mitigation banks is encouraged, but developers may elect to satisfy the mitigation requirements themselves. The cost of purchasing mitigation credits is determined by the bank.

Summary

The most significant legislative actions taken that have impacted wetland losses and loss rates have been the Farm Bills that created agricultural subsidies that functioned to increase wetland loss rates and the 1985 Farm Bill that established the Swampbuster provision and the

Conservation Reserve Program that functioned to reduce wetland losses. When viewed collectively, these programs changed the agricultural sector from being the largest contributor to wetland loss rates to being a supporter of wetland conservation. The 1985 Farm Bill programs are broad in scope, and provide an economic means to achieve desired environmental quality. There is a tenuous economic relationship between agricultural conversion and conservation. Farming is a business that requires profits to support farm families and operations. There will be a constant re-evaluation of the costs of conserving or converting wetlands based on commodity policies and prices, rental rates of CRP and WRP enrollments, cost of drainage systems and how strongly Swampbuster provisions are enforced. Regardless of the changes to commodity support programs, the penalties imposed by Swampbuster will be a deterrent for wetland conversion for farmers that depend upon federal farm program benefits. However, commodity prices will have a more significant impact on farmers with acres enrolled in the CRP. Sufficiently high crop prices will induce withdrawal of enrolled acres and convert the land back to crops. The WRP acres will not be as susceptible since the enrollment agreement is for a much longer time. The significant impact of ACP cost-sharing for wetland conversions has significantly diminished since the 1985 Farm Bill, but it exerted a significant influence on wetland conversions since the 1930's.

The Section 404 permit program is limited in its impact on farming operations due to specified farming exceptions and the periodic judicial redefinitions of program jurisdiction. Farmers with lands bordering clearly navigable streams or wetlands with a nexus to that type of waterway will be affected, but farmers with isolated intrastate wetlands should continue to be exempt. Section 404 permits have less impact on agricultural wetland losses since the only action requiring a permit is dredge and fill. Swampbuster has a broader scope of jurisdiction since it includes all agricultural wetlands and all types of actions that would convert a wetland to productive cropland.

CHAPTER 3

METHODOLOGY

This chapter introduces the methodologies used in this study, identifies the data sources, variables, formulas used to develop critical data and rationale employed for selecting major strata for analysis. The core information used in this study was the database developed by the U.S. Fish and Wildlife Service for the preparation of the status and trends reports for the periods of mid-1950's to mid-1970's (Frayer et al.,1983), mid-1970's to mid-1980's (Dahl and Johnson, 1991), 1986 to 1997 (Dahl, 2000), 1998 to 2004 (Dahl, 2006) and 2005 to 2009 (Dahl, 2011). The basic approach used was to disaggregate the FWS database into Excel spreadsheets that contained specific information on strata and estimates of wetland acreage for each palustrine vegetated wetland type for each of the five report periods. The information developed was used to develop datasets in SPSS to perform statistical analyses on palustrine vegetated wetlands, the eight major strata, and the three palustrine vegetated wetland types for the entire 50-year study period.

The combination of calculations and statistical analyses were developed to answer the research questions and address the hypotheses. The research questions are: : 1) How have wetland loss rates varied in the U.S., over time from 1955-2009 and by geographic strata?; 2) What policies and economic factors account for these variations?; and 3) How can we utilize these policy and economic factors to gain a better understanding of the process of wetland loss in the U.S.? The hypotheses are: 1) policy variables of Conservation Reserve Program, Wetland Reserve Program, Swampbuster and Section 404 of the Clean Water Act reduce vegetated wetland loss rates; 2) agricultural commodity prices are positively related to wetland loss rates; 3) Wetland loss rates are affected by the remaining stock of wetlands available for conversion;

and 4) The factors that have affected wetland loss rate vary geographically (by Strata), and by wetland type.

Wetland inventory and trends

The source of the data used in this study is the FWS database prepared to support the periodic Status and Trends reports. The database provided: 1) raw acreage identified for palustrine vegetated wetland types in each of the randomly selected plots; 2) number of plots located within each physiographic strata (Hammond) and state; 3) changes in acreage for each palustrine wetland type that occurred within each study period; 4) changes in use between wetland types and non-wetland areas. The methods used in this study focused on quantifying the changes that occurred to palustrine vegetated resources at the strata level, determining if there were major strata that exerted a significant influence on individual report periods and if these major strata influenced several or all report periods. Each report period had two associated databases, one for the beginning and ending period. The status and trends reports were not the first studies conducted to determine the status of wetlands, they were just the first to conduct such a study on a truly nationwide basis using a classification system developed to include all types of wetlands for this purpose. Earlier studies produced restricted results because they did not include the entire conterminous United States and were focused on determining wetlands suitable for conversion.

Frayer et al. (1983) prepared the first status and trends report regarding wetland resources in the conterminous United States. The inventory was based on the wetland classification system developed by Cowardin et al. (1979). The inventory identified wetland types and acreages regardless of location or ownership. The study’s mandate was to develop and disseminate a technically sound comprehensive data base concerning the characteristics and extent of the nation's wetlands (Frayer et al., 1983, p7). In order to achieve the desired goal, a stratified random sampling was employed. The strata used were the 36 physical subdivisions identified by Hammond (1970) and state boundaries. The United States was divided into 4 square mile plots (approximately 2 miles per side) with plots randomly selected in proportion to the expected amount of wetland and deepwater habitat estimated by earlier works (Frayer et al., 1983, p15). The study selected 3635 plots to be sampled. The results of the study were based on the original wetland acreage of 215 million acres proposed by Roe and Ayers (1954). The results showed that a net loss of approximately nine million acres of wetlands occurred from 1955 to 1974, with an annual net loss of 458,000 acres including 439,000 acres of palustrine wetlands. Increases in palustrine wetlands occurred in open water (ponds) but decreases occurred in vegetated, forested and emergent wetlands. Over 95 percent of the total wetland losses occurred in palustrine wetlands. Based on the study, the amount of wetlands remaining in the mid-1970's was 99 million acres with the majority of wetland losses (87 percent) due to conversion to agricultural lands.

Tiner (1984) provided status and trends information on wetlands in the United States that echoed information provided by Frayer et al. (1983) on the national level but provided additional information focused on regional wetland changes over time. Tiner used the original wetland acreage of 215 million acres (Roe and Ayers, 1954) like Frayer et al. (1983) and echoed similar findings regarding wetland acreage changes between the mid-1950's and mid-1970's. The states with the greatest losses and types of wetlands were estuarine wetlands in Louisiana and Texas, forested palustrine wetlands in Arkansas, pocosins in North Carolina, prairie potholes in North and South Dakota, and various types of palustrine wetlands in Nebraska and Florida. Tiner echoed Frayer et al. (1983) in identifying agriculture as the cause of 87 percent of wetland losses across the nation.

Dahl and Johnson (1991) updated the Frayer et al. (1983) report and covered the period from the mid-1970's to the mid-1980's. This report used 221 million acres as the original wetland acreage (Dahl, 1990) and determined the wetland acreage in the mid-1970's was 105.9 million acres rather than the 99 million acres reported by Frayer et al. (1983). This difference was attributed to better analytical techniques and information available (Dahl, 2008 personal conversation). The same sampling technique was utilized as in the previous study. The results showed 2.6 million acres of wetlands were lost during the study period with an annual loss rate of 290,000 acres, a 37 percent decrease from the loss rate experienced from the mid-1950's to the mid'1970's. Palustrine wetlands constituted 95 percent (97.8 million acres) of all remaining wetlands with an annual loss rate of approximately 275,500 acres. Within the palustrine wetland system the major classes were forested (52.9 percent), emergent (25.1 percent), shrubs (15.7 percent), ponds (5.7 percent) and other (.6 percent). Overall palustrine wetlands decreased 2.5 million acres with 2.1 million acres converted to non-wetland land uses including 1 million acres that were lost to agriculture (Dahl and Johnson, 1991, p11). The study determined there were 103.3 million acres of wetlands remaining in the conterminous United States in the mid-1980's. During this period, agricultural activities accounted for 54 percent of the lost wetland acreage while other activities accounted for 41 percent (Dahl and Johnson, 1991, p2).

Dahl (2000) followed the same methodology as previous status and trends reports, but increased the number of sample plots to 4,375 in order to apply more finite measurement techniques to ensure a high degree of statistical reliability (Dahl, 2000, p 17). The report revised the wetland acreage as of the mid-1980's identified in Dahl and Johnson (1991), to be 106.1

million rather than 103.3 million. The estimated wetland acreage for 1997 was 105.5 million acres, a loss of about 644,000 acres with an annual loss rate of 58,500 acres, which is an 80 percent decrease from the previous report period of the mid-1970's to the mid-1980's (Figure 2). In 1997, there were 94.3 million acres of palustrine vegetated wetlands comprised of 50.7 million acres of forested wetlands, 25.2 million acres of freshwater emergent wetlands, and 18.4 million acres of freshwater shrub wetlands. A review of specific losses and gains of wetland classes revealed that 98 percent of all wetland losses in the period were palustrine wetlands. The impact on specific classes of palustrine wetlands varied, with forested wetlands decreasing 2.3 percent, emergent wetlands decreased 4.6 percent while shrub wetlands increased 6.6 percent and ponds increased over 13 percent (Dahl, 2001, p45). Approximately 4 million acres of forested wetlands were lost and 2.8 million acres were converted to other wetland types such as shrubs. Emergent wetlands were reduced by 1.2 million acres, and palustrine shrub wetlands increased percent in acreage. The causes for wetland losses were determined to be 51 percent due to urban and rural development, 26 percent due to agriculture and 23 percent due to silviculture.

For the period of 1998-2004, Dahl documented an increase rather than a decrease in total wetland acreage. Although total wetland acreage increased, vegetated wetland acreage decreased during the period. The report showed a net increase of 191,750 acres of wetlands, an average annual rate of gain of 32,000 acres. The study indicated the wetland acreage in 2004 to be 107.7 million acres with 95 percent freshwater (palustrine) wetlands. Palustrine wetlands were composed of 51 percent forested wetlands, 25.5 percent emergent wetlands, 17 percent shrub wetlands and 6.5 percent ponds. The increase in palustrine wetland acreage was attributed to an increase in the restoration and creation of numerous freshwater ponds (Dahl, 2004, p17), with agricultural conservation programs credited as a causal factor for the increase in wetland restorations. New and revamped ponds accounted for approximately 700,000 acres of new wetlands. If the ponds were not considered as wetland areas, wetland losses would have exceeded the gains in palustrine wetland acreage. Palustrine forested wetlands gained 548,200 acres due to natural ecological conversion of shrub wetlands into forested wetlands. The report identified that 61 percent of wetland losses were due to urban expansion and rural development. Conversion to agricultural uses continued to contribute to the loss of palustrine wetlands with agricultural conversion responsible for 33 percent of the forested wetland losses and 75 percent of emergent wetland losses.

The overall results of the 2004-2009 report are not significantly different from the 1998-2004 report. Total wetland acreage decreased by 62,300 acres but different wetland types experienced gains. Overall the vegetated palustrine wetlands decreased by 185,300 acres, but within this general category, both emergent and shrub wetlands increased. These increases were negated, however, by significant decreases in palustrine forested wetlands. As in the previous report, the palustrine pond category increased in acreage.

The reports show the differences in the losses and gains in acreages and loss rates of the three types of vegetated palustrine wetland types (Table 15).

Table 15. Comparison of changes in palustrine vegetated wetland acreage 1955 – 2009

	Loss in palustrine vegetated wetland acreage 1955 - 2009		
Period	Emergent	Shrub	Forested
1955 - 1974	4,671,200	387,100	5,994,000
1975-1985	-220,200	161,100	3,403,400
1986-1997	1,226,200	-1,130,400	1,201,100
1998-2004	142,600	900,800	-548,200
2005-2009	-207,800	-180,100	633,100

Note: Negative values denote gains in acreage.
Source: Frayer et al. 1983; Dahl and Johnson, 1991; Dahl 2000, 2006, 2011

Excel spreadsheets

The data used in this research was obtained from the databases developed by the FWS to support the status and trends reports concerning the nation's wetland resources (Frayer et al, 1981, Dahl and Johnson, 1991, Dahl, 2000, 2006 and 2011. The FWS database was arranged in rows by sample plot number (1-18787 with the number of samples between 3635-5042 depending on report period). Columns identify the estimated acreage of each type of wetland and non-wetland used in each sample plot; the acreage of each plot was 2560 acres. Neither plots nor strata were in consecutive order. The database contained 16 different wetland categories and types. The palustrine wetland types were emergent, forested, shrub, aquatic bed, unconsolidated bottom and unconsolidated shore. Upland (non-wetland) land classifications were identified as agricultural, rural development, urban development, forested plantations (silviculture) and other (Table 16).

Table 16. Example of Fish and Wildlife Service's database

Plot number	Wetland types- 16 types; marine, estuarine, palustrine, riverine, lacustrine			Upland; non-wetland use categories					
	PEM	PFO	PSS	PUB	UA	UB	UO	UFP	URD
1-18787									

A second FWS database contained information that identified each sample plot with its state location and stratum. In order to obtain a complete database, it was necessary to combine pertinent information from both databases into a single general Excel spreadsheet (General spreadsheet) that contained stratum number, sample plots within each stratum, and the estimated acreage for wetland and non-wetland categories (Table 17).

Table 17. Example of Excel spreadsheet that combined FWS databases

Stratum	Plot No.	Wetland and non-wetland categories – 22 possible categories											
		M1	E1	LAC	PEM	PFO	PSS	PAB	PUB	PUS	UA	UB	URD
1-36	1-18787												

The report periods covered both a beginning and an ending year, so it was necessary to create two general spreadsheets for each report period, with between 7200-10000 sample plots to review, separate and distribute between 36 strata for each spreadsheet. Each year was considered to be an observation. The total number of observations was 42,726.

Once the spreadsheets were established, the estimated acreage for each palustrine vegetated wetland type and total sample area for each stratum could be calculated.

A second Excel spreadsheet (Summary spreadsheet) was created that summarized the information from the general spreadsheet in rows for each stratum. The information on wetland types was restricted to the total estimated vegetated palustrine wetland types of emergent, forested and shrub, the total sample area of each stratum, and the total area of each stratum. Key values were determined by ratio estimation theory used by the FWS as explained by Dahl (2006). The proportion of each wetland type in the plot samples in a stratum served as an unbiased estimator of the unknown proportion of that wetland type in the stratum. The acreage of each wetland type within a sample plot was determined and designated " y". The total acreage of each wetland type per stratum was calculated by adding acreages for that wetland type for all the sample plots within each stratum, which was designated as "Ty". The total area (in acres) of the sample plots was designated as "Tx". The ratio of total wetland acreage type to total area of the stratum was calculated as: $r = Ty/Tx$. The estimated total acreage of the wetland type within each stratum was calculated by multiplying "r" by the area (A) of the stratum as:

Total wetland type (i.e. palustrine emergent) acreage = r X A.

This formula was applied to all strata in all report periods to determine the estimated acreage of each wetland type.

Other important values required to conduct correlation and regression analyses were calculated by developing the following formulas:

1. Total palustrine vegetated wetland acres in any stratum (TA):

   TA = APEM (Stratum x) + APFO (Stratum x) + APSS (Stratum x)

   APEM = area of palustrine emergent wetlands within stratum

   APFO = area of palustrine forested wetlands within stratum

   APSS = area of palustrine scrub/shrub wetlands within stratum

   Stratum x would apply to any stratum 1-36

2. Total wetland acreage in a year (TA Year)
   TA Year = TA (Stratum 1) +….TA (Stratum 36)

   Years = 1955, 1975, 1985, 1998, 2004, 2009

3. Total palustrine emergent wetlands (APEM):

   APEM = APEM Strata 1 +…+APEM Strata 36

4. Total palustrine forested wetlands (PFO):

   APFO = APFO Strata 1 +…+APFO Strata 36

5. Total palustrine shrub wetlands (APSS):

   APFO = APSS Strata 1 +…+APSS Strata 36

6. Wetland loss rate (LR) for total wetland acreage between years:

   LR 1975 = TA 1984 – TA 1975/19

   LR 1984 = TA 1975 - TA 1984/9

   LR 1998 = TA 1984 – TA 1998/12

LR 2004 = TA 1998 – TA 2004/6

LR 2009 = TA 2004 – 2009/4

This formula could be applied to values for successive years

7. Total emergent wetland loss rate between years: (LR wetland type)

   LR (wetland type) = LR(wetland type Year 1)-LR (wetland type Year 2) /number of interval years

   This formula would apply to palustrine vegetated wetland types of emergent, forested and shrub

8. Acres lost to agricultural conversion

   Step 1. Determine observed wetland losses by wetland type within stratum

   PEM= emergent wetlands; PFO=forested wetlands; PSS=shrub wetlands

   Total PEM/PFO/PSS acres lost = sum of PEM/PFO/PSS agricultural acres in each plot in the selected stratum.

   Step 2. Determine estimated acreage by wetland type

   Tx = total area of sample in stratum

   A = total area of stratum

   Acres lost = Total (PEM/Tx)(A)

   Loss rate due to agricultural conversion (LR-Agr):

   LR-Agr = Acres lost(wetland type)/number of years

   Years = 19, 9, 12, 6 or 4 depending on report period

   Same formulas would apply for wetland types PFO and PSS

   Step 3. Total loss rate due to agricultural (TLR-Agr) conversion:

   TLR-Agr (any stratum) = LR PEM + LR PFO + LR PSS

9. Acres lost to non-agricultural conversion

   Step 1. Determine observed wetland losses by wetland type within stratum.

   Types of non-agricultural losses are urban development (URD), rural development (UB), upland forest plantation (UFP), and other (UO).

   Total UB, UR, UFP, UO acres lost = sum of UB, UR, UFP, UO acres in each plot in the selected stratum.

   <u>Step 2</u>. Determine estimated acreage by action

   Tx = total area of sample in stratum

   A = total area of stratum

   Acres lost = Total (UB/Tx)(A)

   Use same formula but substitute UR, UFP, and UO values for UB to calculate the acres lost to each of the non-agricultural actions

   Loss rate due to non-agricultural conversion (LR-NonAgr):

   LR-NonAgr = Acres lost(action type)/number of years

   Years = 19, 9, 12, 6 or 4 depending on report period

   <u>Step 3</u>. Total loss rate due to non-agricultural (TLR-NonAgr) conversion:

   TLR-NonAgr (any stratum) = LR UB+ LR UFP + LR URD + LR UO

The summary information provided for each wetland type and stratum enabled estimations to be made for the acreage of each wetland type in each stratum. A summary spreadsheet was created for the beginning and ending year for each report period (Table 18).

Table 18. Summary Spreadsheet for each beginning and ending year of reports

Strata	Tx	PEM	PFO	PSS	Ty	r	A	rPEM	APEM	rPFO	APFO	rPSS	APSS
1-36													

Tx: total area of sample in the indicated stratum

PEM, PFO, PSS: acreage of wetland type in strata as determined from sample plots

Ty: total area observed for palustrine vegetated wetlands in stratum

r: r=Ty/Tx ratio of palustrine wetlands in stratum

A: area of the stratum in acres

rPEM/rPFO/rPSS: ratio of wetland type in stratum; PEM,PFO,PSS/Tx

APEM/APFO/APSS: area of wetland type in stratum (i.e. rPEM multiplied by A)

The acreage information calculated from the summary spreadsheets provided the basis for comparisons between report years to determine loss rates between years, strata and wetland types.

Major strata

Eight strata are considered to be major strata for inclusion in the research, because they contain approximately 81 percent of all the palustrine vegetated wetland acreage, including 58 percent of the sample plots, 81 percent of the wetland acreage that decreased from 1955-2009, and encompass all or parts of 31 states found in the Midwest, Lower Mississippi River Valley and the Southeast United States. The eight strata selected are: North Central Lake Swamp-Moraine Plains (Stratum 15), Dakota-Minnesota Drift and lake-bed Flats (Stratum 21), Middle Western Upland Plain (Stratum 26), Lower Mississippi Alluvial Plain (Stratum 28), East Central

Drift and Lake-bed Flats (Stratum 29), Appalachian Highlands Stratum (31) Gulf Atlantic Rolling Plain (Stratum 34), and Gulf Atlantic Coastal Flats (Stratum 35) (Table 19).

Table 19. List of Strata used in Status and Trends Reports

Strata number	Strata Description	Average Number of sample plots	Percent of total samples	Percent of palustrine wetlands
35*	Coast Atlantic Coastal Flats	805	20.3	21.4
34*	Gulf Atlantic Rolling Plain	526	13.3	22.4
28*	Lower Mississippi Alluvial Plain	342	8.6	8.6
15*	North Central Lake Swamp-Moraine Plains	305	7.7	17.1
21*	Dakota-Minnesota Drift and Lake-bed flats	93	2.3	5.0
26*	Middle Western Upland Plain	93	2.3	2.3
29*	East Central Drift and Lake-bed Flats	83	2.1	2.2
31*	Appalachian Highlands	66	1.7	2.2
Total		2313	58.3	81.2
36	Coastal Zone	980	24.7	0.6
24	Mid-continent Plains and Lake-bed Flats	67	1.7	1.4
33	Lower New England	64	1.6	1.9
19	High Plains	59	1.5	0.7
9	Northern Rocky Mountains	52	1.3	1.3
8	Basin and Range Area	42	1.1	1.3
32	Adirondack-New England Highlands	41	1.0	1.0
4	Central Valley of California	32	0.8	0.3
12	Wyoming Big Horn Basins	29	0.7	0.2
30	Eastern Interior Uplands and Basins	29	0.7	0.8
27	Ozark-Ouachita Highlands	29	0.7	0.6
16	Upper Missouri Basin Broken Lands	26	0.7	1.3
22	Nebraska Sand Hills	26	0.7	0.6
11	Middle Rocky Mountains	22	0.6	0.3
25	Southwest Wisconsin Hills	20	0.5	0.3
13	Colorado River Plateaus	18	0.5	1.3
23	West Central Rolling Hills	18	0.5	0.5
5	Columbia Basin	12	0.3	0.2
18	Rocky Mountain Piedmont	11	0.3	0.2
7	Harney-OwyheeBroken Lands	10	0.3	1.0
10	Snake River Lowland	10	0.3	0.4
2	Puget-Willamette Lowland	10	0.3	0.2
17	Southern Rocky Mountains	9	0.2	0.3
1	Coast Range	9	0.2	0.3
3	Cascade-Klamath Sierra Nevada Ranges	8	0.2	0.5
6	Blue Mountains	8	0.2	0.6
14	Upper Gila Mountains	4	0.1	0.1
20	Stockton-Balcones Escarpment	2	0.1	0.0

Source: Dahl, 2011
*Strata included in study

The number of sample plots within each stratum remained stable until the 2006 report when 311 additional plots were added to ten different states, which affected the acreage values in different strata. An additional 290 plots were added in the 2011 report. An average plot number per stratum was used to reflect the increased number of samples used in the studies. The number of plots was not reduced during the study period and the increased number of plots did not affect the determination of major strata. Stratum 36 had the greatest number of sample plots, and contained the greatest area, but had a very low ratio of wetland sample area to total sample area (Ty/Tx = 2.0), so the percentage of wetlands within the stratum was consistently low. All study years contained strata that showed both a loss and a gain of wetland acreage, but the losses always exceeded the gains, though at a reduced rate over the study period.

Dependent and independent variables

The focus of this research is that palustrine vegetated wetland loss rates are considered to be a function of several variables: 1) the amount of total wetland and wetland types that exist; 2) federal regulatory programs that serve to restrict and regulate wetland conversions; 3) federal programs that provide economic incentives to preserve, restore or create wetlands, and 4) commodity prices of major crops that affect decisions to convert wetlands to increase crop production and farm income. Conversion of palustrine vegetated wetlands to agricultural land has been identified as a significant cause for wetland losses. Over 95 percent of all wetlands in the conterminous United States are palustrine wetlands (Dahl, 2006) and conversions of wetlands to agricultural use accounted for 87 percent of all conversions for the period of mid-1950's to mid-1970's, 54 percent for the period of mid-1970's to the mid-1980's, and 26 percent from 1986-1997.

Dependent variables identified in this study are palustrine vegetated wetland loss rate (loss rate) and loss rate due to agricultural conversions. Loss rates are determined by subtracting the wetland acreage of one report period from the following report period and dividing by the number of years. The loss rate due to conversion of wetlands to agriculture was determined by summing the acres observed as having changed from a palustrine wetland type in the prior report to agricultural use in the subsequent report, applying ratio estimation theory (Dahl, 2000). The ratio estimation theory was applied based on the ratio of a particular land use acreage (wetland, agricultural lands or other) observed in a stratum to the total acres sampled in that stratum. That ratio value was then multiplied by the total area of the stratum to identify the estimated acres of the land use type.

These variables can be statistically analyzed to determine their significance in determining palustrine wetland loss rates. The independent variables that are considered significant are divided into three groups: policy, price, wetlands remaining. Policy factors include Conservation Reserve Program rental rates and enrolled acres, Wetland Reserve Program enrolled acres, Swampbuster provisions of the Food Security Act of 1985, and Clean Water Act Section 404 permits. The 1986 Tax Revision Act is also considered to be a significant independent variable, but its enactment coincided with that of the Swampbuster provisions, so it was not possible to differentiate between the impacts of these two policy items. The two variables were perfectly collinear. Although only Swampbuster was included, its impacts should be interpreted as both Swampbuster and the Tax Revision Act. The Clean Water Act Section 404 permit program is a regulatory program affecting wetland conversions, the Conservation Reserve and Wetland Reserve Programs provide economic incentives for landowners to conserve wetlands, and the Swampbuster provisions provide economic disincentives if agricultural wetlands were converted to cropland after 1985. The price group includes the prices of corn, wheat and soybeans. These variables support the conversion of wetlands because sufficient price levels would tend to encourage farmers to convert wetlands to additional cropland to increase income. The third independent variable is the percent of wetlands remaining. It is difficult to estimate the percentage of wetlands remaining in any stratum because the original acreage is unknown and wetland acreage is dynamic; wetland acreage constantly varies due to decisions of landowners, economic forces, land values, development pressures, and improved technology that can better define and identify wetland resources. The Status and Trends reports reflected this volatility. The ending wetland acreage of one report always varied from the beginning acreage of the succeeding report from two to six million acres. Overall the palustrine shrub wetland acreage increased over the 50-year period although acreage decreased between the mid-1970's and mid-1980's (Dahl and Johnson, 1991), and between 2005-2009 (Dahl, 2011). Dahl (1990) estimated total wetland losses for each state from 1780 to 1980, but the information could not be directly used to determine percentage of wetlands remaining at a specific year because: 1) the wetland estimates are for the entire state; 2) the ending period was between status and trends report periods; 3) neither strata nor wetland types were identified; and the strata usually contain parts of several states so determining the wetland percentage remaining would have to be based on a weighted average assuming the selected sample plots contained wetland acreage. This was not considered to be more accurate than the procedure used. The percent of wetland remaining was determined based on the acreage estimated in 1956 as being 100 percent. These variables are hypothesized to have a positive impact on loss rates (Table 20).

Table 20. Independent variables

Independent variables	Type	Units	Updated to 2009 value	Data source
CRP rental rate	Policy	Dollars/ac/yr	yes	USDA
CRP acres	Policy	Acres	no	USDA
WRP acres	Policy	Acres	no	USDA
Corn price	Price	Dollars/bu	yes	NASS
Wheat price	Price	Dollars/bu	yes	NASS
Soybean price	Price	Dollars/bu	yes	NASS
Percent wetlands remaining	Neither	Percentage based on 1956 acres	no	FWS

The effective date for the policy variables was the date the policies were enacted. In the cases of Clean Water Act Section 404 permits and Swampbuster, values were 1 when the policy was effective and 0 when it was not effective. The values of the commodities were obtained from the National Agriculture Statistical Service for each state within a particular stratum. Using a weighted average technique the values for each state were combined into a calculated value representative of the stratum. The values were updated to 2009 values using a Bureau of Labor inflation calculator. The same weighted average technique was used to determine the Conservation Reserve and Wetland Reserve Programs enrolled acreage and the Conservation Reserve Program rental rates. The rental rates were updated to 2009 values by the same inflation calculator. The vegetated palustrine wetland acreage data for all wetland types was obtained from the FWS database prepared to support the status and trends reports.

Matrices and statistical program analyses

In order to analyze the multi-year wetland data created on the summary Excel spreadsheets, matrices were created using the SPSS statistical program. Matrices were created for the total wetland information from 1955-2009, the eight major strata and the three palustrine vegetated wetland types. The columns of information included year (1955-2009), loss rates, CRP rental rate, CRP enrolled acres, WRP enrolled acres, Swampbuster, CWA404, commodity prices of corn, wheat and soybeans, percent of wetlands remaining, and loss rate due to agricultural conversion. The year column reflected the FWS status and trends reports periods. The years established were: 1956-1974; 1976-1984; 1986-1997; 1999-2004; and 2005-2009. The transition years between reports were deleted to prevent data overlap.

The methodology followed for analyzing the data in the matrices is:

1. Determine correlation between all variables. High correlation coefficients will indicate a strong relationship between variables; a positive sign will indicate the relationship is positive and a negative sign will indicate an inverse relationship. The expected results are for the policy variables to have a negative relationship and the price variables to have a positive relationship to wetland loss rates (Table 21).

Table 21. Univariate statistics on dependent and independent variables

Variables	Minimum	Maximum	Mean
Dependent variables			
Total Loss rate	118260	698006	408133
Loss rate due to agriculture	61226	616837	339032
Independent variables			
CRP rental rate	33.35	115.80	74.58
CRP acres	0	4074759	2037380
WRP acres	0	412438	206269
Corn price	1.00	5.26	3.13
Wheat price	1.14	7.28	4.21
Soybean price	1.82	11.50	6.66
Percent wetlands remaining*	62	100	81
Loss rate due to agriculture	991	586629	293810

*Based on estimated wetland acreage in 1955

Perform regression analyses using palustrine vegetated wetland loss rate and loss rate due to agriculture actions as the dependent variables and all other variables as independent variables. This could be written as a general linear regression model (Neter, et al., 1996):

$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_{p-1} X_{i,p-1} + \varepsilon_i$

Where Y_i is wetland loss rate

$B_{0,}$ $\beta_{i1,}\ldots,$ β_{p-1} are parameters

$X_{i1},\ldots,$ X_{i2} are known constants (predictor variables)

ε_i is the error

With all the predictor variables added, the full model would be:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \varepsilon$

Where Y is the expected wetland acreage

β_0 is the Y intercept of the regression plane

$\beta_{i1,}\ldots,$ β_{11} are the parameters

$X_1,\ldots,$ X_8 are the predictor variables previously identified

ε_i is the error

Using the above model, regressions were performed for the total study period (1955 – 2009), for each vegetated palustrine wetland type (emergent, shrub and forested), and selected major strata. The regression coefficients are displayed with the independent variables and the Adjusted R^2 value in columns and the individual strata and wetland types in rows. The independent variables are divided into policy and price sections; the expected values of policy variables being negative and the expected value of price variables showing a positive value.

Principle component analysis (PCA) is a variable reduction process that is applied to reduce or simplify the number of independent variables while maintaining a high level of explained variance. PCA can be used to clarify regression results that are unclear due to multicollinearity among variables. The application identifies one or more principle components that are composed of several but not all of the independent variables. The PCA process included in SPSS statistical program identifies principal components, the influence exerted by each of the selected independent variables on the principle component and a variable for the principal component(s) that can be regressed against a dependent variable. The result of the regression provides a better understanding of the relationship between the principal component(s) and the dependent variable.

CHAPTER 4

RESULTS

The hypothesis of this research is that federal governmental policies focused on conservation, restoration, and regulation of wetland conversions has a negative correlation with vegetated palustrine wetland loss rate. Commodity prices of corn, wheat and soybeans have a positive correlation with vegetated palustrine wetland loss rate. The percentage of palustrine wetlands remaining also has a positive correlation with vegetated palustrine wetland loss rate. These results are consistent, with minor variations, across geographic wetland strata and wetland types.

The results are based on a statistical analysis of the palustrine vegetated wetland acreage data prepared to support the FWS status and trends reports concerning wetlands in the conterminous United States between the mid-1950's and 2009. Correlation analysis, multiple regression analysis and principal component analysis identified Swampbuster/Tax Law revisions of 1986 and Conservation Reserve Program acreage and rental rates as the most significant policy variables that reduced the vegetated palustrine wetland loss rate, with corn price being the most significant commodity price increasing that rate.

Correlations with palustrine vegetated wetland loss rate

A correlation analysis verified the hypothesized relationships between the dependent variable—palustrine vegetated wetland loss rate -- and the independent variables. A negative correlation exists between the policy variables Swampbuster/Tax law revisions of 1986, Conservation Reserve Program, Wetland Reserve Program, and the Clean Water Act Section 404 regulations suggesting these policies and regulations prevented or slowed wetland conversions and encouraged wetland restoration, thus lowering the loss rate. The positive correlation with commodity prices of corn, wheat and soybeans indicate higher prices stimulated increased conversion of wetlands to cropland to increase yield and farm profits. The positive correlation with the percentage of wetlands remaining indicates that differences in vegetated palustrine wetland acreages available for conversion impacted changes to loss rates.

Overall the correlation coefficients were moderate to strong, significant and consistent throughout the strata and wetland types with the exception of palustrine shrub wetlands that showed a significant negative correlation with the independent variable percent of remaining wetlands (Table 22).

Table 22. Correlation Matrix between loss rate and independent variables 1956 - 2009

Policy hypothesis = negative						Price hypothesis = positive				
Wetland loss rate (acre/year)	CRP Rental Rate	CRP acres	WRP acres	Swamp-Buster	CWA 404	Corn Price	Wheat Price	Soy bean Price	Percent Wetlands Remaining	Acres drained by ACP funded support
All strata	-.854	-.820	-.366	-.886	-.797	+.840	+.803	+.710	+.883	+.847
Wetland Strata										
15 North Central Lake Swamp Moraine Plains	-.817	-.762	-.589	-.845	-.818	+.870	+.840	+.698	+.854	+.846
21 Dakota Minn Drift and Lake Bed Flats	-.844	-.870	-.553	-.932	-.352*	+.670	+.664	+.752	+.692	+.376
26 Middle Western Upland Plain	-.893	-.893	-.557	-.938	-.787	+.866	+.839	+.758	+.791	+.833
28 Lower Mississippi Alluvial Plain	-.895	-.902	-.578	-.952	-.771	+.851	+.826	+.750	+.703	+.819
29 East-Central Drift and Lake Bed Flats	-.626	-.642	-.531	-.644	-.840	+.779	+.744	+.541	+.699	+.821
31 Appalachian Highlands	-.236*	-.109*	-.838	-.299	-.465	+.492	+.467	+.296	+.332	+.432
34 Gulf Atlantic Rolling Plain	-.389	-.658	-.887	-.523	-.533	+.736	+.717	+.452	+.659	+.726
35 Gulf Atlantic Coastal Flats	-.944	-.917	-.489	-.970	-.730	+.827	+.804	+.754	+.806	+.817
Wetland types										
Emergent Wetlands	-.712	-.755	-.625	-.711	-.842	+.811	+.778	+.617	+.759	+.779
Forested Wetlands	-.784	-.768	-.404	-.821	-.852	+.813	+.782	+.656	+.962	+.881
Shrub Wetlands	-.803	-.726	-.131*	-.813	-.456	+.637	+.628	+.682	-.637	+.543

*Indicates correlation is not significant

The eight major strata have different characteristics that contribute to the amount of changes in wetland acreage and loss rates. The value of the correlation coefficient reflects the strength of the relationship between variables with higher values indicative of stronger relationships. The strongest relationships with loss rate were with the independent variables Swampbuster/Tax law revision of 1986, corn price, Conservation Reserve Program rental rates, wheat price, and Conservation Reserve Program acres.

Hammonds' geophysical regions of the conterminous United States served as one stratum level, and present significant diversity in a number of physical factors, predominant wetland types, agricultural activity and susceptibility for development, that affect the results of the study. Stedman and Dahl (2008), Frayer et al. (1983), Dahl and Johnson (1991), and Dahl (2000, 2006, 2011) identified that changes in wetland resources in specific regions of the country may not reflect the same trends as those on the national scale. It is reasonable to expect differences between strata and between strata and the national trends concerning the impact of the various independent variables on wetland loss rates since the independent variables vary between states. Study results show differences in the type of palustrine wetlands that experienced the greatest losses. Palustrine emergent wetlands suffered the most significant losses in half the strata and had the highest average loss rate across all strata. The losses of emergent wetland acreage occurred in strata that included all or parts of agriculturally productive states such as Ohio, Indiana, Illinois and Iowa, and the Northern Great Plains prairie pothole region. This supports the hypothesis that a negative relationship exists between policies, especially agricultural policies that encourage wetland conservation, and wetland loss rates. This also explains the positive correlation between commodity prices and wetland conversions. Emergent wetland loss was not the highest in the Lower Mississippi Alluvial Plain (stratum 28). In this stratum, forested wetland losses showed the highest losses, which is reflective of harvesting floodplain forests. Gulf-Atlantic Rolling Plain (stratum 34) also experienced significant losses to forested wetlands. Strata 35 (Gulf-Atlantic Coastal Flats) showed a balance between emergent and forested wetland losses associated with harvesting of floodplain forests in the Southeast (Table 23). The shrub wetlands had the lowest and weakest correlation coefficients and the value for percent of wetlands remaining was opposite of expected. Shrub wetlands showed the lowest average loss rate, which is expected since shrub wetland acreage increased during the 50-year study period, so a negative value for this variable is reasonable. The status and Trends report data was captured in five separate periods. Each period showed gains and losses in wetland types. The percent of wetland losses shown in Table 23 are based on the losses recorded in all five report periods.

Table 23. Percentage of palustrine wetland changes in major strata

Stratum	States included	Percent of palustrine wetland losses by wetland types		
		Emergent	Foreste d	Shrub
15 North-Central Lake-Swamp-Moraine Plains	MN, WI, MI, IN, IL, MT, SD and ND	77%	4%	19%
21 Dakota-Minnesota Drift and Lake-bed flats	ND, SD and MN	64%	5%	31%
26 Middle Western Upland Plain	IA, MN, IL, IN, KY, SD and NE	78%	15%	7%
28 Lower Mississippi Plain	MO, KY, TN, AR, MS, LA	6%	93%	1%
29 East-Central Drift and Lake-bed Flats	IL, IN, MI, OH	60%	4%	36%
31 Appalachian Highlands	NY, PA,OH, WV, MD, VA,KY, TN, NC, SC, GA, AL	7%	56%	37%
34 Gulf-Atlantic Rolling Plain	GA, LA, FL, SC, AL, AR, TX, MS, NC, TN, VA, MD, NJ, KY, PA, DE, IL, OK, NY	14%	81%	5%
35 Gulf-Atlantic Coastal Flats	GA, LA, FL, SC, AL, TX, MS, NC, VA, MD, NJ, DE,	37%	44%	19%
Average		43%	36%	19%

Correlations with loss rate due to agriculture conversion

Wetland losses due to conversion to agricultural land continued at different rates throughout the study period. The correlations are similar in sign to the overall loss rate correlation (Table 22). The same independent variables were used. The policy variables were negatively correlated with the loss rate due to agricultural conversion and the commodity prices showed a positive correlation. The percent wetland remaining variable also reflected a positive correlation. This reflects the significant impact of farm policies and commodity prices on wetland conversions and loss rates. Overall, the correlation coefficients were moderate to strong, significant and consistent throughout the strata and wetland types. There is one exception to the expected sign results: palustrine shrub wetlands showed a negative correlation with the percent of wetlands remaining (Table 24).

Table 24. Correlation Matrix between agricultural loss rate and independent variables 1956 - 2009

Policy hypothesis = negative						Price/per cent remaining hypothesis = positive				
Agricultural wetland loss rate (acre/year)	CRP Rental Rate	CRP acres	WRP acres	Swamp-Buster	CWA 404	Corn Price	Wheat Price	Soy bean Price	Percent Wetlands Remaining	Acres drained by ACP funded support
All strata	-.791	-.773	-.405	-.827	-.852	+.850	+.809	+.655	+.917	+.883
Wetland Strata										
15 North Central Lake Swamp Moraine Plains	-.762	-.817	-.589	-.845	-.818	+.870	+.835	+.698	+.854	+.792
21 Dakota Minn Drift and Lake Bed Flats	-.842	-.818	-.500	-.903	-.351	+.606	+.600	+.692	+.664	+.374
26 Middle Western Upland Plain	-.713	-.708	-.416	-.748	-.873	+.788	+.754	+.593	+.760	+.885
28 Lower Mississippi Alluvial Plain	-.885	-.895	-.586	-.942	-.783	+.854	+.827	+.743	+.712	+.827
29 East-Central Drift and Lake Bed Flats	-.628	-.625	-.444	-.647	-.828	+.777	+.745	+.554	+.647	+.811
31 Appalachian Highlands	+.340	+.463	-.579	+.297	+.109*	-.051*	-.056*	-.147*	-.250*	-.174
34 Gulf Atlantic Rolling Plain	-.684	-.466	-.520	-.742	-.870	+.853	+.811	+.541	+.820	+.726
35 Gulf Atlantic Coastal Flats	-.742	-.772	-.570	-.805	-.839	+.802	+.770	+.613	+.898	+.867
Wetland types										
Emergent Wetlands	-.774	-.817	-.666	-.836	-.807	+.819	+.789	+.660	+.739	+.847
Forested Wetlands	-.833	-.835	-.519	-.880	-.835	+.846	+.816	+.703	+.963	+.878
Shrub Wetlands	-.938	-.945	-.616	-.993	-.606	+.801	+.783	+.790	-.581	+.705

Shrub wetland correlation with percentage of wetlands remaining is a negative value rather than the expected positive value regardless of the dependent variable. Overall, shrub wetland acreage increased over the 50-year study period, although acreage did decrease about 900,000 acres (Dahl, 2006) in the 1998-2004 period and 180,000 acres in the 2004-2009 period (Dahl, 2011). The overall increase in acreage explains the negative correlation coefficient. Changes in shrub wetland acreage can result from: 1) conversion of shrub wetlands to non-wetland use such as agricultural or development; 2) restoration or creation of shrub wetlands through conservation actions; and 3) changes in vegetation type that result in a classification change to another type of palustrine wetland. For wetland classification purposes, a shrub is considered to be a type of woody vegetation less than 20 feet tall (Cowardin, 1979), so natural growth of some species or harvesting of mature trees (silviculture operations) can cause a change in wetland classification just based on vegetation height. Examples of this type of conversion are: 1) between 1986-1997, 2.4 million acres of palustrine shrub wetlands changed to palustrine forested wetlands while 2.8 million acres of palustrine forested wetlands changed to palustrine shrub wetlands; and 2) between 1998-2004, 2.6 million acres of palustrine shrub wetlands changed to palustrine forested wetlands while 1.4 million acres of palustrine forested wetlands changed to palustrine shrub wetlands. In addition, 1.0 million acres of palustrine shrub wetlands changed to palustrine emergent wetlands. Conversions between wetland types impact the acreage of wetland types as does the conversion of shrub wetlands to agricultural and non-wetland use. From 1956-2009 the amount of shrub wetlands converted to agricultural land decreased while conversions from agricultural land to shrub wetlands increased (Table 25), indicating conservation farm policies also impacted shrub wetland acreage.

Table 25. Acres converted between palustrine shrub wetlands and agricultural use 1955-2009.

Years	Shrub wetland to agricultural land (acres)	Agricultural land to shrub wetland (acres)
1955-1974	952,600	0
1975-1985	272,224	23,154
1986-1997	76,256	0
1998-2004	59,492	43,040
2005-2009	41,928	69,716

Regression

Multivariate regressions were performed for the period 1955 – 2009, for each of the eight major strata, and the three palustrine vegetated wetland types of emergent, forested and shrub. The dependent variables were palustrine vegetated wetland loss rate, palustrine vegetated loss rate due to agricultural conversions and palustrine vegetated loss rate due to non-agricultural actions. In all cases, the independent variables were the policy variables of Swampbuster/Tax law revision of 1986, Clean Water Act Section 404 regulations, Wetland Reserve Program acres, Conservation Reserve Program rental rates and enrolled acres; the commodity variables were corn, wheat and soybean prices; and the percentage of palustrine vegetated wetland acres remaining.

Dependent variable – palustrine vegetated wetland loss rate

The regression results were not as definitive as the results of the correlation matrix (Table 14). The high Adjusted R^2 values of 0.981 for stratum 21, and above 0.868 for all other strata, indicate that the correct independent variables were identified. The only variables whose coefficients were partially consistent with the hypotheses of negative values for policy variables and positive coefficients for commodity variables and percent of wetlands remaining however, were Clean Water Act Section 404 (CWA404) and corn price. The summary of the negative and positive coefficients for each independent variable do not present a clear picture of their relationship to loss rate and are inconsistent with the correlation results. The signs of the regression coefficients are inconsistent and often do not agree with the hypothesis; there were few variables determined to be statistically significant (Table 26). This condition suggests that multicollinearity is affecting the results caused by strong relationships among the independent variables.

Table 26. Collected results of regressions for overall, for each strata, and for each wetland type. N=45 in each case. Threshold for significance = 0.05. Dependent variable = loss rate

	Policy hypothesis=negative					Price hypothesis/Pct left = positive					
	SB	CWA 404	WRP	CRP rent	CRP Ac	Corn	Soy bean	Wh eat	Pct Left	ACP acres	R^2 Adj
Overall	-.44	-.37	+.26	NS	NS	NS	+.25	NS	+.22	NS	.958
Individual Strata											
15-N. Cen. Lake Swmp	NS	-.64	-.16	NS	NS	NS	+.45	NS	NS	NS	.932
21-Dak-MN Drift/Lake	-1.5	+.19	-.17	NS	NS	NS	-.12	NS	-.45	NS	.981
26-Midwest Upland Pl	-.50	-.44	NS	NS	NS	+.29	+.22	-.30	NS	NS	.973
28-Lower Miss Alluvial	-.62	-.40	NS	NS	NS	+.25	+.17	-.31	NS	NS	.977
29-E. Cen. Drift/Lake	+.45	-.89	-.21	NS	NS	+.58	+.50	-.55	NS	NS	.868
31-App. Highlands	+.77	-.52	-.97	NS	NS	NS	+.23	NS	NS	NS	.887
34-Gulf-Atl. Plain	+.44	-.43	-1.0	NS	+.20	NS	+.25	NS	NS	NS	.894
35-Gulf-Atl. Coastal	-1.06	-.12	+.12	+.18	NS	NS	NS	-.13	+.16	+.09	.987
Wetland Types											
Emergent Wetlands	NS	-.71	-.28	NS	NS	NS	+.34	-.23	+.16	NS	.911
Forested Wetlands	-.14	-.27	+.15	NS	NS	NS	+.20	NS	+.57	NS	.962
Shrub Wetlands	-1.7	+.22	+.84	NS	NS	NS	NS	NS	+.45	NS	.872
Significant Negative	7	10	6	0	0	0	1	5	1	0	
Significant Positive	2	2	4	1	1	3	9	0	5	1	

Dependent variable – loss rate due to agricultural conversion

Regression results with the dependent variable being loss rate due to agricultural conversion lacked clarity and were not as definitive as the results of the correlation matrix (Table 16). The high Adjusted R^2 values of 0.976 for shrub wetlands and above 0.8 for all other variables indicate that the correct independent variables were identified. However, the only variables whose coefficients were partially consistent with the hypotheses of negative values for policy variables and positive coefficients for commodity variables and percent of wetlands remaining were Clean Water Act Section 404 (CWA404) and corn price. The summary of the negative and positive coefficients for each independent variable do not present a clear picture of their relationship to agricultural loss rate and are inconsistent with the correlation results. The signs of the regression coefficients are inconsistent and often do not agree with the hypothesis, there were few statistically significant independent variables (Table 27).

Table 27. Collected results of agricultural loss rate regressions for overall, for each strata, and for each wetland type. N=45 in each case. Threshold for significance = 0.05.

	Policy hypothesis=negative					Price hypothesis/Pct left = positive					
	SB/ Tax	CWA 404	WR P	CRP rent	CRP Ac	Corn	Soy bean	Wh eat	Pct Left	ACP acres	R^2 Adj
Overall	-.24	-.63	NS	NS	NS	NS	+.28	-.36	+.35	NS	.945
Individual Strata											
15-N. Cen. Lake Swmp	-.16	-.60	-.09	NS	NS	NS	+.38	NS	NS	NS	.945
21-Dak-MN Drift/Lake	-1.5	+.22	-.11	NS	NS	NS	-.24	NS	-.41	NS	.921
26-Midwest Upland Pl	NS	-.85	NS	NS	NS	+.53	+.38	-.63	NS	NS	.903
28-Lower Miss Alluvial	-.56	-.43	NS	NS	NS	+.28	+.19	-.33	NS	NS	.973
29-E. Cen. Drift/Lake	+.40	-.90	NS	NS	NS	NS	+.63	NS	NS	NS	.820
31-App. Highlands	+.81	-.11	-1.0	NS	+.20	NS	NS	NS	NS	NS	.948
34-Gulf-Atl. Plain	NS	-.81	NS	NS	NS	+.58	+.35	-.57	NS	NS	.917
35-Gulf-Atl. Coastal	-.94	-.54	NS	+.65	NS	NS	+.19	-.32	+.37	NS	.922
Wetland Types											
Emergent Wetlands	-.24	-.58	-.30	NS	NS	NS	+.23	-.25	+.14	NS	.916
Forested Wetlands	-.26	-.19	NS	NS	NS	NS	+.12	NS	+.52	NS	.978
Shrub Wetlands	-.78	-.05	-.16	NS	NS	NS	NS	NS	-.14	NS	.992
Significant Negative	8	11	5	0	0	0	1	6	2		
Significant Positive	2	1	0	1	1	3	9	0	4		

Multicollinearity effect

The unclear results of the regressions indicate they are affected by multicollinearity, a condition when the independent variables are closely correlated with each other. Multicollinearity adversely impacts the products of a regression analysis by creating inaccurate or confusing information regarding how the independent variables interact with or explain the dependent variable. Because of multicollinearity, we cannot attribute changes in the wetland loss rate to individual independent variables. Multicollinearity emerges in this dataset due to the coincidence in time of the major policy variables.

When faced with a multicollinearity problem, the most common statistical strategy is to employ principal components analysis to generate orthogonal explanatory variables, though this comes at the expense of the interpretability of the results. Multicollinearity is indicated when two or more independent variables are highly correlated. The independent variables can be divided into three general categories: 1) policies that includes Swampbuster, Conservation Reserve Program, Wetland Reserve Program, and the Clean Water Act Section 404 regulations; and 2) commodity prices that include corn, wheat and soybeans; and 3) percent of wetlands remaining. A correlation matrix of these variables on the national scale shows a moderate to strong positive correlation between variables within each category and a moderate to strong negative correlation between variables in the different categories (Table 28). Strong correlations among variables indicate they affect each other or are codetermined by a third factor (e.g. time) rendering indeterminant the individual impacts of the independent variables on the dependent variable. This is true for both the variables within and between categories. When correlations between independent variables for all strata and wetland types are considered, 94 percent of the correlations showed significant correlation at the .01 level and an additional four percent at the

.05 level of significance. The number of statistically significant correlations between all independent variables supports the concern that multicollinearity is impacting the validity of the regression coefficients.

Table 28. Correlation matrix of independent variables for all strata

\ P>R \ Pearson's R\	CRP Rental Rate	CRP acres	WRP acres	Swamp-buster/ Tax Law	CWA 404	Corn Price	Wheat Price	Soy bean Price	Pct Remaining	ACP drained acres
CRP Rental Rate		.000	.000	.000	.000	.000	.000	.000	.000	.000
CRP Acres	.954		.000	.000	.000	.000	.000	.000	.000	.000
WRP acres	.481	.657		.000	.012	.000	.001	.000	.000	.003
Swampbuster	.947	.947	.580		.000	.000	.000	.000	.000	.000
CWA 404	.576	.576	.353	.608		.000	.000	.000	.000	.000
Corn Price	-.794	-.861	-.672	-.839	-.783		.000	.000	.000	.000
Wheat Price	-.770	-.834	-.657	-.814	-.809	.962		.046	.000	.000
Soybean Price	-.750	-.786	-.523	-.807	-.283	.663	.591		.000	.001
Pct Remaining	-.723	-.737	-.500	-.769	-.812	.900	.846	.614		.000
ACP drained acres	-.671	-.671	-.411	-.708	-.911	.841	.851	.468	.834	

Principal Component Analysis

Principal component analysis is a procedure that reduces the number of variables to a few artificial variables called principal components that explain the majority of the variance in the original variables (www.statistics.laerd.com). It is an effective tool that can clarify regression analyses where multicollinearity is a concern. In order for principal component analysis to be considered appropriate, the following criteria were verified: 1) a linear relationship exists between variables; sample size was adequate as established by the Kaiser-Meyer-Oberlin measure of sampling; and Bartlett's test of sphericity showed the data were suitable for application of principal component analysis. The principal component analysis was completed using the application included in the SPSS statistical program and following the protocol presented by the University of Texas (www.utexas.edu) that provides for discretion in identifying the best principal components for each of the cases. A key determining factor in principal component analysis is eigenvalue that in general terms represents the variance of the principal component.

The method used to select the principal components was the eigenvalue-one criterion that automatically selected components that had an eigenvalue of at least 1.0. Each component selected also included a variance value that represented the percent of variance accounted for by that component. The selected components had a percent of variance value that ranged from 76 to 84 percent. All strata and wetland types had only one principal component. A second important factor in evaluating the principal component analysis is component loadings -- a value that represents the correlation between the variable and the component with higher values being more significant. The loadings ranged from .697 to .965.

The explained variances were high, and the signs of the loadings agreed with the hypothesis of policy variables being negative and commodity variables being positive with percentage of vegetated palustrine wetlands remaining being positive. Following the analysis protocol, the variables Wetland Reserve Program and Clean Water Act Section 404 values were usually filtered out since they were not strong enough to warrant final consideration as a factor in the principal components (Table 29). Principal component analysis performed on the data with the dependent variable being agricultural loss rates produced similar results since the values of the independent variables remained constant.

Table 29. Eigenvalues and loadings for combined strata, each stratum and each wetland type

			Loadings									
Stratum	Eigen Value	Vari-ance	SB/Tax	CRP acres	CRP Rent	WRP	CWA 404	Corn	Wheat	Soy-beans	Pct Left	ACP
Combined strata	6.513	.8141	-.949	-.944	-.918	ns	ns	.953	.927	.783	.891	.838
S15	6.327	.7909	-.951	-.905	-.994	ns	ns	.935	.911	.778	.886	.787
S21	6.369	.7961	-.953	-.937	-.885	ns	ns	.932	.911	.793	.949	.754
S26	6.310	.7888	-.950	-.944	-.928	ns	ns	.936	.916	.794	.827	.793
S28	6.101	.7627	-.948	-.935	-.914	ns	ns	.934	.916	.777	.728	.804
S29	6.459	.8074	-.951	-.944	-.937	ns	ns	.935	.916	.793	.888	.840
S31	6.464	.8081	-.961	-.895	-.928	ns	ns	.919	.900	.799	.928	.852
S34	6.510	.7233	-.937	-.720	-.867	ns	ns	.949	.929	.674	.961	.797
S35	6.350	.7937	-.953	-.937	-.907	ns	ns	.930	.912	.787	.848	.838
PEM	6.205	.7756	-.946	-.943	-.919	ns	ns	.937	.917	.789	.746	.823
PFO	6.436	.8045	-.949	-.945	-.920	ns	ns	.932	.913	.791	.881	.832
PSS	5.693	.8133	-.955	-.958	-.932	ns	ns	.928	.913	.804	ns	.805
Mean	6.31	.790	-.950	-.758	-.765			.935	.915	.780	.867	.814
Std Dev	.230	.023	.005	.544	.535			.009	.034	.034	.075	.028

The loadings in Principal Component Analysis indicate the contribution of each of the independent variables to the principal component; the greater the value the more significant the contribution with the sign value not considered. The variables that had the highest loadings most frequently were Swampbuster, Corn price, Conservation Reserve Program acres and Conservation Reserve Program rental rates. The variables with the lowest loadings were Wetland Reserve Program and Clean Water Act Section 404 regulations. The rankings of the correlation coefficients of the independent variables is similar to the results of the principal component analysis rankings with the top three variables being Swampbuster, corn price and Conservation Reserve Program rental rates. Conservation Reserve acres was close to being in fourth place in the correlation analysis. A review of both the correlation and principal component analyses verifies that Swampbuster, corn price, CRP rental rates and CRP acres enrolled had significant influences on palustrine vegetated loss rate.

The PCA process identified a variable for each principal component that was used in a regression with each dependent variable. Regardless of the dependent variable considered, a positive regression coefficient indicates a tendency for the dependent variable to increase as the price variables becomes larger relative to the policy variables.

In the case of total loss rate, all years, all strata and wetland types have positive coefficients that suggest commodity prices have a greater influence on loss rate than policies. Agricultural loss rate shows the same results except that Strata 31 has a negative coefficient indicating in the Appalachian Highland, policies have a more significance influence on loss rate. This is logical since the Appalachian Highland strata is not a significant agricultural production area, so agricultural policies would not have as significant an impact on wetland loss rates.

Table 30. PCA regression coefficients

	Total Loss Rate		Agricultural Loss Rate	
	Coefficient	Adjusted R^2	Coefficient	Adjusted R^2
All Years	.921	.845	.901	.808
S15	.918	.839	.931	.864
S21	.819	.665	.777	.595
S26	.960	.920	.835	.691
S28	.967	.924	.960	.920
S29	.763	.574	.755	.561
S31	.370	.119	-249	.042
S34	.676	.446	.849	.714
S35	.962	.923	.879	.769
PEM	.860	.733	.892	.791
PFO	.901	.808	.941	.884
PSS	.768	.582	.947	.895

The principal component analysis produced results that were similar to the correlation results with the policy variables having negative value and the commodity prices and percent of wetland remaining variables having positive values. Use of principal component analysis clarified the ambiguity caused by multicollinearity in the regression analysis by reducing the number of variables considered, while maximizing the variance considered. The following Discussion chapter will interpret these findings in light of the driving forces of wetland conversion in the U.S. over the study period.

CHAPTER 5

DISCUSSION

The results of this research indicate significant relationships exist between the loss rate of vegetated palustrine wetlands and Swampbuster provisions of the Food Security Act of 1985, rental rates for and enrollment in the Conservation Reserve Program, corn (and to a lesser extent wheat and soybeans) prices, and the percentage of wetlands remaining according to the 1955 wetland status and trends report. The results reflect the intricate relationships between federal legislation, regulatory programs, legal decisions, economic factors, and changes in society's view and understanding of the importance of wetlands and the need to merge conservation programs with agricultural policies. There are many specific actions and programs that contributed to the loss rate of palustrine vegetated wetlands from the mid-1950's to 2009. Each program, policy or factor was individually significant, but when their impacts were collectively reviewed, the overall impact is meaningful.

Based on research results, the component that most significantly influenced palustrine vegetated loss rate is the Food Security Act of 1985. This Act revolutionized the content of all subsequent farm bills by adding meaningful conservation compliance and land retirement provisions that included Swampbuster and the Conservation Reserve Program. Federal agricultural policies that stimulated and supported the conversion of wetlands to agricultural use resulting in high wetland loss rates changed focus to stimulate the inclusion of conservation provisions in the Food Security Act of 1985, that ultimately decreased the palustrine vegetated wetland loss rate. A discussion of these contributory factors will clarify and emphasize the significance of Swampbuster, the Conservation Reserve Program, and corn prices in determining the palustrine vegetated loss rate from the mid-1950's to 2009.

Food Security Act of 1985 (P.L. 99-198)

Title XII of the Food Security Act of 1985 contained the conservation provisions that became known as Sodbuster, Swampbuster and the Conservation Reserve Program (CRP). The stated purpose of Title XII Conservation was to "remove highly erodible land and wetlands from crop production." Two of its main components (Swampbuster and CRP) were included and identified as variables that significantly impacted palustrine vegetated wetland loss rates. The Food Security Act of 1985 was a response to farm policies that were costly, environmentally damaging and ineffective. It significantly revised farm policies by creating opportunities for increasing farm income by conserving rather than converting wetlands to farmland, reduced the rate of erosion and provided economic disincentives for wetland conversions. The 1985 Farm Bill is inextricably linked with changes to wetland loss rates from the mid-1980's to 2009.

The genesis for farm bills was the Great Depression, Dust Bowl and New Deal era of the 1930's when agricultural income and production decreased, erosion losses were extreme, and unemployment levels were high (Malone, 1986). The first farm bill, the Agricultural Adjustment Act of 1933, set the tone for future farm bills by recognizing that crop prices and farm income could be controlled by controlling the production of crops; less supply increased prices that financially benefitted the farmer. In the 1930's, 20 percent of the U.S. workforce was employed in agriculture and about 8 percent of the gross domestic product was from farming (Arha et al., 2007), so improving the economic conditions of the farm sector by federal agricultural policies was in the national interest. A commodity price support policy was initiated that guaranteed prices of certain crops would not fall below a set price. Over the next 50 years, however, farm policies failed to significantly reduce surpluses as global factors, such as World War II, encouraged increased crop production and associated wetland conversions. Between 1950 and 1970, farm productivity increased 49 percent (Cain and Lovejoy, 2004), during a period when 87 percent of wetland losses were for agricultural use (Dahl and Johnson, 1991). The failure of Soviet agriculture in the 1970's generated an export demand for American crops. Farmers were encouraged to plant fencerow to fencerow and marginal lands and wetlands were converted into farmland to take advantage of high prices and increased profits. Farm policies failed to reduce commodity surpluses as agricultural programs contained in the various farm bills were manipulated to allow farm acreage to increase at the expense of wetlands, which were converted in order to generate surplus commodities. Farm policies prior to 1985 encouraged wetland conversion as evidenced by 87 percent of wetland losses between the mid-1950's and mid-1970's, being due to agriculture conversions.

Capital Investment and soil saturation levels

Converting wetlands to cropland involves making a capital investment in drainage systems to reduce soil saturation levels. The economic feasibility of this investment depended upon the relationship of capital investment cost and crop prices. A positive economic return was not possible unless the present value of crop profits exceeded the drainage investment cost. The benefit of installing drainage is that it allows wetland acreage to be economically cropped when soil saturation levels are high (Figure 7).

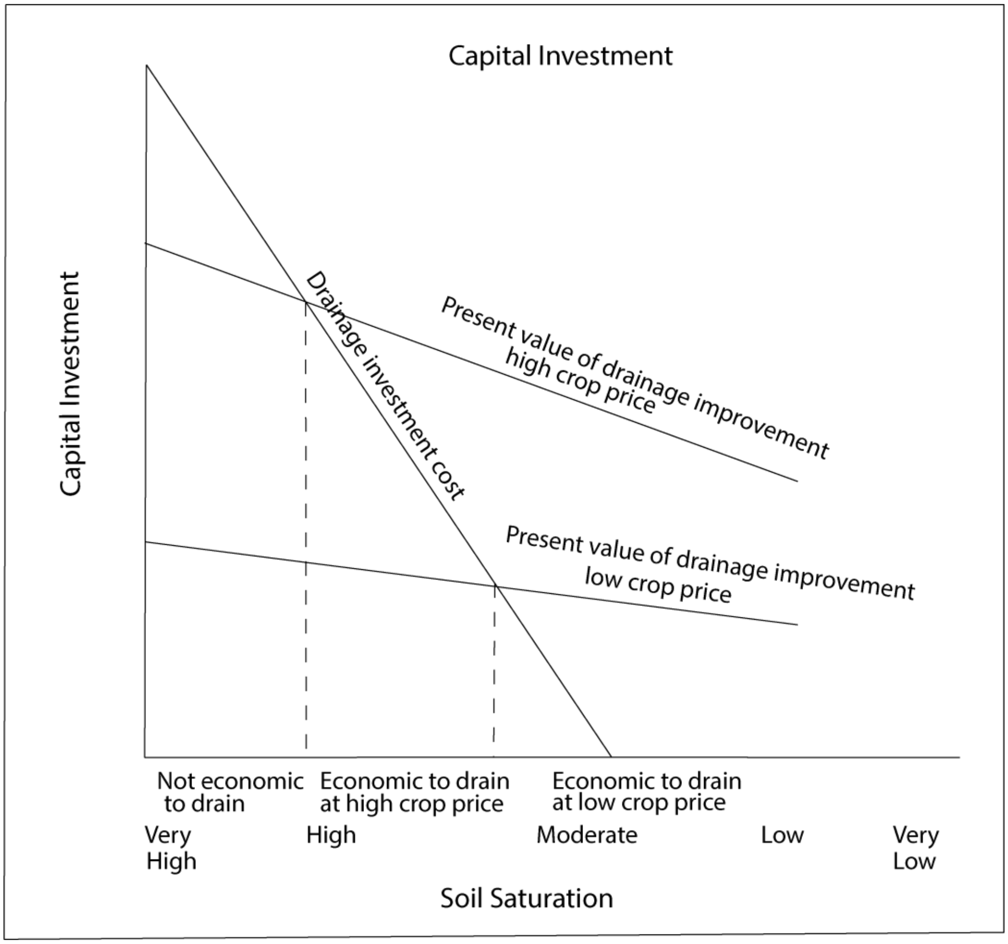


Figure 7. Relationship of soil saturation level capital investment in drainage and profitability at high and low crop prices

The high crop price condition would justify draining extensive wetland areas, but low crop price conditions would restrict drainage to only moderately wet areas. Lower crop prices would conserve wetlands while higher crop prices would convert wetlands. Favorable farm policies and tax laws favored capital investments and wetland conversions.

If capital improvements were not made to drain wetlands, benefits from cropping would depend upon natural soil saturation levels. Soils that are very wet cannot be economically farmed due to the inability of seeds to germinate as well as farm equipment not being able to operate in wet soil conditions. Farmers must determine when the soil is too wet to economically farm. In order to improve farming conditions, drainage systems must be installed, but this is an added long-term cost to production. Highly saturated soils cannot be economically farmed unless the crop prices are sufficiently high to generate profits that justify the extra capital investment of drainage systems. As crop prices increase, the installation of drainage systems becomes economically reasonable and advantageous on soils with higher levels of saturation based on the potential increase in farm profits from increased production. This provides a positive correlation between crop prices and wetland loss rates. High crop prices enable drainage systems to be reasonable and wetlands are converted to farmland. Low prices result in status quo for farm operations because drainage is not an economical option; wetlands will not be converted but conserved. High crop prices expand the range of economic benefits of cropping but low crop prices limit cropping to acreage with low soil saturation levels (Figure 8).

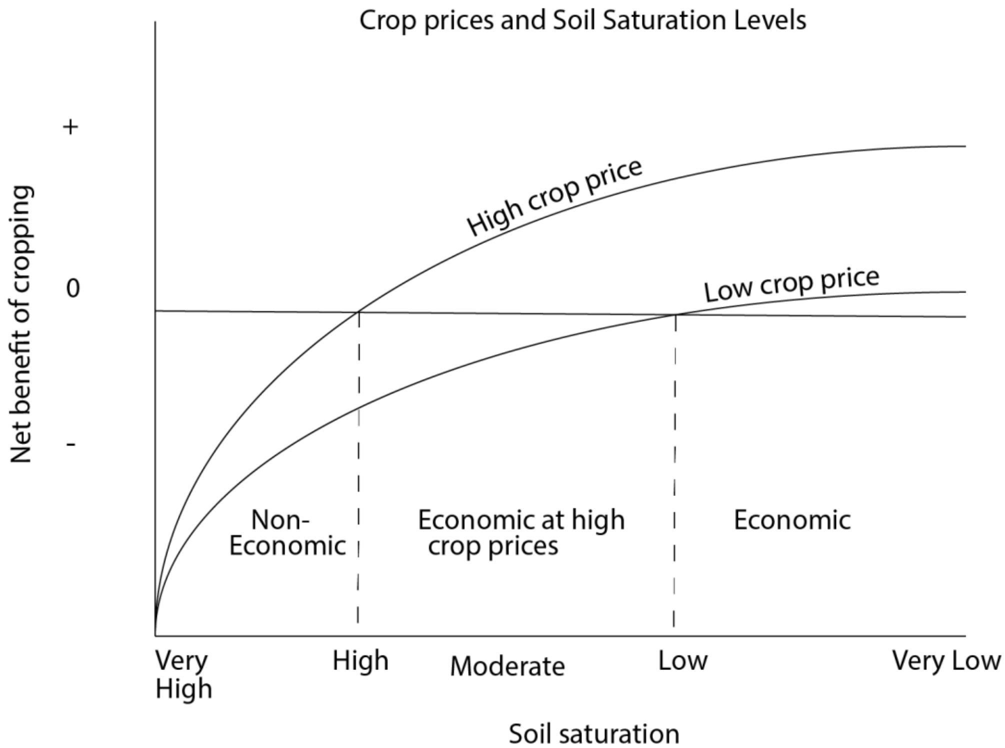


Figure 8. Effect of crop prices on profitability of drainage across soil saturation levels.

Commodity prices

The commodities selected as independent variables were corn, wheat and soybeans. These are the three crops that have been harvested in the greatest quantity annually in the United States since 1956. The most significant losses of palustrine vegetated wetlands from the mid-1950's until the mid-1980's were due to conversion to agricultural uses with the support of federal agricultural policies established in Farm Bills. Drained wetlands were found to be highly productive areas for growing crops, especially corn (Diedrick, 1981). The states of Illinois, Iowa, Indiana and Ohio have over 13 million acres of drained wetlands in farm production, which represents 40 percent of all cropland in those states (Mitsch and Gosselink, 2000). Farm policies since the 1930's encouraged wetland drainage through financial, technical and engineering support in order to increase land under agricultural production. Market prices significantly impacted the fate of wetland resources as increased cropland results in increased profits. Commodity prices could be considered to be the major stimulant for wetland conversions to agricultural land until the mid-1980's. The power of commodity prices in determining the fate of palustrine wetland resources has been seen in the Midwest as farmers installed additional drainage tile systems or replaced aging systems to eliminate surface water (Dahl, 2011). In addition, the market for corn as a biofuel has caused an increase in corn prices, which also has enticed farmers to increase their corn acreage at the expense of wetlands.

The research shows there is a strong positive correlation between the annual price of all three crops and palustrine vegetated wetland loss rate on the national level and in most strata and wetland types. Several factors contribute to the dominant role of corn price affecting other crop prices: 1) the rotation between corn and soybeans is dominant and reduces planting of wheat and other crops; and 2) corn is planted in greater percentage than soybeans in corn-soybean crop rotation cycles. Corn usually has the highest correlation coefficient and is considered to be a dominant crop and impacts the prices of other commodities. As the price of corn increases, farmers are motivated to increase the acres of corn planted at the expense of other crops such as soybeans and wheat. This reduces the supply of the other crops, but thereby increases their price. This strong effect of corn influences wetland loss rate; if corn prices are high, more wetlands will be converted to cropland. This leading role of corn price is reflected in the principal component analysis; corn has the second highest mean loading value of all variables. This also suggests that if corn prices are low so also are soybean and wheat prices resulting in less motivation for farmers to convert wetlands and the opportunity for enrolling in the CRP could be a preferred option.

The strong positive correlation between all commodity prices (Table 28) suggests that wetland loss rates increase as the price of commodities increase. Prior to the 1970's, there were no regulatory restrictions on wetland conversions. The decision to convert or not convert a wetland would most likely be based on the price of the commodity that would be grown on the converted wetland. Support and encouragement for draining wetlands from the Department of Agriculture, as well as price supports that artificially increased the value of crops produced on converted wetlands, facilitated the massive loss of wetlands until the mid-1980s (Scodari, 1997).

Although three crops are considered prime independent variables, only corn is identified as the primary commodity that influences palustrine vegetated wetland loss rate. Several authors have identified the positive impacts drained wetland soils have on corn productivity (Prince, 1997). This suggests that as corn price increases, the impact of the policy items would decrease; there could be a price for corn that will induce farmers to let the CRP contracts expire and plant corn since it would be financially beneficial. The same could occur with Swampbuster, but the price of corn would need to be substantial to jeopardize the loss of federal benefits. High prices will reduce the price support effect.

Commodity prices and wetland conversions

The 1985 Farm Bill was a significant piece of legislation that changed farm policies from a focus on production and agriculture-related conservation benefits that occurred on the farm to a focus on environmental management and quality improvements that would occur off the farm such as clean air, water, biodiversity and other ecosystem services (Arha et al., 2007). The 1985

Farm Bill served as the vehicle for making changes in resource management in the agricultural sector by leveraging the agriculture program payments into environmental quality improvements (Claassen, 2004). From a wetland loss standpoint, the Farm Bill provided an economic means for assessing the value of wetlands in comparison to commodity prices. Decisions regarding converting or conserving wetlands could be determined by real benefit-cost calculations. The CRP program provided an incentive to conserved wetlands; Swampbuster established a cost to the farmer of converting an acre of wetland. Prior to 1985, decisions regarding wetland conversions or conservation focused on the economics of capital investment for drainage systems and commodity prices (Figures 7 and 8). The major factors were soil saturation levels and commodity prices, with high prices being economically advantageous.

The results of the study show a positive correlation between wetland loss rates and commodity prices regardless of the dependent variable. Percent of wetlands remaining are also positively correlated with wetland loss rates, which have a connection with commodity prices. Remaining wetlands are the resource for future conversions; if there are fewer wetlands available, then fewer can be converted. The importance of commodity prices in wetland loss rates is also substantiated by the principal component results that reflect positive correlations between commodity prices and wetland loss rate, with corn price being a significant factor. When the price of corn increases, it stimulates farmers to shift crops from soybeans and wheat to corn. As a result, the reduced production of the other crops results in an increase in their prices. Corn is a crop that presents more economic opportunities due to its diverse uses such as feed, gain and biofuel.

The 1985 Farm Bill merged conservation goals and resource management with farm economics in a workable and productive package. The Food Security Act of 1985 had a significant impact on reducing palustrine vegetated wetland loss rates from the mid-1980's to 2009 by presenting a voluntary program that successfully encouraged farmers not to convert wetlands to agriculture and provided an acceptable positive economic incentives program that would temporarily retire highly erodible and sensitive land from farming while reducing erosion rates

Swampbuster

The power and success of Swampbuster to reduce wetland loss rates are also based on economic considerations. Swampbuster established the price of wetland drainage (the value of federal farm benefits to the farm), which farmers could compare against the potential profit from increased yield on converted wetland acreage. A key factor in the decision is the commodity cost. The program exerts a greater impact when crop prices are low than when prices are high. In the low price condition, farmers are more dependent upon federal programs such as price supports, so wetlands will be converted less often. Low crop prices produce marginal benefits that are significantly decreased by loss of program eligibility. The loss of these would not sustain farming operations and favor wetland conservation and decrease of loss rates. Farmers are less dependent on price supports during high price conditions, so high crop prices would tend to increase wetland conversion and loss rate, but low crop prices would tend to conserve wetlands. If a farmer did not participate in federal programs, Swampbuster had no impact and wetlands could be converted with no adverse economic impacts (Figure 9).

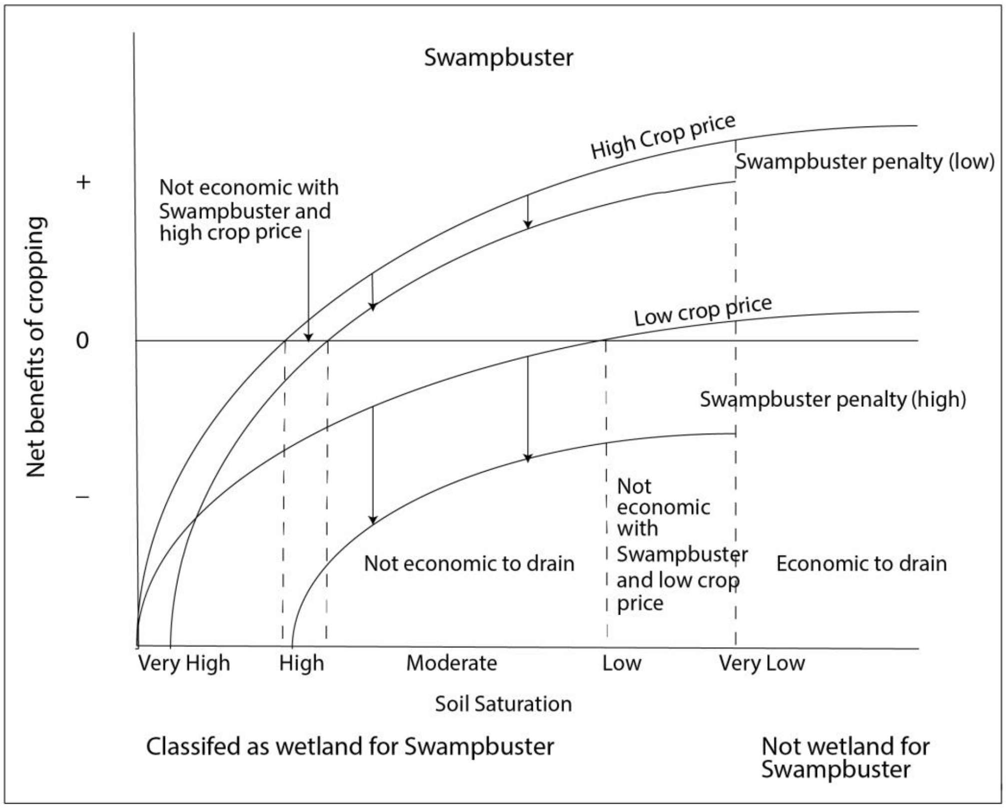


Figure 9. Effect of Swampbuster and price supports on profitability of wetland drainage under high and low crop prices

The results of this research show that Swampbuster has a significant impact on palustrine vegetated wetland loss rates both on a national level and in most strata and wetland types. Research indicates there is a strong negative correlation between Swampbuster and palustrine vegetated wetland loss rate; as Swampbuster became effective the wetland loss rate decreased. This suggests that the economic value of maintaining eligibility for federal programs exceeds the potential income increases that could result from wetland conversion and farming. The research also shows a strong negative correlation between Swampbuster and commodity prices, indicating that the effect of Swampbuster would weaken as commodity prices increase. The impact of Swampbuster on decreasing wetland loss rate depends on crop prices and profits from producing a particular crop remaining lower than the value of federal farm benefits. A significant increase in commodity prices and potential profit could lessen the value of staying in the program and could motivate farmers to convert wetlands to cropland. Correlation between Swampbuster and loss rate is strongest when the dependent variable is agricultural loss rate and weakest when the dependent variable is non-agricultural loss rate. This emphasizes the impact of Swampbuster on decisions regarding wetland losses in the agricultural environment; the potential loss of federal benefits is a significant deterrent to wetland conversion.

Conservation Reserve Program

CRP rental rates exert a greater impact when crop prices are low than when crop prices are high (Figure 10). Enrolling acreage into the CRP places a limit on the financial return the farmer would receive per acre. In high crop price conditions, the farmer would receive a greater benefit than the CRP rental rate. In the low crop price condition however, enrolling acreage will produce relatively greater benefits. This indicates that when commodity prices are low, farmers would increase enrollment in the CRP, but when commodity prices are high, farmers would not enroll or remove acreage from the program. Vegetated palustrine wetland loss rate would increase when crop prices are high and decrease when crop prices are low.

Soil saturation levels are a key component in decision-making regarding how wet the soil can be to be effectively farmed and whether it is economically beneficial to farm wet soil or to enroll the acreage into the CRP and receive the rental payment. When soils are very wet, farming operations can be affected in several ways: 1) planting may be delayed until the soil dries sufficiently, but the planting must occur within certain time frames to allow crops to mature for a significant harvest; 2) some areas only permit farming in some years because of long-term ponding; and 3) attempts to farm wet soils results in lost seed and chemicals that have to be reapplied at significant cost. CRP payments provide an economic buffer that ensures a certain income regardless of whether the commodity price is high or low. CRP rental rates compete with the per acre profit levels determined by crop prices and eliminate or at least minimize the concerns over how wet the soil can be to produce economic benefits. High crop prices and low CRP rates provide an incentive to farm moderately wet soils. High CRP rates and high crop prices could result in increased profits if the land is farmed.

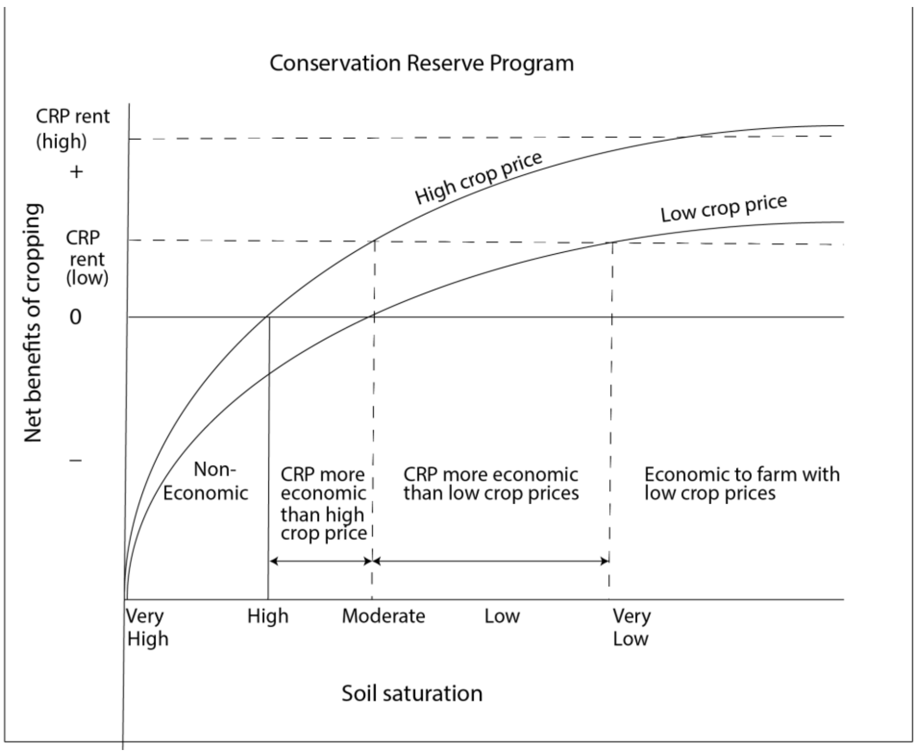


Figure 10. Effect of Conservation Reserve Program on wetland drainage under high and low crop prices.

This research divided CRP into two variables: rental rate and enrolled acres. Based on the results of this research, both enrolled acreage and rental rates significantly impacted palustrine vegetated wetland loss rates. There is a strong negative correlation between both the

CRP variables and the loss rate and a strong positive correlation between the CRP acres and rental rates. The negative correlation shows that as program rent and acres enrolled increase, the palustrine vegetated wetland loss rate decreases. As rental rates rise, they exceed the net profit from lands with a greater degree of soil saturation – but this also depends on crop prices. CRP rental rates and crop prices thus interact to structure farmer's decisions on whether to convert and crop lands with various degrees of soil saturation. This also shows that collinearity between the two exists – price impacts acreage enrolled. These relationships suggest that the CRP has been successful in reducing the conversion of wetlands to agricultural use and has decreased the wetland loss rate.

The CRP provides potential uncertainty for wetland resources. Significant changes in commodity prices towards the end of the 2007 enrollment period motivated farmers to leave the program and convert the wetlands to agriculture, with North Dakota experiencing a decrease of over 12 percent in enrolled acreage (Dahl, 2011). CRP rental rates and enrolled acres ranked high as variables that significantly impacted palustrine vegetated wetland loss rates. The correlation between these two aspects of the CRP was very strong and positive on the national level, in all major strata and wetland types. The two variables have a negative correlation with palustrine vegetated wetland loss rate suggesting that loss rates decreased as rental rate and enrolled acreage increased. The principal component analysis confirmed that CRP rental rates and enrolled acres contributed significant loading on the principal components and had a major impact on palustrine vegetated loss rate.

These relationships suggest that, overall, the CRP has been significant in reducing the conversion of wetlands to agricultural use. The strength of the correlation varies depending on whether the dependent variable is wetland loss rate, loss rate due to agricultural conversion or loss rate due to non-agricultural conversion (Tables 14, 16 and 17). The strongest correlations exist between the variables and agricultural loss rates. Both CRP rental rates and CRP enrolled acres are negatively correlated with wetland loss rates. The negative correlation shows that as program rent and acres enrolled increases, the palustrine vegetated wetland loss rate decreases. This suggests that the rental rates were sufficiently high to entice farmers to take marginal land out of production since the rent would exceed the costs of production and expected yield. The strong positive relationship between CRP rental rates and enrolled acres suggests rental rates were a significant financial inducer for acreage enrollment; as rental rates increased, more acres were enrolled and wetland loss rates decreased.

The CRP provides potential uncertainty for wetland resources. Based on the research results up to 2009, however, CRP rental rates and enrolled acres have exercised a positive influence on overall wetland resources. In all strata and on the national level, the trend was for enrolled acres to increase reflecting the positive reception of land owners with rental rates remaining fairly constant. The impact is greater for agricultural than non-agricultural conversion as expected.

Conservation Reserve Program rental rates and enrolled acres ranked high as variables that significantly impacted palustrine vegetated wetland loss rates. The correlation between these two aspects of the CRP was very strong and positive on the national level, in all major strata and wetland types. The two variables had a negative correlation with palustrine vegetated wetland loss rate suggesting that loss rates decreased as rental rate and enrolled acreage increased. The CRP rental rates and enrolled acres contributed significant loading on the principal components and had a major impact on palustrine vegetated loss rate.

Wetland Reserve Program

The Wetland Reserve Program (WRP) provides farmers the opportunity to evaluate whether qualified acreage would have more value if retained as cropland or converted to wetland. If enrolled, the acreage would be nonproductive cropland for at least 30 years with a rental payment commensurate with the length and type of contact. The farmer has to make long-term consideration of crop prices. WRP easement payments could exceed both the high and low crop price conditions making it economically advantageous to enroll in the program. Low crop prices would not be expected to economically compete with high WRP easement payments. It is possible, however, that high crop prices could exceed WRP easement payments, so it would be economically beneficial to not enroll in WRP. The overall condition, however, would be expected to favor enrollment in the WRP (Figure 11).

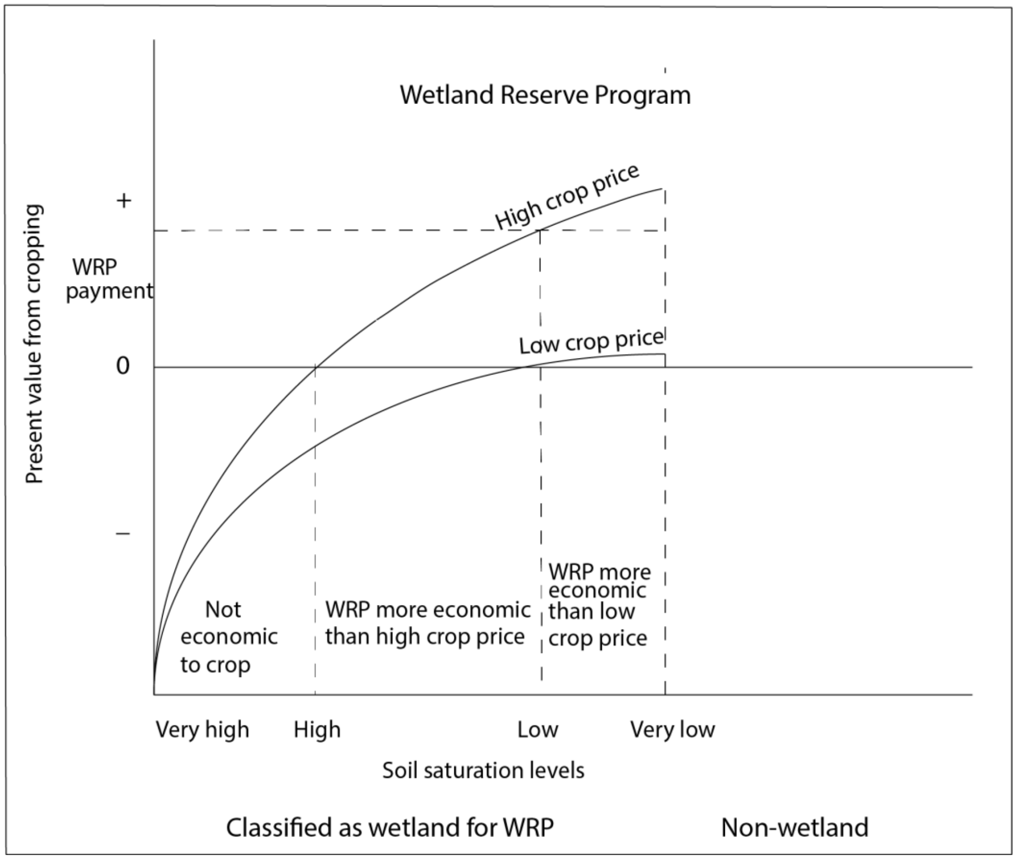


Figure 11. Wetland Reserve Program and present value of cropping.

The WRP enrollment acreage has a negative correlation with palustrine vegetated wetland loss rate indicating that as the acres enrolled in the WRP increased, wetland loss rate decreased. It must be noted that enrollment acreage limit for the WRP is far smaller than the CRP; in 2009 WRP had only 2.3 million compared to CRP's 33.7 million acres. The program has increased enrollment each year, however, contributing to a decreasing palustrine vegetated wetland loss rate, but with a weaker effect than CRP. WRP enrollment has a positive correlation with CRP rental rates and enrolled acres, indicating the programs are collinear. The WRP is also closely associated with Swampbuster. The stronger effects of both CRP and Swampbuster dominate WRP's collinear effects.

Clean Water Act Section 404

Section 404 of the Clean Water Act has a negative correlation with wetland loss rates and a positive correlation with other policy variables; this demonstrates there is collinearity among these variables. Section 404 requirements apply to some of the same actions that other Natural Resource Conservation Service programs sponsor, such as the Swampbuster provisions of the Food Security Act of 1985. There can be instances where an action that requires a Section 404 permit could be a violation of the Swampbuster provisions and an acceptable action under Swampbuster could be a violation of Section 404 (CRS, 1996). The impact of Section 404 is dwarfed by the effects of agriculture conservation policy and program exceptions in agricultural environments. Most Section 404 permits are not issued for draining or filling of agricultural wetlands, but are more prevalent for non-agricultural actions such as development, road construction and fossil fuel exploration. Agricultural associated actions require few if any individual Section 404 permits.

The effect of Section 404 on wetland loss rate was not determined to be a significant factor in palustrine vegetated wetland loss rate based on the results of the principal component analysis performed. The loadings of Section 404 on the principal component were of insufficient value to be a factor in determining the principal component. Section 404 is negatively correlated with both total loss rate and agricultural loss rate but has a positive correlation with non-agricultural loss rate. This difference in correlation is expected since there are many agricultural exceptions to Section 404 requirements and non-agricultural loss are not associated with the agricultural environment.

Percentage of Wetlands Remaining

This variable was included in order to consider the question of whether decreased wetland loss rates could be due to a lack of remaining palustrine vegetated wetlands. The Fish and Wildlife Service has identified the status and trends that have occurred in wetland resources from the mid-1950s to 2009, and the reports have shown a constant decrease in total wetland acreage from the mid-1950's until 2004 when the wetland acreage increased on a national level.

Wetlands continue to be converted to other uses through 2009 and the acreage of wetland resources has decreased. The percentage of palustrine vegetated wetlands remaining has a positive correlation with loss rate nationally and in each major strata and wetland type. This suggests that when sufficient acres of wetland exist, the loss rate is higher because there are more wetlands that could be converted. The correlations between other independent variables and percentage of wetland remaining showed negative correlations with policy variables and positive correlations with commodity prices. This suggests that as the percentage of wetlands remaining decreases, there are fewer acres eligible for enrollment in the CRP and WRP, fewer acres that would be impacted by Swampbuster decisions, and fewer opportunities for application of Section 404 regulations. The positive correlation with commodity prices suggests that as prices increase, more wetlands will be converted to agriculture uses. The principal component analysis results indicated this variable is not a significant factor in determining wetland loss rate; the mean principal component loading was the lowest value of all variables.

CHAPTER 6

WETLAND LOSS MODEL

. Palustrine vegetated wetland acreage in the conterminous United States has been reduced from an estimated 99.8 million to 97.6 million acres (Frayer, et al., 1983; Dahl, 2011) since 1955, due to conversion to agriculture, urban and rural development, silviculture and other actions. Since initiation of the National Wetland Inventory in 1955, however, the rate of palustrine vegetated wetland losses plummeted from 581,700 acres per year from 1955-1974 to 46,321 acres per year from 2005-2009. Wetland losses have been more severe on palustrine vegetated wetlands compared to all wetlands that experienced an initial loss rate of 458,000 acres per year from 1955-1974 to 13,800 acres per year from 2005-2009, with a net gain from 1998-2004. Agricultural production was the dominant force behind palustrine vegetated wetland loss rates until farm policies were changed by the Food Security Act of 1985, which created conservation compliance and land retirement programs that effectively reduced palustrine vegetated wetland loss rates nationally and regionally.

The research has identified independent variables that significantly contributed to wetland loss rates over the past 50 years. It has also been shown that these variables exhibit strong multi-collinearity. A model that explains changes in wetland loss rates must incorporate not only the variables, but must indicate the strength of their relationships because it is the relationships that drive the results.

Key factors that shape the model include:

1. Conversion of wetlands to agricultural use is a major force that dominates changes in wetland loss rates. This is true on a national and regional level and affects all three types

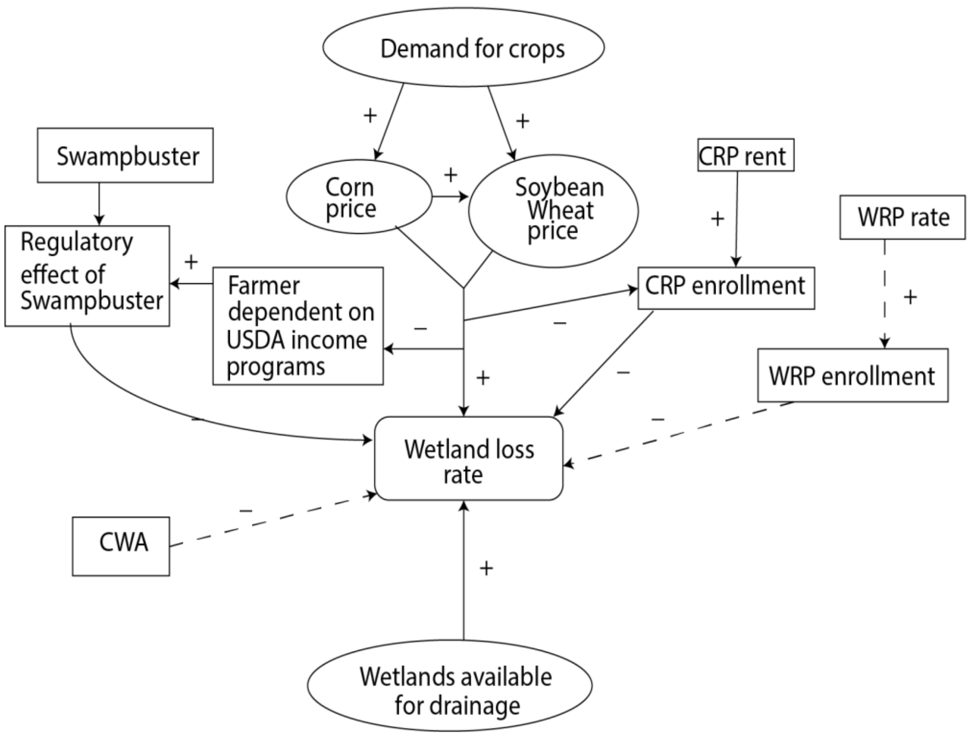
of palustrine vegetated wetlands. The major agricultural producing states in the Midwest and Lower Mississippi Valley are included in the major strata studied.

2. Economic factors drive decisions based on whether wetland conservation or conversion is most profitable.

3. Two major forces that influence decisions to convert or conserve wetlands include policy issues that work to reduce wetland loss rates and commodity prices that function to encourage wetland loss rates. The interaction between these two opposing factors influences the loss rate. The strength of these forces on wetland loss rates vary over time and are dynamic. A decision to drain a wetland can sometimes be reversed as can enrollment into a conservation program.

4. Statistical analysis shows there is a significant negative correlation between policy variables and loss rates, and a positive correlation between commodity prices and percent of wetlands remaining with wetland loss rate. Regression analysis is inconclusive in quantifying the relative roles of these variables, however, due to multicollinearity. The principal component analysis clarified the relationships between the dependent and independent variables and identified the variables having the most significant impact on wetland loss rate.

Based on the results of this research, a model is proposed that shows the relationship between the variables responsible for the palustrine vegetated wetland loss rate across strata and wetland types (Figure 12).



. **Figure 12.** Wetland loss rate model.

According to the model, wetland loss rate is the result of the synergistic impact of policy and price factors that depend upon a source of existing or created/converted wetlands. The correlation between the policy variables and total loss rates are negative, indicating they function to reduce wetland loss rates. The correlation between commodity prices and loss rates are positive, indicating they function to increase loss rates. The rectangular boxes indicate policy actions, the oval shapes are commodity price factors, and percent of wetlands remaining that are available for conversion. The solid lines indicate a strong effect while the dotted lines indicate a weak effect. The model is applicable to the eight major strata, though less so for strata such as the Appalachian Highlands where agriculture is less important, and provides the flexibility to include policy actions when implemented over the 50-year study period.

A wetland loss model for agricultural loss rates is slightly different from total wetland loss rate. Most agricultural activities are exempt from Clean Water Act Section 404 permitting, so that policy item is not considered relevant. The other variables are focused on agricultural actions, so they will have similar but stronger impacts, especially the price of corn (Figure 13).

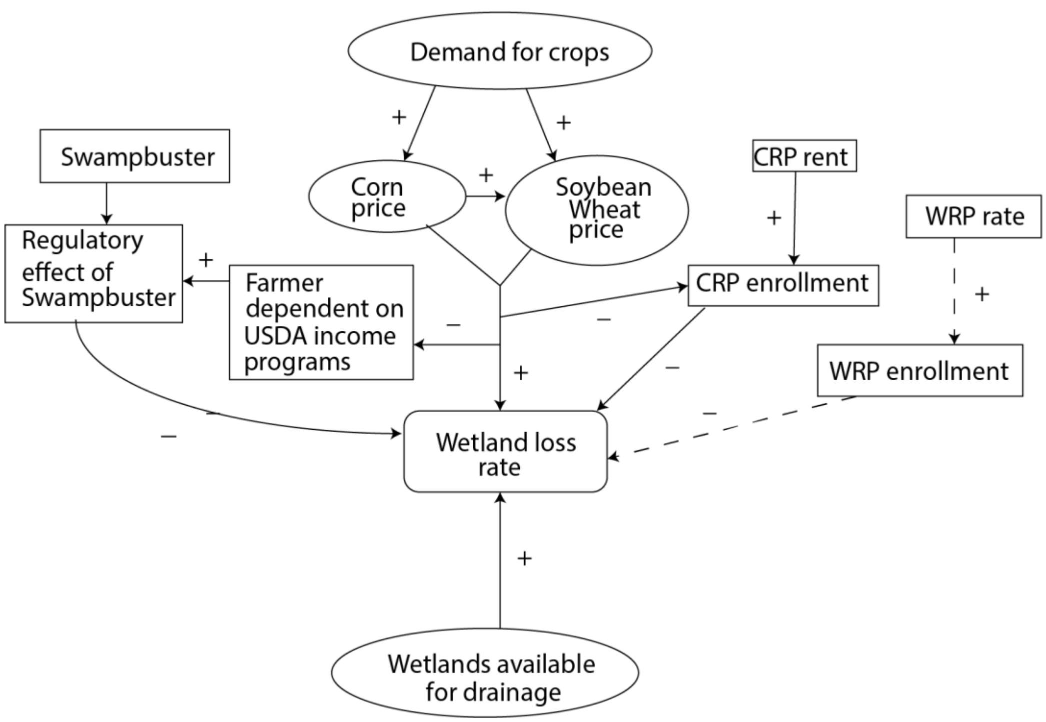


Figure 13. Agricultural loss rate model

Commodity prices

Based on the model, commodity prices have a strong positive effect on wetland loss rate with corn price being a major commodity that impacts the price of both soybeans and wheat. Commodity demand establishes their prices; corn is a high demand commodity. As corn price increases, farmers would increase corn production at the expense of soybeans and wheat. The reduced supply of these commodities increases their prices. Overall, the increased prices of these commodities stimulate farmers to increase wetland conversions to increase acreage under production and profits. Corn is a key factor in wetland conversion rates and increases in wetland loss rate.

Commodity prices, especially corn, show a consistent positive correlation with palustrine vegetated wetland loss rate, supporting study hypotheses. The price of corn has a significant impact on wetland loss rate in all the major strata studied. Although the regression results were unclear due to multicollinearity, the principal component analysis (PCA) recognized the strong correlation between corn and wetland loss rate and determined corn was one of the top four variables that determined wetland loss rates. Corn price is highly correlated with the other commodities and the policy variables that were indicated by PCA as major contributors to wetland loss rate. Corn price could be considered to be a keystone variable in determining wetland loss rate. The strong correlation between corn and wetland loss rate was shown to exist in all major strata and all palustrine wetland types. The correlation coefficients increased when only loss rate due to agricultural conversions was considered.

Policy variables

The Food Security Act of 1985 initiated the Swampbuster provisions and the Conservation Reserve Program, two policy items that have been major forces in determining wetland loss rate. Both programs show a strong negative correlation with palustrine wetland loss rate because they affect the economic base of farm operations, and a strong negative correlation with commodity prices. Policy variables provide the opportunity to economically conserve wetlands while commodity prices provide an economic stimulant to convert wetlands. Although each policy is voluntary, they exert a very strong effect on decisions regarding wetlands. The potential economic impacts of these programs on farm operations provide the basis for a rational evaluation on whether to conserve or convert wetlands in the agricultural environment.

Swampbuster

Commodity prices have a negative impact on policy variables. In the case of Swampbuster, high commodity prices decrease the farmer's dependency on federal program benefits so there is less motivation to comply with Swampbuster provisions (See Figure 9). A farmer could convert wetlands to cropland, lose program eligibility but still be profitable when crop prices are high. Swampbuster provisions are a significant deterrent to wetland conversions when crop prices are low. The penalty for violating Swampbuster provisions is relative to the income based on commodity prices; higher prices reflect a lower penalty but low crop prices present a higher penalty. Low crop prices increase a farmer's dependency on federal benefits, which increases the possibility that Swampbuster will increase wetland conservation and decrease wetland loss rate. Crop price support policies have changed over the 50-year report period. Crop price supports is a financial support program administered by the Department of Agriculture.

Participation in the program guarantees a set price for crops. If a farmer losses eligibility for federal program benefits due to not complying with Swampbuster, the farmer also loses price support benefits.

Swampbuster was consistently shown to have a strong negative correlation with wetland loss rate. PCA identified Swampbuster as an influential variable affecting the principal component.

Conservation Reserve Program

High commodity prices decrease the impact of CRP (Figure 10). CRP rental rates benefit farmers during periods of low crop prices and will motivate farmers to enroll acres into the program; low commodity prices have a positive impact on CRP enrollment. Low commodity price conditions increase enrollment and wetland conservation, which decreases wetland loss rate. High crop prices will reduce enrollment for new acreage and will stimulate disenrollment of existing acreage when contracts expire. High commodity prices will provide sufficient income to the farmer that will be greater than the CRP rental rates. Increased enrollment due to higher crop prices emphasizes the economic benefits of wetland conversion that increases wetland loss rate.

The two CRP variables of rental rate and enrolled acres composed the other two highly ranked variables by PCA in determining wetland loss rate.

Wetland Reserve Program

WRP exerts a weaker impact on wetland loss rate due to its low enrollment authorization and the long-term enrollment requirements. Program payments will stimulate enrollment if the payments sufficiently exceed low crop prices; this results in a decrease in wetland loss rates.

When crop prices are higher than WRP payments however, wetlands would be converted to agricultural land and the wetland loss rate will increase. Another factor that impacts the strength of WRP as a policy that reduces wetland loss rate is the extended length of the contracts, which are much longer than CRP contracts. A disadvantage of WRP is that once wetlands have been enrolled, they cannot be converted to agriculture if the commodity prices increase.

Clean Water Act Section 404

Clean Water Act Section 404 permit program has a weak impact on wetland loss rate due to its limited applicability to regulate agricultural actions. Historically, the majority of palustrine wetland losses have occurred due to conversions to agriculture, but Section 404 has limited applicability in agricultural locations. In addition, the program has a dynamic history of changing and uncertain jurisdiction, high rate of approval for permits, general permits that ensure approval of filling small wetlands, agricultural exemptions to specific actions, and a mitigation program that may, or may not (Brown and Lant, 1999) increase wetland acreage through mitigation banks. Section 404 jurisdiction is not impacted by commodity prices but is determined by the type of action and whether the action is located within program jurisdiction. Section 404 has a very limited scope of actions, which are controlled within wetlands. Swampbuster provisions have a broader scope of jurisdiction in agricultural areas because policy provisions impact wetland conversion regardless of the cause. Section 404 has more applicability in non-agricultural areas.

CHAPTER 7

CONCLUSION

Based on a review of wetland data over the past 50-years, several conclusions have been identified:

1. The main causal factor in total wetland loss rate and agricultural wetland loss rates is commodity prices, with corn being most significant. This is based on the combination of correlation, principal component analysis and regression of the principal component analysis variable with the loss rates. Regression of PCA variables indicated a tendency for both total loss rates and agricultural loss rates to increase.
2. The primary independent variables that contributed to palustrine vegetated loss rates are corn price, Swampbuster provisions, and the Conservation Reserve Program. Corn price is associated with increasing wetland loss rate whereas Swampbuster and Conservation Reserve Program tend to decrease wetland loss rates.
3. Policy variables have significantly contributed to reducing wetland loss rates.
4. A significant factor in wetland loss rates is the economic decision-making that compares commodity prices with conservation program payments.
5. Policy items reduce wetland loss rates; commodity prices increase wetland loss rates.
6. The significant reduction in palustrine vegetated wetland loss rates identified in the mid-1980's, cannot be totally attributed to the conservation policies initiated by the 1985 Farm Bill. Consideration must also be given to the difficult economic conditions of the agricultural sector including low crop prices, high interest rates, decreased exports, Midwest droughts, low farmland values and increased oil prices

that increased farm costs. These conditions did not encourage wetland conversions. Swampbuster and Conservation Reserve Program provisions in the 1985 Farm Bill provided economic incentives and disincentives to conserve wetlands.

7. The remaining stock of palustrine wetlands impacted loss rates. Several key Midwest agricultural states (Illinois, Iowa, Indiana and Ohio) had lost 88 percent of their estimated original wetlands by 1980.
8. The Corps of Engineers' Section 404 permit program was not determined to be a significant factor in reducing wetland loss rates, especially agricultural loss rates due to the number of agricultural exceptions.
9. The conservation programs contained in the 1985 Farm Bill have exerted a more significant influence on reducing wetland loss rates than Section 404 permits.
10. The Conservation Reserve Program had a more significant impact on wetland loss rates than the Wetland Reserve Program.
11. Wetland loss rates have decreased, but palustrine vegetated wetlands continue to be converted to other uses.

Future research

Additional research could be conducted on:

1. Identification of the variables that impact non-agricultural wetland loss rates.
2. Causal factors associated with loss rates of non-vegetated palustrine wetlands from 1956-2009.
3. The impact of the 1985 Farm Bill on non-vegetated palustrine wetlands, riverine wetlands and lacustrine wetlands.

4. Have the SWANCC and Repanos decisions regarding Section 404 jurisdiction impacted non-agricultural wetland loss rates?

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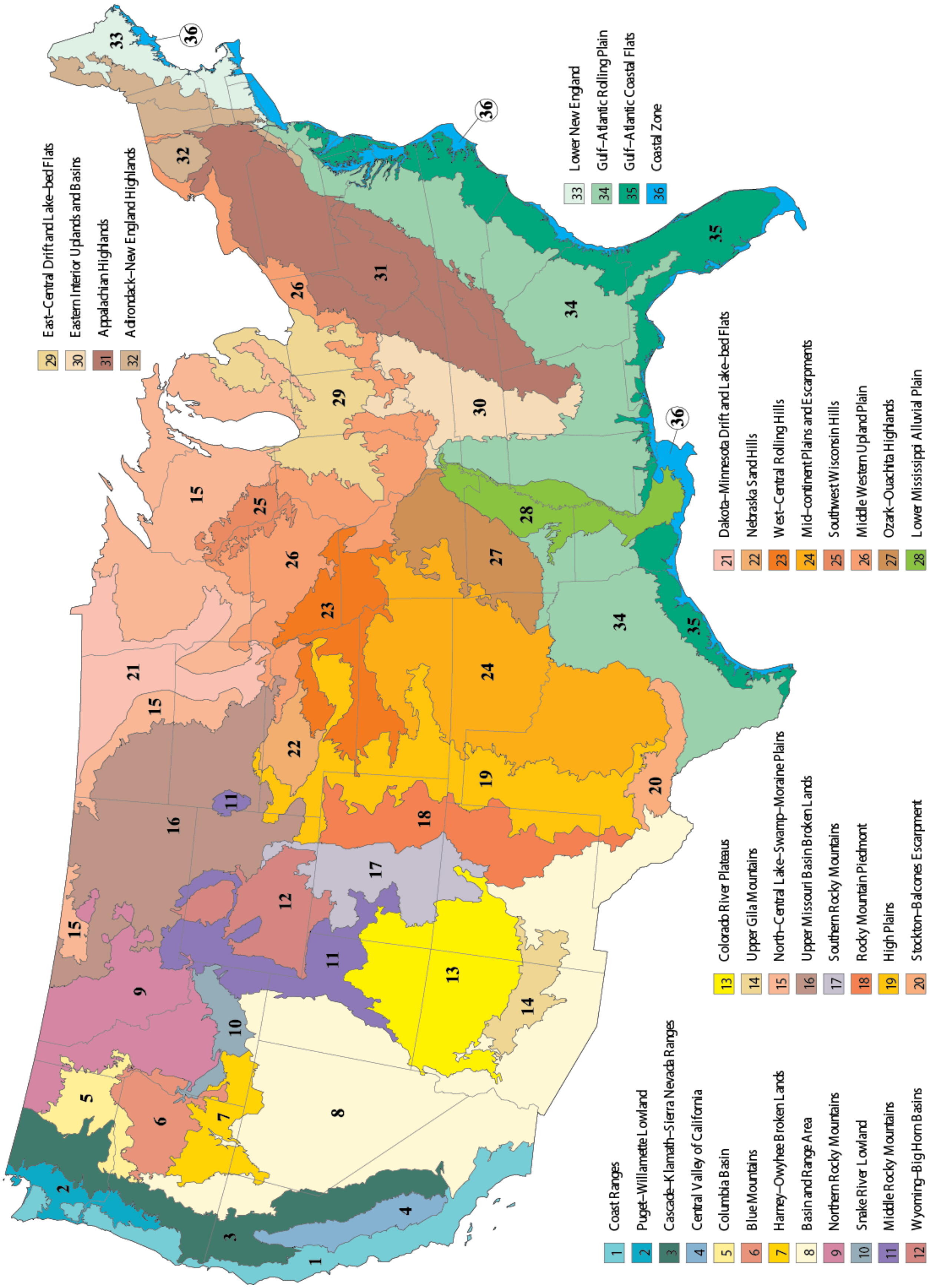
APPENDICES

Appendix A

Map of Strata used in U.S. Fish and Wildlife Service's Status and Trends of Wetlands in the Conterminous United States


1 Coast Ranges
2 Puget–Willamette Lowland
3 Cascade–Klamath–Sierra Nevada Ranges
4 Central Valley of California
5 Columbia Basin
6 Blue Mountains
7 Harney–Owyhee Broken Lands
8 Basin and Range Area
9 Northern Rocky Mountains
10 Snake River Lowland
11 Middle Rocky Mountains
12 Wyoming–Big Horn Basins
13 Colorado River Plateaus
14 Upper Gila Mountains
15 North-Central Lake–Swamp–Moraine Plains
16 Upper Missouri Basin Broken Lands
17 Southern Rocky Mountains
18 Rocky Mountain Piedmont
19 High Plains
20 Stockton–Balcones Escarpment
21 Dakota–Minnesota Drift and Lake-bed Flats
22 Nebraska Sand Hills
23 West-Central Rolling Hills
24 Mid-continent Plains and Escarpments
25 Southwest Wisconsin Hills
26 Middle Western Upland Plain
27 Ozark–Ouachita Highlands
28 Lower Mississippi Alluvial Plain
29 East-Central Drift and Lake-bed Flats
30 Eastern Interior Uplands and Basins
31 Appalachian Highlands
32 Adirondack–New England Highlands
33 Lower New England
34 Gulf–Atlantic Rolling Plain
35 Gulf–Atlantic Coastal Flats
36 Coastal Zone

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