ASSESSMENT OF BLACKBIRD DAMAGE TO SUNFLOWER AND CORN FIELDS IN THE PRAIRIE POTHOLE REGION OF NORTH DAKOTA

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

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ABSTRACT

Klosterman, Megan Elise, M.S., Department of Biological Sciences, College of Science and Mathematics, North Dakota State University, September 2011. Assessment of Blackbird Damage to Sunflower and Corn Fields in the Prairie Pothole Region of North Dakota. Major Professor: Dr. George M. Linz.

North Dakota is the top sunflower producing state in the United States, annually harvesting about 405,000 ha (1 million acres). Up to 63% of this crop is grown in central North Dakota in an area known as the Prairie Pothole Region (PPR). Since the early 2000s, corn also has become a major crop in the PPR due to the development of hybrids for northern crop areas and increases in corn prices. Blackbirds (Icteridae) can cause significant damage to both ripening corn and sunflower. It has been three decades since a comprehensive sunflower damage survey was conducted in the PPR. I assessed blackbird damage to ripening sunflower and corn in 120 randomly-selected plots during three growing seasons, 2008-2010. Damage was analyzed across four strata (Northeast Drift Plains, Northwest Drift Plains, Southern Drift Plains and Missouri Coteau) within the PPR. Landcover was analyzed to determine possible variables (pasture, corn, sunflower, open water, wetland, small grains, developed, wooded, beans and other) related to blackbird damage. Stepwise logistic regressions were performed along with AIC model selection to determine significant ($p<0.1$) independent variables related to sunflower and corn damage. Average damage to sunflower (2.14%) was higher than damage to corn (0.33%), with sunflower in the Southern Drift Plains having the greatest levels of damage (11.11%). Beans and wetland showed the greatest significance in relation to sunflower damage (p=<0.001, p=0.035), according to the selected AIC model. The most significant landcover variables surrounding damaged corn fields was open water (p=0.022), showing an increase in damage, and pasture (p=0.056), showing a decrease in damage. The results of this study provide data to help producers make informed decisions about crop selection and location.

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1. INTRODUCTION

The Great Plains of North America spans the central region of the continent and consists of vast grasslands, agricultural fields and numerous wetlands that provide wildlife habitat. The northern Great Plains contain an area known as the Prairie Pothole Region (PPR). This region consisted of mixed grass prairie and wetlands until the 19th century when farmers began intensively tilling the soil for agricultural purposes (Cowardin et al., 1981; Samson et al., 2004). Tilling has changed the landscape from grassland and riparian habitats to a matrix of grain, grazing pastures, other cultivated crops and Conservation Reserve Program (CRP) land (Stewart and Kantrud, 1973; Johnson at al., 2005).

Within the PPR of North Dakota, many wetlands have been filled and cultivated to increase agricultural production in the state. In wet years, these wetlands often become too saturated to till and then provide wildlife habitat within the cultivated matrix. These wetlands can produce thick cattail (*Typha spp.*) stands that provide prime roosting and nesting habitat for wetland and grassland avian species (USDA NRCS, 2011). One of the most abundant avian groups using cattail wetland habitats is blackbirds (Icteridae), which feed on surrounding ripening crops, especially sunflower and corn.

North Dakota is the top sunflower producer in the United States, annually harvesting about 405,000 ha (Peer at al., 2003). Red-winged blackbirds (*Agelaius phoeniceus*), common grackles (*Quiscalus quiscula*) and yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) can cause significant damage to this crop (Cornell Laboratory of Ornithology 2006a, 2006b, 2006c; Peer et al. 2003). The National Sunflower Association considers blackbird depredation to be a key factor in the reduction of sunflower acreage in the PPR (Kleingartner, 2002),

The last comprehensive field damage survey was completed in 1979 and 1980 (Hothem et al., 1988). Hothem et al. (1988) estimated bird damage to sunflower in North Dakota to be between $US 4 and 11 million. Peer et al. (2003) used a bioenergetic model and estimated that blackbird damage was valued at $US 5-10 million. Sunflower prices have increased since these monetary losses were calculated (USDA NASS, 2011b). Wywialowski (1996) estimated bird damage to corn in the top ten producing states and found that damage was nearly $US 25 million. In North Dakota, corn has recently become an economically important crop. Based on grower observations, potential economic losses from blackbird depredation within the state have become a concern.

Blackbirds tend to feed on corn and sunflower during early ripening but some damage can occur after the crops achieve physiological maturity in September, especially by male and female common grackles (COGR), male red-winged blackbirds (RWBL) and yellow-headed blackbirds (YHBL). These males have larger bodies and beaks than do females allowing them to feed on the mature seed (Dolbeer, 1980; Linz et al., 1984; Homan et al., 1994; Peer et al., 2003).

RWBL breeding population densities in North Dakota, South Dakota and

Minnesota are among the highest in the nation (Peer et al., 2003). YHBL breed in deep water wetlands in the PPR region where sunflower production is high (Twedt et al., 1991), and the population in North Dakota increased over 300% from 1967-1981 (Besser, 1985). Likewise, the COGR population in North Dakota has also grown, increasing from 334,500 breeding pairs in 1967 to 777,000 pairs in 1990 (Stewart and Kantrud, 1972; Nelms et al., 1994). According to the BBS (Sauer et al., 2011), the population for all three of these species declined in the United States from 1999- 2009. Blackbird populations in North Dakota reach their peak in August and September when sunflowers are reaching maturity (Peer et al., 2003). These resident and migratory populations have led to extensive damage in agricultural fields such as sunflower and corn.

Complaints of blackbird damage to corn have increased in recent years. Thus, corn may be providing an alternate food source for foraging blackbirds. Quantitative surveys of blackbird damage to corn, however, have not been conducted in North Dakota. In 2008, 2009 and 2010, I assessed blackbird damage in ripening sunflower and corn fields in the PPR of North Dakota using the 'Ralston 120' 3.2 x 3.2-km sample sites (Ralston et al., 2007); these sites were dispersed randomly and proportionately across four strata (Northeast Drift Plains, Northwest Drift Plains, Southern Drift Plains and Missouri Coteau).

Additionally, I used landcover maps to analyze the amount of damage found within a sample site in relation to surrounding vegetation and landscape. In this study, I sought to (1) estimate blackbird damage to sunflower and corn crops within the PPR of North Dakota and (2) determine relationships between surrounding landcover variables and crop damage across the study area. My aim was to provide producers and wildlife managers with data that may aid in making informed decisions on crop placement and developing management strategies.

2. STUDY AREA

2.1. Prairie Pothole Region of North Dakota

My study area (95,200 km^2) is the PPR of North Dakota (Fig. 1). The Prairie Pothole Region (PPR) consists of an area covering 800,000 km^2 in central North America, spanning parts of Canada and the United States (Johnson et al., 2005). The topography of the PPR consists of undrained depressions, known as potholes, sloughs or wetlands, which formed during the Pleistocene Epoch (Stewart and Kantrud, 1973; Neimuth and Solberg, 2003; Johnson et al., 2005). These wetlands are scattered throughout a matrix of grassland, agricultural fields and Conservation Reserve Program (CRP) land (Stewart and Kantrud, 1973; Johnson at al., 2005).

The PPR experiences a variable climate, which can lead to drastic changes in water levels and vegetation cover (Poiani et al., 1996; Johnson et al., 2005). The central region of the PPR experiences moderate precipitation and temperatures, with precipitation often higher in the east and lower in the west of the region (Johnson et al., 2005).

Precipitation is also variable across years, with periods of drought and above average precipitation levels (Niemuth and Solberg, 2003; Johnson et al., 2005). For example, in the 1930s there were severe drought conditions, which caused a shift in the grassland habitat and economic losses to agricultural producers throughout the PPR (Johnson et al., 2005); conversely, in 2008-2010 precipitation was above average (Appendix VII). These fluctuations in precipitation are a common historical pattern in the PPR of North Dakota.

Wetlands in the PPR once covered 11% of North Dakota or 2 million ha (Cowardin et al., 1981; Sauer et al., 2011). In 1967, total wetland area was estimated at 1.3 million ha (Stewart and Kantrud, 1973), and by the 1980's wetland area had decreased to 1.1 million ha (Sauer et al., 2011). This is a 45% loss of wetland area since the early 1900's (Sauer at al., 2011). Most of these wetlands are < 0.4 ha, and losses have been due to drainage for agricultural development (Cowardin et al., 1981; Samson et al., 2004; Sauer et al., 2011). Shelterbelt planting began in the 1930s with the onset of the "dust bowl" drought. Shelterbelts consist of rows of trees and shrubs planted around agricultural fields and homesteads to prevent wind erosion and damage as well as to provide protection from harsh weather. A plan was formulated to plant shelterbelts in a narrow belt (161 km wide x 1,931 km long) that spanned the Central Plains, covering regions from North Dakota to Texas, where climatic and soil conditions could sustain tree growth (Zon, 1935). This plan was never fully established but shelterbelts have become a common feature on the plains throughout North Dakota.

In an earlier study, Stewart and Kantrud (1972) divided the PPR into four strata (Northeast Drift Plains, Northwest Drift Plains, Southern Drift Plains and Missouri Coteau). These physiographic strata have variable precipitation and weather patterns (Table 1). The Drift Plains is flatter than the Missouri Coteau (MC) due to glacial drift on the plains (Cowardin et al., 1981). Large moraines can be found on the edge of the region, caused by glaciation, which formed low rolling hills in the Missouri Coteau (Ralston et al., 2007). Due to this difference in topography and glaciation, the Coteau contains more wetland basins than the Drift Plains regions, although the Drift Plains contains many natural basins formed from the James and Sheyenne rivers (Cowardin et al., 1981).

Table 1. Mean precipitation data for years influencing the study period based on all available NDAWN recording stations within the study region (Prairie Pothole Region of North Dakota).

Strata	**2007 Precipitation (mm)**	**2008 Precipitation (mm)**	**2009 Precipitation (mm)**	**2010 Precipitation (mm)**	**Four Year Average (mm)**
NEDP	466	446	396	533	462.47
NWDP	338	382	307	471	374.53
SDP	482	470	368	518	459.11
MC	445	414	356	435	412.86
Yearly Average	433	428	357	489	433

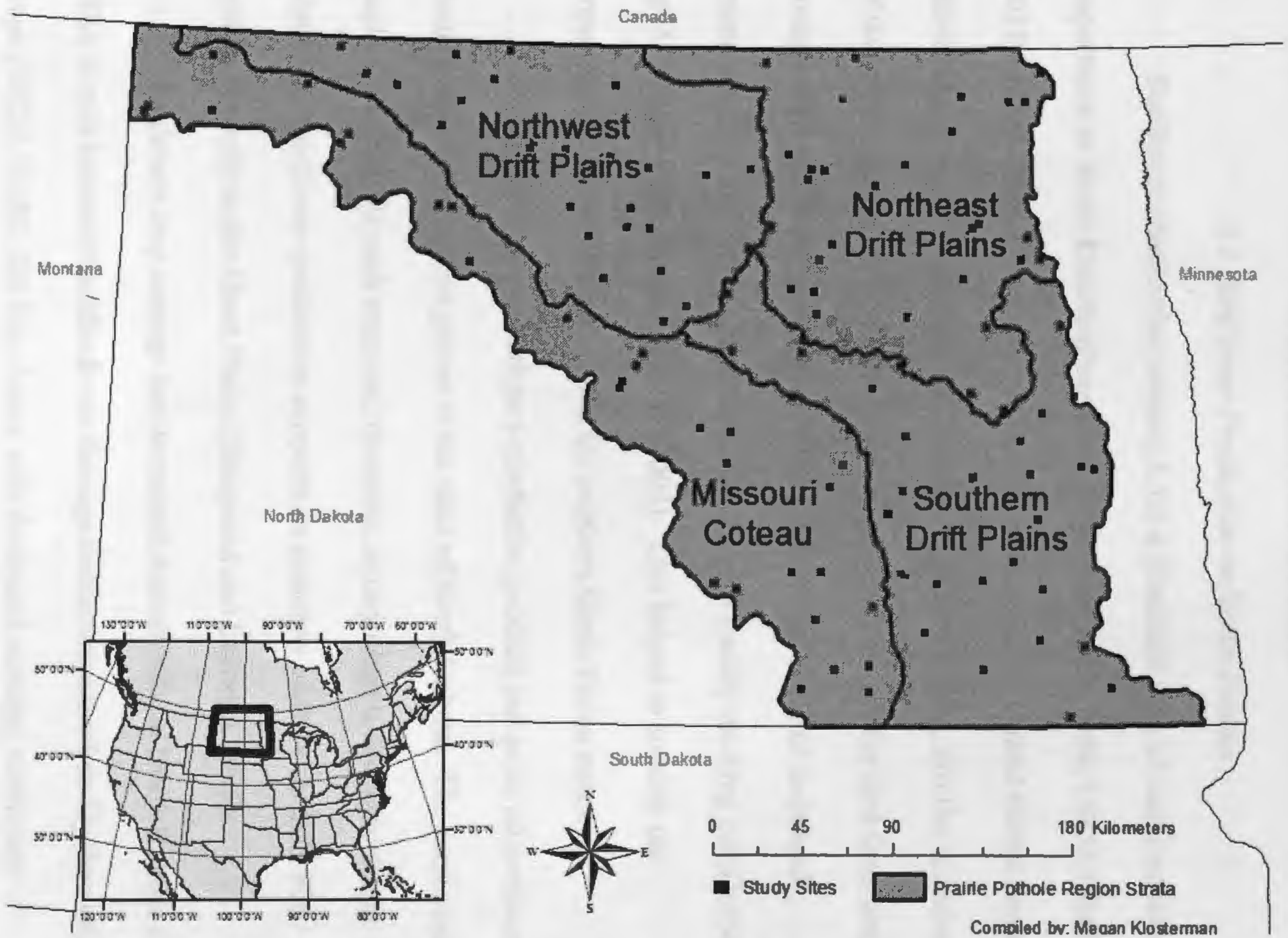

Figure 1. The strata of the Prairie Pothole Region of North Dakota with location of study sites.

3. LITERATURE REVIEW

3.1. Sunflower Production in North Dakota

Sunflower (*Helianthus annuus L.*) is a rotational crop of major economic importance in North Dakota (Peer et al., 2003; Linz et al., 2004; USDA NRCS, 2011). North Dakota is the top sunflower producer in the United States, annually harvesting about 405,000 ha [1 million acres] (USDA NASS, 2011b). Cultivation of this crop began in the 1960s to meet the growing demand for bird feed, and around 1975 sunflower production in the northern Great Plains increased dramatically to meet international demand for high quality cooking oil (Dolbeer, 1975; Besser, 1978; Blackwell et al., 2003). This helped to solidify the importance of the sunflower crop in the northern Great Plains states.

Sunflower is grown both as a confection product and as an oil producer. Both forms of the crop are grown in the state of North Dakota. The sunflower oil market is a valuable cash crop and, therefore, is important to the agricultural economy. Sunflower production supports an economy worth over $US 906 million annually in the Great Plains (Bangsund and Leistritz, 1995).

Sunflower crop acreage has decreased dramatically in North Dakota since 1986, in part because blackbirds can damage sunflower more heavily than other crops (USDA NASS, 2011b). Along with decreased acreage, sunflower production has shifted to drier western regions of the state where wetlands are not as prevalent. Oil seed varieties are more heavily damaged by wildlife than many other varieties (Besser, 1978; Mason et al., 1989, Linz and Hanzel 1997; Linz et al., In press). The oil seeds provide a high caloric diet for postbreeding blackbirds undergoing premigratory fattening (Besser, 1978; Peer et al., 2003).

According to the National Agricultural Statistics Service (NASS), the value of sunflower in North Dakota has risen dramatically in the last few years (USDA NASS, 2011b). In 1999, production was at 847,000 metric tons (1.9 billion lbs) worth about $US 155 million. By 2009 the production had decreased to 685,560 metric tons (1.5 billion lbs) worth $US 307.4 million. This result is due to an increase in value from $US 8.18 per cwt to $US 20.40 per cwt (USDA NASS, 2011b).

3.2. Corn Production in North Dakota

Corn (*Zea mays* L.) has been a major crop in the United States for many decades (USDA NRCS, 2011). In North Dakota, this crop has not been as important as small grains and sunflower. Today corn is grown in abundance in North Dakota where sunflower production has declined due to bird predation as well as competition from other crops. Growers have noticed blackbirds in ripening corn and have become concerned that corn will simply replace sunflower in the blackbirds' diet. In the top ten corn producing states, damage increased from 1971 to 1981 (Besser and Brady, 1986; Wywialowski, 1996). This damage, mostly from blackbirds, totaled nearly $US 25 million (Wywialowski, 1996). These data and grower observations have led to concerns in North Dakota, where the crop has increased from 76.6 million bushels in 1999 to 285 million bushels in 2008.

3.3. Crop Damage from Common Pests

Many farmers experience setbacks and financial distress from a variety of wildlife. Sunflower experiences damage from a variety of pests other than blackbirds. Humans have tried many techniques to rid fields of these pests, with limited success.

The most damaging pests to sunflower are those that damage the head of the crop (Charlet et al., 1997). The banded sunflower moth (*Cochylis hospes* Walsingham) is one of many head feeding pests affecting the sunflower crop today (Ganehiarachichi, 2009). The moth's preferred egg laying period is during the R2 and R3 sunflower growing stages (NDSU Extension Service, 2010). These moths emerge from the soil during the summer and then feed on the pollen, flower tissue, and developing sunflower seeds at the edge of fields (Jyoti and Brewer, 1999; Mundal and Brewer, 2008). Webbing in the sunflower head is often a sign of sunflower moth activity in a field (Knodel and Charlet, 2010). Insecticides have been marginally successful because they cause the extermination of helpful insects as well as pest species (Jyoti and Brewer, 1999). Researchers are investigating the use of parasites to control population sizes of the sunflower moth (Charlet, 2000).

The sunflower seed maggot (*Neotriphritis finalis* Loew) is often found in eastern North Dakota, and its range covers most of North America (Ganehiarachchi, 2009; NDSU Extension Service, 2010; Charlet et al., 1997). The larvae feed on the undeveloped ovaries of flowers and tend to cause more head damage than many other species (NDSU Extension Service, 2010). There are two full generations per year with adults emerging during the first week of July and the middle of August; eggs are laid on the corolla of partially opened sunflowers (Ganehiarachchi, 2009; NDSU Extension Service, 2010).

Some pests attack multiple crops. The corn rootworm (*Diabrotica spp.)* has been found to affect native sunflower populations that border corn fields (McKone et al., 2001). The eggs of the rootworm can be found in the soil of corn fields where the larvae feed on roots (McKone et al., 2001). After the corn rootworm matures, it disperses to neighboring fields and grasslands where it feeds on the flowers and pollen of plants in the family Asteraceae. The damage from these rootworms could affect commercial sunflower plants, especially, if these fields are planted near corn fields.

Pests tend to attack a variety of locations on the plant with severity dependent on the location of the damage. One location for severe damage is the stem, and numerous pests tend to attack and affect this region of the plant. The sunflower stem weevil (*Cylindrocopturus adspersus* LeConte) burrows into the stem during its larval stage and spends the winter in tunnels it has formed (Charlet et al., 2009; Charlet et al., 1997). This weakens the stem, causing the plant to break. The stem weevil is also a known carrier of pathogens such as Phoma black stem (*Phoma macdonaldii* Boerema) which can further weaken stems and is an economic problem for sunflower producers (Charlet et al., 2009). Other pests that are similar to the stem weevil are the long-horned beetle (*Dectes texanus* LeConte) and the root boring moth (*Pelochrista womonana* Kearfott), both destroy the stem of the sunflower (Charlet et al., 2009; Charlet et al., 1997).

Fungal pathogens are another common cause of damage to crops. Rust (*Puccinia helianthi* Schwein) is a fungus that causes significant sunflower damage (Markell et al., 2009). A characteristic of this fungus is bright orange cups that turn brown or black as they mature; this fungus often forms in August in states such as North Dakota (Markell et al., 2009). Rust often causes the most damage when it forms early in the season.

Corn suffers from a large number of pests as well. Similar to the sunflower stem weevil, the corn weevil (maize weevil, *Sitophilus zeamais* Motschulsky) has become a major pest. Unlike the stem weevil, the maize weevil attacks the crop post harvest by consuming corn in storage facilities (Garcia-Lara et al., 2010). Researchers have found that some corn varieties seem to be resistant to the maize weevil's damage (Garcia-Lara et al., 2010).

Corn smut (*Ustilago zeae-maydis* Persoon) is a devastating fungal disease that infects corn (Miller et al., 1996). Smut is most commonly found on sweet corn but has also been observed on many field corn varieties (Cornell Lab of Ornithology, 2006). High temperatures and humidity provide the most favorable conditions for growth of the fungus (Miller et al., 1996). Smut is often found on the ears and tassels of the plant, producing a mass known as a gall (Miller et al., 1996). The gall produces spores (sporidia) that are carried by the wind to new fields (Miller et al., 1996). Smut galls are consumed as a delicacy in some regions such as Mexico, which has led to farming of smut in some areas (Miller et al., 1996).

Sclerotinia (*Sclerotinia sclerotiorum* Lib) is a major economic pest in the corn and sunflower industries as well, causing white mold in a variety of other crops (Dorrance and Mills, 2008). This fungus tends to develop on loose-husked varieties where moisture can easily access the kernels (Wicklow and Horn, 1984). Insects tend to initiate the sclerotinia growth in corn by providing an entry point for fungal invasion (Wicklow et al., 1982). Sclerotinia can, however, be controlled by exposure to sunlight since this fungus needs wet or moist conditions to establish and grow (Dorrance and Mills, 2008). When sclerotinia is exposed to high levels of sunlight, the fungus often decreases in size and area (Wicklow et al., 1982). Sclerotinia head-rot in sunflower is more damaging in confection varieties, and fungicides have been ineffective in protecting these crops (NSA, 2006). Damage from this fungus has cost agriculture producers up to $US 280 million annually across all susceptible crops (NSA, 2006).

Wildlife damage is one of the largest contributors to corn damage and is not uniformly distributed (Wywialowski, 1996). This damage is often greater near water and woodlands, which provide prime habitat for many wildlife species (Wywialowski, 1996). In many areas, hunting and trapping are used as controls to limit the amount of wildlife adjacent to crop land. Hunting and trapping are the most cost effective methods to control the wildlife populations that consume and destroy corn crops (Conover, 2001). Hunting also causes wildlife to be more aware of potential dangers, which limits their time on agricultural land. Corn damaging species include bear, deer, raccoon, wild turkey, rabbits and mice (Wagner et al., 1997).

The largest wildlife pest in many areas is the white-tailed deer (*Odocoileus virginianus* Zimmerman), which can cause more than $US 500 million in damage to agricultural crops such as corn (Conover, 2001). In states such as Montana, deer damage was found to be moderate to high in all regions (Irby et al., 1997). White-tailed deer were also the cause of the most damage to corn crops in Pennsylvania, and most of this damage occurred during the tasseling stage of growth (Tzilkowski et al., 2002).

Blackbear (*Ursus americanus* Pallas) have also been an animal of concern in some parts of the United States. Bears raid corn fields and often cause large monetary losses to the grower (Garchelis et al., 1999). Garchelis et al., (1999) found that bears frequent corn fields more than any other crop, which leads to greater damage to these fields. A study in Massachusetts showed that damage from bears primarily occurs from August through October (Jonker et al., 1998). In most situations, bear habitat does not overlap with the sunflower production area. During the last 15 years, however, the northern Minnesota Black Bear population expanded into western Minnesota where these bears can cause significant sunflower damage (Ditmer et al., 2011).

3.4. Blackbird Damage to Sunflower and Corn

Various bird species cause significant damage to both sunflower and corn in the United States. From 1971 to 1981, bird damage to corn increased in the top ten corn producing states (Wywialowski, 1996). The most noteworthy of these species (Fig. 2) are the common grackle (COGR), red-winged blackbird (RWBL), and yellow-headed blackbird (YHBL) [Dolbeer, 1978]. The National Sunflower Association (NSA) considers blackbird depredation of sunflower to be a key factor in the reduction in sunflower acreage, and corn may be providing an alternate food for foraging blackbirds, thus reducing damage in sunflower (Kleingartner, 2002). Blackbirds tend to be more abundant in cropland landscapes than many other species (May et al., 2002). A nationwide corn damage survey was conducted in 1970 that covered most states affected by blackbird damage, but North Dakota was not included because of limited corn acreage (Stone et al., 1972). With an increase in sunflower damage in the state, many producers have switched to corn production in order to ensure their yield and profit.

Figure 2. Main species of damage-causing blackbirds in the Prairie Pothole Region of North Dakota: yellow-headed blackbird (*Xanthocephalus xanthocephalus),* common grackle (*Quiscalus quiscula*) and red-winged blackbird (*Agelaius phoeniceus*).

North Dakota's overall blackbird population surpasses all other states in the U.S. due to prime habitat, migration pathways and food distribution (Otis et al., 1986; Peer et al., 2003). According to Stewart and Kantrud (1972), the number of breeding pairs reaches nearly 3 million in the state, with individual fall roosts commonly containing 10,000-100,000 birds and occasionally reaching up to a million or more individuals (Besser, 1978; Linz and Hanzel, 1997). The RWBL has been noted as one of the most abundant breeding birds in the Dakotas (Besser, 1978; Igl and Johnson, 1997). In fact, YHBL, RWBL and COGR comprise over 10% of the North Dakota avian abundance (Nelms et al., 1994). These blackbirds cause sunflower damage ranging from $US 5-10 million (Peer et al., 2003). Sunflower is most vulnerable to bird predation over a six-week period, which is one of the longest time spans for predation to occur in an agricultural field. It comprises 20-70% of the blackbird diet in many northern regions (Besser, 1978; Linz et al., 1983). This damage is sporadic for producers and can range from 0-100% damage among neighboring fields (Blackwell et al., 2003). Average damage across the region often ranges from 1-2% per field (Hothem et al., 1988).

Sunflower and corn in the region provide a high caloric diet that is needed for migration (Krapu, 2004). Sunflower, specifically of the oil seed variety, is the most preferred food source due to its essential proteins and fats that are vital for maintenance processes prior to and during migration (Besser, 1978; Linz and Hanzel, 1997). This crop serves as a food source near maturity when blackbirds are preparing for fall migration (Peer et al., 2003). Corn is typically foraged pre-maturity during the "milk" or "dough" stage when the kernels are soft and easily accessible. Both male and female COGR and male RWBL and YHBL can forage on corn continuously up to harvest.

According to the Cornell Lab of Ornithology (2006a), the COGR is the number one threat to sprouting corn in many regions of the United States. This species prefers to nest in trees, typically conifers, located in open landscapes but is well adapted to the disturbances caused by agriculture and urbanization (Besser, 1978; Homan et al., 1996). The grackle can be found nesting and roosting in a wide variety of landscapes if optimal habitat cannot be found. Corn seeds are a preferred food source of the species, which leads to the damage seen in agricultural fields in the United States.

RWBL also feed extensively on seeds, yet insects are another significant source of energy (Cornell Lab of Ornithology, 2006b). Males eat more corn seeds than females, which primarily feed on insects and weed seeds (Linz et al., 1983; Peer et al., 2003). This species is one of the most abundant birds in North America and can live and forage in a variety of locations (Blackwell and Dolbeer, 2001). The preferred nesting habitat for this species is in or near marsh lands and wet areas where nests are built in the tall marsh vegetation, but this species also uses roadsides, drainage ditches and pastures (Albers, 1978; Besser, 1978, 1985a; Nelms et al., 1994; Blackwell and Dolbeer, 2001; Peer et al., 2003). Cattails offer good nesting structures in these habitats.

Similar to the RWBL, the YHBL nests in wet areas that provide cattail and reeds as nesting substrate (Nelms et al., 1994). Pairs typically nest in the prairie wetlands and tend to be dominant over the RWBL, which they push out of prime habitat (Twedt and Crawford, 1995; Cornell Lab of Ornithology, 2006b). Similar to COGR and RWBL, the YHBL feeds on insects, grain and seeds which allow it to utilize agricultural development (Peer and Bollinger, 1997; Cornell Lab of Ornithology, 2006c).

Just prior to migration in the fall, these individuals join to form large flocks that forage in surrounding fields. Population fluctuations can cause drastic changes in crop damage and control efforts. According to Besser (1985b), the RWBL population declined by 29% from 1967 to 1982 in North Dakota, yielding a breeding population of 1.5 million pairs in 1982. The Breeding Bird Survey (BBS) also reported declines in RWBL populations across the entire survey area, although estimated damage to corn crops in Ohio did not correlate with the BBS population records (Stehn and de Becker, 1982; Blackwell and Dolbeer, 2001). This decline has been connected to predation as a major source of nest failure, increase in urbanization and agricultural technology, and a decline in hay fields which serve as feeding and roosting habitat (Blackwell and Dolbeer, 2001; Sawin et al., 2003). The YHBL population increased significantly in population in North Dakota, growing by 370% from 1967 to 1982 (Besser, 1985b). The COGR population has remained reasonably constant in previous years, but in North Dakota the population more than doubled from 1967 to 1990 (Stewart and Kantrud, 1972; Homan et al., 1996). According to the BBS, the population for all three of these blackbird species has declined in the United States from 1999-2009 (Sauer et al., 2011). However, in North Dakota during this same 10-year period, the RWBL and YHBL population decreased, and the COGR population increased (Sauer et al., 2011).

3.5. Landcover and Habitat Preference

Forcey et al. (2007) found that habitat variability and stratification influence avian populations. Interpretations of multiple scales are necessary to understand the influence of habitat variables to a population (Forcey et al., 2007). In dry seasons, bird populations tend to congregate into larger flocks due to lack of suitable habitat spread across the landscape (Besser, 1978; Forcey et al., 2007). Landscape factors should be viewed on both a broad level and a localized, seasonal time scale.

Conversion of native grassland in North Dakota to agricultural land and the drainage of wetlands, the main non-crop habitat for avian species throughout the PPR, have lead to a decrease of avian diversity in the region (Higgins et al., 2002; May et al., 2002; Grant et al., 2004; McMaster et al., 2005; Schaaf et al., 2008). The PPR is a region in the North Central Plains that is marked by a large number of wetland areas. This region has provided prime habitat for migrating avian species for centuries. With agriculture becoming the greater part of the landscape, many of these wetlands have been modified with practices such as tilling (Naugle et al., 2001). This modification has allowed the hybrid cattail (*Typha glauca* Godr.), a cross between the common cattail (*Typha latifolia* L.) and the narrow-leaved cattail (*Typha angustifolia* L.), to invade these systems and fill the wetlands with dense vegetation (Linz et al., 1996). Dense cattail vegetation decreases the diversity of avian species in the area but provides prime roosting habitat for the RWBL and YHBL (Linz et al., 1996; Blackwell et al., 2003).

Shelterbelts are another new addition to the landscape of the central plains. These shelterbelts are rows of trees that provide protection for humans and agriculture from winds, cold temperatures and snow (Yahner, 1982; Haas, 1995). These tree rows provide prime habitat for species such as the COGR, where it can be the most abundant nesting species (Yahner, 1982; Homan et al., 1996).

Conservation Reserve Program (CRP) land has renewed some of the grassland habitat. This United States Department of Agriculture (USDA) program pays farmers to plant part of their land with a variety of grassland species (Higgins et al., 2002). CRP land increases habitat for many avian species and provides wildlife with thick, dense herbaceous cover. This program has helped convert large areas from agricultural land to idle habitat (McMaster et al., 2005). The RWBL is the most abundant avian species found on CRP land (Best et al., 1997). The lack of native species in CRP might be due to the lack of insects found on CRP land compared with the abundance found on native prairie (McIntyre and Thompson, 2003). Mowing of CRP land limits the number of RWBL, but has no effect on the number of YHBL (Horn and Koford, 2000).

Blackbirds flock together prior to migration, and the conversion of the landscape has provided these species with prime roosting and feeding habitats. Cattail-choked wetlands are scattered in agricultural areas, as are shelterbelts (Tome et al., 1991). These habitats provide roosting blackbirds easy access to high caloric feed such as corn, sunflower and insects that reside in these fields (Linz et al., 2004). Habitat surrounding fields, as well as vegetation within fields, such as grass and weeds, affect the presence of some bird species (Schaaf et al., 2008). Weeds and insects surrounding and within these fields increase the rich food resources that provide energy during stop-over periods of migration (Schaaf et al., 2008).

Cropland represents the third largest land use in the United States and provides habitat for birds during migration in the northern Great Plains of North America (Hagy et al., 2010). Depredation of cropland can sometimes be mediated by strategically planting decoy plots, depending on the surrounding landscape (Hagy et al., 2010). Previous studies showed that about 94 species use cropland, and the RWBL was recorded as the most common species found in crop fields throughout the U.S. (Lokemoen and Beiser, 1997; Hagy et al., 2010). Economically important crops are left vulnerable to these species because of their late harvest. Sunflower and corn are often harvested later in the season than most other crops in North Dakota (Linz et al., 2004). This allows blackbirds to feed on crops up to fall migration in September (Dolbeer, 1978).

3.6. Climate Change

Variation of season variables changes the behaviors of some nesting birds such as blackbirds. Specific factors such as nesting, feeding and migration have been studied in relation to changes in climate and were shown to vary based on the species being observed (Weatherhead, 2005). In a European study, about a third of birds (approximately 22 out of 65 species) began nesting and laying earlier in relation to the North Atlantic Oscillation, which caused a rise in spring temperatures (Crick et al., 1997). Higher temperatures are thought to increase the insect population, which supplies a greater food source for nesting bird populations (Ewald and Rohwer, 1982). This increase in the insect population may cause a change in blackbird diet by providing an easily accessible food source other than crops. By using smaller climate variations such as those caused by the North Atlantic Oscillation Index (NAOI), which causes deviations in rainfall and temperature in the northern hemisphere (Weatherhead, 2005), it is possible to estimate how a longer term climate change would affect blackbird species' feeding habits.

Climate change may lead to modification of landscapes and habitats in a region. Intensification of farming practices may occur to better use the time of suitable weather conditions for growing (Kleijn et al., 2010). Along with climate change, agricultural landscapes may be altered to better fit the growing condition of the area, but the effect this may have on bird populations has seldom been studied (Pearce-Higgins and Gill, 2010). With seasons, such as spring, beginning earlier, common practices such as planting and mowing take place sooner. Change in climate could have a detrimental effect on bird populations that have not fledged in time to avoid the destruction of nesting habitat (Kleijn et al., 2010; Pearce-Higgins and Gill, 2010).

3.7. Damage Control Mechanisms

Many efforts have been made to control the damage produced in agricultural fields by these avian species. These efforts range from habitat control and destruction to toxic baits. Controls for blackbird pests are heavily researched, though many of these methods are ineffective and costs of protection often exceed the cost of damage.

One of the most common systems for avian damage control is the propane cannon. These cannons emit a loud noise that startles and scares off foraging blackbirds. The sound is often amplified by use of a large metal drum as a base for the cannon (Besser, 1978; Linz and Hanzel, 1997; Linz et al., 2011). In many instances, the noise only startles the birds for the first few attempts. After this introductory period, the birds become accustomed to the sound and continue their normal foraging behavior (Bomford and O'Brien, 1990; Bomford, 1992). Usually this method is combined with some kind of lethal control such as shotgun fire or "shell crackers" (12-gauge shotgun containing a firecracker round instead of a shot) in order to better frighten the flocks (Besser, 1978; Bomford and O'Brien, 1990; Bomford, 1992).

A nonlethal control for blackbirds today is the destruction of dense cattail choked wetlands (Blackwell et al., 2003; Linz and Homan, 2011). Glyphosate is an herbicide used to kill cattail in these wetlands. This chemical can be locally sprayed or distributed by plane or helicopter. Glyphosate reduces cattail coverage and fragments stands, which reduces the area for optimal roosting habitat near grain fields (Linz et al., 1996; Linz and Homan 2011).

DRC-1339 is a lethal chemical that can be added to bait, such as rice, to limit the population of blackbirds in a vicinity. Birds that ingest the bait often die within 24-72 hours of consumption (Linz et al., 2000; Goldberg et al., 2004). DRC-1339 causes necrosis of the kidneys and stops the body from releasing uric acid (Linz et al., 2000). This chemical quickly degrades when exposed to sunlight and precipitation (Linz et al., 2000). This bait was used in Louisiana to control blackbird numbers in rice paddies (Linz et al., 2000). Baiting has not been found to be cost effective for producers experiencing damage to ripening crops in many situations (Winter et al., 2009).

Another lethal attempt to reduce blackbird populations is to use surfactant sprays. These sprays are applied by coating blackbirds using a "curtain" spray, sprinkler systems or aerial application (Stickley et al., 1986). This spray is a compound known as PA-14 and was the only lethal chemical registered by the Environmental Protection Agency (EPA) for use on roosting blackbird populations, although it is no longer registered (Stickley et al., 1986; Linz et al., In press). This product works by allowing water to penetrate feathers and wet the skin. Once water penetrates, the insulating properties of the feathers are no longer effective and the bird succumbs to hypothermia during cold weather (Stickley et al., 1986). Application of the surfactant has been used in Kentucky and

Tennessee resulting in inconsistent reductions in bird roost populations due to varying weather conditions (surfactant works in a narrow range of weather conditions [Stickley et al., 1986]). Survivors from an application often move to new roosting sites, and populations can rebound shortly after treatment (Stickley et al., 1986; Glahn et al., 1991).

Some products are meant to dissuade blackbird populations without lethal repercussions. Flight Control® is a product used to repel birds from fields but is not currently registered for use on ripening crops, such as sunflower (Cummings et al., 2002; Linz et al., In press). This product is made of 50% anthraquinone, a chemical with bird repellent properties, which causes birds to become sick after feeding on treated seeds (Cummings et al., 2002).

Another method to prevent blackbird damage to crops such as sunflower and corn is to directly modify the crop itself. In some instances, companies have produced varieties of corn that provide more husk coverage of the seed. New crop varieties reduce damage due to the extra effort that is needed to reach the kernels. In sunflower breeding, heads that tend to turn downward earlier in the season have been selected, which requires birds to exert more effort in order to reach the seeds on the underside of the head (Besser, 1978; Linz and Hanzel 1997).

Anthocyanins have also been studied to determine level of repellency to blackbirds (Mason et al., 1989). Anthocyanins are purple pigments that decrease the palatability of the sunflower hulls (Mason et al., 1989). In Ohio, a study was conducted to determine whether birds would show a preference toward a commercial oil seed variety over this experimental, bird resistant cultivar (Mason et al., 1989). While it was found that blackbirds prefer the commercial oil seed variety to the resistant variety, it was also found that if the resistant variety were the only available food source, then populations did not hesitate to feed on this "resistant" crop (Mason et al., 1989).

The early portion of the season is an important time for many crops such as sunflower. By planting at different times of the season, it is possible to escape the heavy damage produced by some of these pests (Brugger et al., 1992). The black cutworm (*Agrotis ipsilon* Hufragel) is a pest that often attacks the crop during its early stages, similar to rust (Rodriguez-del-Bosque and Loera-Gallardo, 1993). By planting crops early, it is possible to escape the severe damage caused by some of these pests.

Blackbird damage is often distributed unevenly, and damage management can be costly. Since bird damage is often unpredictable, producers often look for ways to avoid production loss from the start. The last comprehensive damage survey in North Dakota was conducted in 1979 and 1980, and it showed an estimated economic loss between $4 and 11 million (Hothem et al., 1988). According to Peer et al. (2003), economic damage to sunflowers from RWBL, YHBL and COGR totaled $US 5.4 million. Landcover is often tied to loss of yield in a given area, although damage is distributed unevenly throughout neighboring fields. It is useful for producers to understand conditions that may lead to extensive damage in their crop fields.

3.8. Past Studies

Many experiments have been conducted in relation to blackbird damage to crops in the United States. By using these data and methodology, scientists can better assess damage that is found today. Scientists have approached this problem using a number of different methodologies

3.8.1. 1969-1980

In 1969, De Grazio et al. (1969) used weight to assess corn damage produced from bird populations. For this experiment, kernels that were left on the ears were weighed. Using a table, the dry weight lost was calculated. This table included the "average cumulative weight of kernels on each half inch section for each size class" (De Grazio et al., 1969). The dry weight was determined based on length of ear and the length of damage. Later a new table was formed using regression equations for each size class.

De Grazio's study area was 24,346 ha. (94 square miles) and contained the most marsh land and bird damage in Brown County, Ohio. Starting at the most accessible corner of the field, two plots per field were set up and data were collected in 30.5 meter (100 foot) sections in each row. These rows were randomly selected, and the number of steps into each row was randomly determined. In late September, a count of damage and undamaged ears was taken in each section and damaged ears were measured.

Stone et al. (1972) measured bird damage to corn across the entire United States. For this survey, Stone used the length to weight table from De Grazio's work (1969). Twenty-four states accounting for 98% of the harvested corn acreage in the United States were surveyed. Again, fields were randomly chosen, and two rows in each field were selected as transects. Stone (1972) measured the length of the damaged and undamaged rows of kernels in each unit. These data were then compared to the De Grazio (1969) table in order to determine total dry weight lost.

In 1975, Dolbeer tested the accuracy of two common methods for measuring sunflower damaged by blackbirds. These methods included the template method and visual method. The template method used a template with 5-cm^2 sections cut out. This template allows the user to count the number of squares covered by damage and thereby estimate the total area of the damage. The visual method used a crosshairs implement that was marked at every 2-cm interval. The crosshairs were centered on the sunflower head and the percent damage for the head was estimated by using this visual aid.

Dolbeer (1975) collected and manually damaged heads to a known level. Four observers were then chosen to assess the heads using first the visual method and then the template method. These estimates were then compared to the true loss of each head. Dolbeer (1975) found that both methods work well at low levels of damage. Individuals most commonly underestimated when using the template method and overestimated when using the visual method. There was less variation among observers when using the template method, but the visual method was less time consuming.

3.8.2. 1980-2000

Wakely and Mitchell (1981) compared farmer surveys to actual damage in the field. For this study, counties in Pennsylvania were grouped according to surface area planted in corn. Sampled areas were randomly selected from each of these groups, and two rows were randomly selected in the fields and marked as transects. Wakely and Mitchell (1981) collected four measurements to analyze the damage to each group (percent of fields with damage, number of damaged ears per row, percent of ears that were damaged and the estimated weight of damaged corn). To determine the estimated weight of corn lost, they measured the length of the ear and the length of the damage. Weight was then determined using the De Grazio method (De Grazio, 1969).

From 1979 to 1981, Hothem et al. (1988) measured loss of the sunflower crop to blackbird depredation in South Dakota, Minnesota and North Dakota. His study aimed to estimate the overall level of bird damage (Hothem et al., 1988) and was the last comprehensive blackbird damage survey conducted.

The template method was used to estimate bird damage on each head. Based on area planted as sunflower, counties were divided into random sections. At least two fields per county were selected for damage estimates. In 1979 and 1980, 933 and 555 fields were assessed, respectively. Rows were selected randomly, and subsamples of five heads were measured. The diameter of the head, as well as the diameter of any undeveloped center, was measured to determine total area of the developed seed head (Hothem et al., 1988).

Of the three surveyed states, North Dakota had the highest damage in 1980 and Stutsman County, specifically, had more damage in 1980 than 1979. Around 2% of the fields surveyed had losses greater than 10% (Hothem et al., 1988). These data are an example of how irregular distribution of damage can be across years and among fields in a given area.

In conjunction with the Hothem et al. (1988) project, a second study was done to determine if physical features within and surrounding sunflower fields impacted blackbird damage levels (Otis and Kilburn, 1988). The variables analyzed in this study included the occurrence of certain habitat types near the field, distance between rows, size of the field, plant height and average head size (Otis and Kilburn, 1988). The authors found that occurrence of wetlands had a significant impact on the level of damage experienced in the field. Wetland presence also increased damage levels, whereas pasture presence reduced damage. Landscape factors often did not influence blackbird choice once a field had been selected. Other significant factors to damage levels included presence or absence of trees or plowed fields, row spacing and weed density in the surveyed field (Otis and Kilburn, 1988). Both of these studies mentioned possible errors in damage estimates due to shrinkage and compensation for damage in individual sunflower heads (Sedgwick et al., 1986).

In a study conducted in 1981-1982, Sedgwick et al. (1986) studied shrinkage and growth compensation in sunflowers. In their study, sunflower heads were manually damaged at different intensities and across sunflower head-size classes to examine how the sunflower would respond. All damage was inflicted after 25-50% ray flower drop, and damage was evaluated at 2-week intervals until harvest.

Sedgwick et al. (1986) found that more shrinkage of damaged regions and seed growth compensation occurred when heads were damaged earlier versus later in the season. The variation of compensation due to time of damage was listed as the most important factor affecting damage estimation. It is difficult to determine the time of damage in a field; therefore, seed loss estimation is not always as accurate as anticipated.

In late September 1986, Linz et al. (1989) conducted a sunflower damage survey in northeast Benson County and west central Ramsey County, North Dakota. This survey was designed to determine blackbird damage patterns in a 79,772-ha (308-mile^2) area. In 1986, damage was measured at 8.1%, with 7% of the fields receiving > 30% damage. In 1987 damage was estimated at 4.3%, with no fields experiencing >30% damage. Oil content was measured to establish if this had an effect on the amount of blackbird damage to the region. Linz et al., (1989) found that oil content did not affect damage to a noticeable degree.

The chronology and distribution of blackbird damage to sunflowers were studied by Cummings et al. (1989). Cummings et al. (1989) selected 24 oil-seed variety sunflower fields, and each field was surveyed for damage once every three days beginning at ray petal drop and continuing until harvest. Amount of damage was compared along transects through the field. Each field was divided into the inside region (> 46 m from the edge) and edge region (< 46 m from the edge) and compared.

Distribution of damage within each field was not different between the inner region and the edge. The number of birds peaked in late September, and most damage occurred within 18 days of anthesis, with soft seed receiving the most damage. Damage decreased toward harvest.

3.8.3. 2000-Present

Peer et al. (2003) constructed a bioenergetic and economic model to estimate the impact of birds to sunflower yields. Bioenergetic models are used to provide estimates that are derived without taking direct measurements in the field. Their objective was to develop an accurate bioenergetic model that would incorporate blackbird biology, population dynamics and metabolism with both energetic and economic components.

Consumption for the model was determined by viewing the esophageal contents of RWBL, YHBL and COGR. Data on esophageal contents from the period of sunflower maturation were collected from Linz et al. (1984), Twedt et al. (1991) and Homan et al. (1994). Total amount consumed was multiplied by 1.225 to compensate for dry mass. The economic value of the damage was calculated by multiplying the amount of sunflower consumed by the average market price of the sunflower for that period. Peer et al. (2003) found that male RWBL populations caused the most sunflower damage, followed by male COGR, male YHBL and female COGR. The models formed were independent of the actual field damage calculations and were meant to be used in conjunction with field surveys to provide a better understanding of blackbird damage. The model was developed to be flexible in order to adjust it to a more localized scale, if accurate population counts could be obtained.

4. METHODS

4.1. 2008 and 2009 Field Seasons

Stewart and Kantrud (1972, 1973) stratified the PPR into Missouri Coteau, Northwest Drift Plains, Northeast Drift Plains and Southern Drift Plains. Ralston et al. (2007) proportionally allocated 120 3.2 x 3.2-km (1,036 ha) sample plots ('Ralston 120') to the four strata. In July or August, each of these "Ralston" plots was visited and examined for the presence of sunflower or corn fields in a 1.6-km^2 (1 mi^2; 640 acres) area placed in the center of each 3.2 x 3.2-km plot. If corn or sunflower fields were present within the described area, then field placement was recorded and the width of each field was measured. In late September, I estimated bird damage in all corn and sunflower fields in the 1.6-km^2 area placed in the center of each 3.2 x 3.2-km plot. Across all years, 53% of the 1.6-km^2 areas did not contain corn nor sunflower fields.

4.2. 2010 Field Season

The 2008 and 2009 field season methodology did not produce as many surveyed fields as needed for a robust damage estimate. To increase the sample size, the methodology was modified to produce a larger data set in 2010. In 2010, I estimated bird damage in all corn and sunflower fields in a 1.6-km^2 area placed in the center of each 3.2 x 3.2-km plot. In the event that no fields were located in this area, then I surveyed 4.8 km (3 mi) from the center in each cardinal direction for the presence of a sunflower or corn field. The first sunflower or corn field observed in this area was surveyed for damage from 20 - 30 September. This sampling methodology resulted in a large sample size. As in 2008 and 2009, I surveyed Ralston et al. (2007) sites for the presence of fields in July or August and collected damage estimates in late September.

4.3. Damage Estimate Collection

I divided each sampled field into two strata, each containing an equal number of rows. One row was randomly selected from each stratum. These rows served as transects for the study. In each transect, the first sample plot of five consecutive sunflower heads or corn ears was a randomly selected distance in meters between 0 m (i.e., the edge of the field) and 135 m. After establishing the first plot, I systematically sampled plots of five consecutive sunflower heads or corn ears every 135 m until reaching the end of the field. This sampling scheme typically provided at least six sample plots per transect. If an uncultivated area existed within the sampled row, I walked through as if it were a cultivated section. If the sunflower heads and corn ears were damaged by birds, I estimated the percentage of head or ear that had been damaged (Dolbeer, 1975). For undamaged heads and ears, I simply recorded 0% damage. The percent loss for each field was calculated by averaging the percent loss of all heads across both strata. The average damage in each field was used to calculate average percent losses within each physiographic stratum and across the strata. Damage was estimated in sunflower fields by using the template method because it was shown to produce less variation among observers (Dolbeer, 1975).

In 2008, damage in corn fields was estimated by measuring the length of the damaged ear and the length of the damaged area and then determining the percentage of damage for the measured ear. In 2009 and 2010, I calculated corn field damage by measuring the length and circumference of damaged ears as well as the length and width of the damaged area (Fig. 3). I then used these data to calculate the estimated percentage of damage for each ear.

Using the 'Ralston 120' wetland classification plots, ground surveys, and USDA crop and land cover data maps, I selected and mapped habitat variables (wetland, pasture, developed, wooded, sunflower, corn, beans, small grains, open water, other) within the study region (PPR of North Dakota) using Geographic Information Systems (GIS) software (ArcMap 9.3). Both open water and wetland habitats were selected as landcover variables due to the classification definition of open water used by National Land Cover Data (NLCD); "all areas of open water, generally with less than 25% cover of vegetation or soil (Wickham et al., 2010)." Open water according to this definition would provide limited blackbird nesting or roosting habitat. By incorporating both landcover types as separate independent variables, I attempt to limit any exaggeration of blackbird habitat in the study area.

Figure 3. Methods for measuring sunflower and corn damage in study fields. Sunflower damage was measured using the template method and corn damage was measured using length and width measurements. (Photos courtesy of Megan Klosterman)

4.4. Landscape Analysis

Using the GIS program (ArcMap 9.3), maps were created to visualize the damage across the study region and to show landcover within 4.8 km of each surveyed field. To accomplish this, I used landcover raster maps (56m x56m pixels) from the United States Department of Agriculture National Agricultural Statistics Service (USDA NASS).

I determined accuracy of these maps using the metadata provided by the USDA as well as using crosstab calculations (USDA 2008, 2009, 2010). To determine accuracy, the 2008 and 2009 landcover maps were brought into the GIS program and combined to produce a map showing regions that were similar across years. Data from this combined map were then exported to a Microsoft Access file where the data were arranged in a crosstab layout. These data were exported to Microsoft Excel in order to better manipulate the data.

I used Excel to determine producer's accuracy (omission error) and user's accuracy (commission error) of the landcover classification (Jenson, 2005). Overall accuracy and the coefficient of agreement were also determined from these data (Jenson, 2005). Once this analysis was accomplished, I reclassified the original landcover maps into the habitat variables determined for this study. These new, reclassified maps were then brought into a GIS document and combined to produce a new map showing similar regions across years. Again, I exported these data to Microsoft Access and Excel in order to perform the crosstab and accuracy calculations. This process was repeated using the 2009 and 2010 USDA NASS landcover maps to determine accuracy between these two years.

I exported the newly reclassified maps into the GIS program and layered data points showing the latitude and longitude of the center of each study site over the landcover raster. Using these maps, data sheets and county maps, I determined the latitude and longitude of each field surveyed. I determined the township, range, and section of each field from hand drawn maps of the field area on the data sheets compared to the field area on the county maps. The GIS maps were then viewed to determine if the landcover and field location in the township, range, and section area matched these other two map types. Next, I determined the latitude and longitude for the center of the field. This process was done for each field surveyed in 2008, 2009 and 2010. Data sheets were then formed for each year showing field location, crop type and average percent damage per field.

I exported these data into ArcMap to locate the exact points and surrounding landcover of each surveyed field. I then clipped and dissolved the PPR shapefile and added the image to the map.

Using the field layer data, I created a 4.8-km buffer around each field and clipped the landcover raster to the extent of the buffer (Fig 4). The buffer provided an area of landcover surrounding each field. I then recorded the total area of each landcover variable type for each clipped raster field buffer. These data were statistically analyzed in order to determine any relationship between landcover and crop damage from blackbirds.

4.5. Statistical Analysis

4.5.1. Significance of damage across strata and years

I used a nested design to analyze the data. I sorted the data using a block design in which strata were recorded within crop types and years were used as replications. For data recorded as 0% damage, the value was changed to 0.01% to perform these calculations. For strata that contained no fields for a given year, damage was recorded as N/A, and methods were used to find a single missing

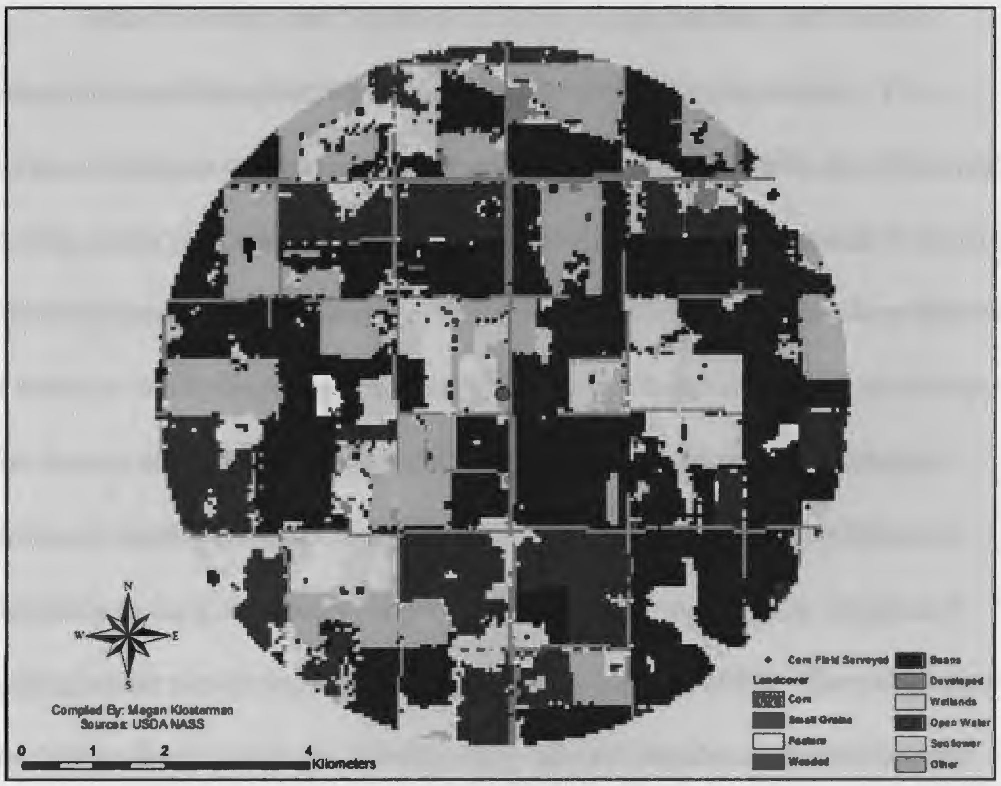

Figure 4. An example of one of the clipped raster buffers (4.8 km) surrounding the surveyed fields. These buffers were used to determine the significance of surrounding landcover types in reference to blackbird damage.

value for a block design following Snedecor and Cochran (1980). These new values were then used in significance calculations. I performed an arcsin transformation on the data, and then a two level nested PerMANOVA was completed to determine significance of the data. A PerMANOVA is an analysis of variance that utilizes permutations and allows the user to use any distance measurement that fits the data (Statistix 9., 2008).

Both Euclidean and Sorenson distance measurements were used to determine significance between crop types as well as between strata. The Sorenson distance measurement is a similarity coefficient that looks at the area of overlap under regression curves, whereas the Euclidean measurement is based on a linear measurement of distance (McCune and Grace, 2002). Euclidean distance is based on the Pythagorean Theorem ($a^2+b^2=c^2$), whereas Sorensen similarity, also known as the Bray-Curtis coefficient (BC), is based on a proportion or similarity coefficient (McCune and Grace, 2002). This means that Sorensen similarity looks at the area of similarity between two data sets, or the area of overlap under two or more curves (McCune and Grace, 2002). The calculation for this similarity would be represented by shared abundance divided by total abundance (McCune and Grace, 2002). Euclidean distance is used most often in block design experiments and is equivalent to an analysis of variance (AOV) measurement, although AOV measurements often use a Square Euclidean distance measurement. A Square Euclidean distance measurement is more susceptible to outliers and results in statistics that are comparable to permutation tests of Pearson Coorelation (McCune and Grace, 2002). Since block analyses are often based on a permutation distribution, there is no necessity for choosing a Square Euclidean distance measurement. Calculations were completed using PC-ORD 6 software.

4.5.2. Landcover analysis

I used the statistical program Statistix to interpret the landcover versus blackbird damage data. Using landcover within the clipped raster field buffers, I conducted a logistic step-wise regression to determine which independent variables were significantly related to the presence of damage. Damage data were entered into the system using a binomial configuration, with 1 representing damage in fields and 0 signifying damage free fields. The logistic regression looks at the relationship of independent variables to the presence of damage or a lack of damage in surveyed fields. The equation used in this regression is represented by $1/(1+e^{-(a+bx)})$ showing that negative coefficients mean an increase in damage and positive coefficients mean a decrease in damage (Statistix 9., 2008). Significance was represented by p-values measuring < 0.1. Corn and sunflower damage data were analyzed separately to establish significant independent variables for each crop type.

Akaike's Information Criterion (AIC) was also used to analyze the significance of the independent variables to blackbird damage across crop types. Only fields with damage were entered into the AIC analysis. The best model was chosen, based on Cp and AICc values, and a least squares regression was used to determine significance of the model variables.

The Mallows' Cp value shows the index of bias for the model in the case that an important independent variable may not have been included in the original analysis (Statistix 9., 2008). The Cp value should be ≤ the number of parameters in the model. A lower Δ AICc value signifies support of the model (0-2: substantial, 4-7: considerably less, >10: essentially none) (Statistix 9., 2008). The model that fit both of these criteria was selected to determine significance of the selected variables using the least squares regression. This regression is represented by the equation Y=a+b1*X1+b2*X2, showing that positive coefficients represent an increase in damage and negative coefficients represent a decrease in damage (Statistix 9., 2008).

5. RESULTS

5.1. Blackbird Damage Estimates

In 2008, I surveyed 38 cornfields and 14 sunflower fields for blackbird damage. The majority of corn was planted in the southeast (Southeastern Drift Plains [SDP]) and most of the sunflower was planted in the northern region (Northeast and Northwest Drift Plains [NEDP, NWDP]), respectively (Fig. 5). In 2009, I surveyed 30 cornfields and 15 sunflower fields, with the distribution of corn and sunflower fields following the same regional trend as in 2008 (Fig. 6). In 2010, the number of fields surveyed was nearly doubled using the expanded sample scheme. I surveyed 65 cornfields and 23 sunflower fields, with field location again following the same regional trend as the previous two years (Fig. 7). I compared damage across years using only the fields within the 1.6-km^2 sample plots (Fig. 8, Table 2). I also conducted a separate analysis of the entire data set for 2010. Damage estimates were calculated for each stratum within the PPR (Fig. 9, 10, 11, 12, 13, 14 and 15). Of all sunflower fields surveyed within the 1.6-km^2 sample plots, 9.7% received >10% damage. Sunflower fields near the SDP tended to have higher damage estimates than those located in the northern Drift Plains (Table 3).

The cost of damage in 2008, based on overall production value in the state, was $US 7.3 million (SE: ± $US 2.8 million) for corn and $US 3 million (SE: ± $US 2.3 million) for sunflower (Fig. 16, Table 4). In 2009, the cost was

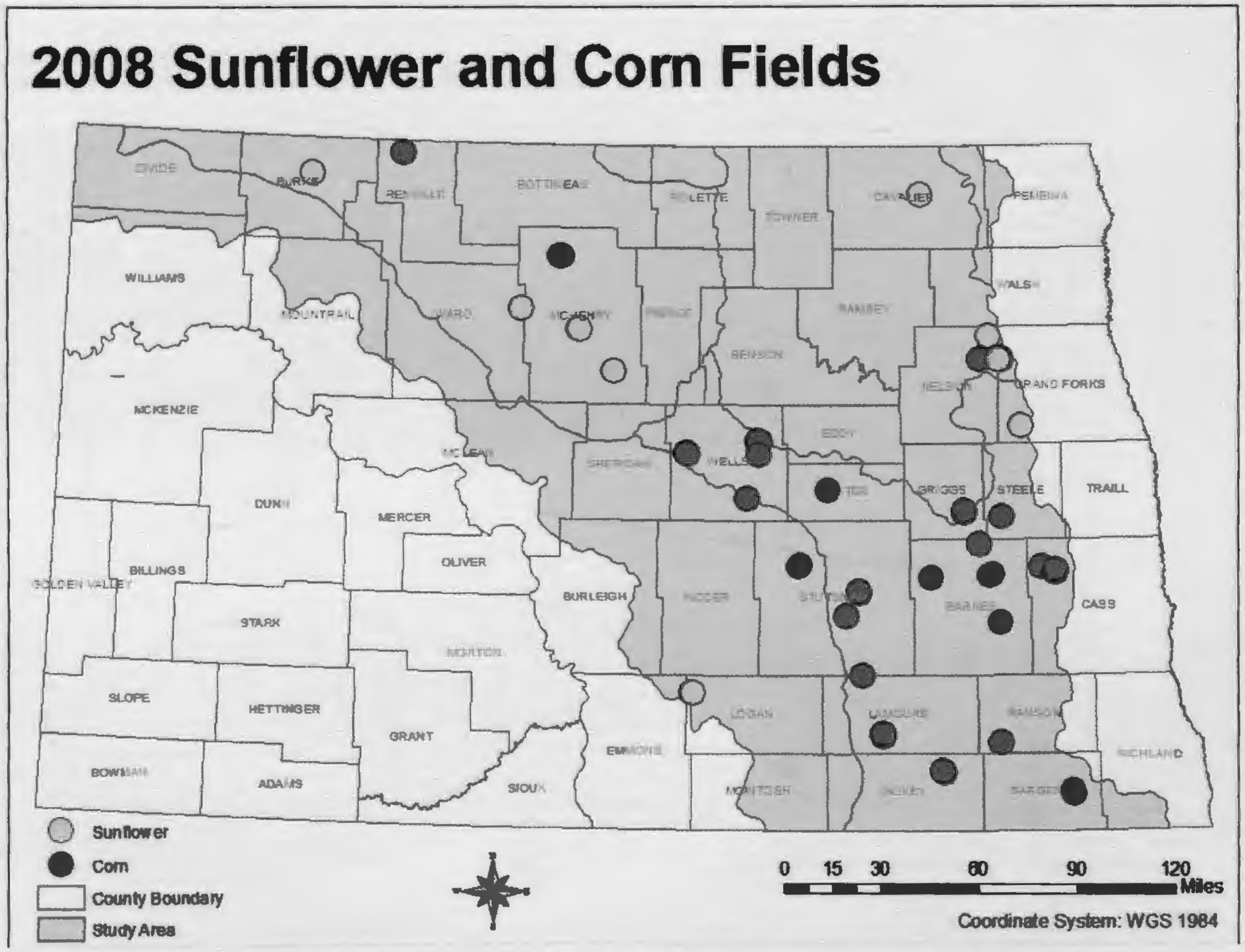

Figure 5. Field locations (corn: n=38, sunflower: n=14) for 2008 study fields in the Prairie Pothole Region of North Dakota.

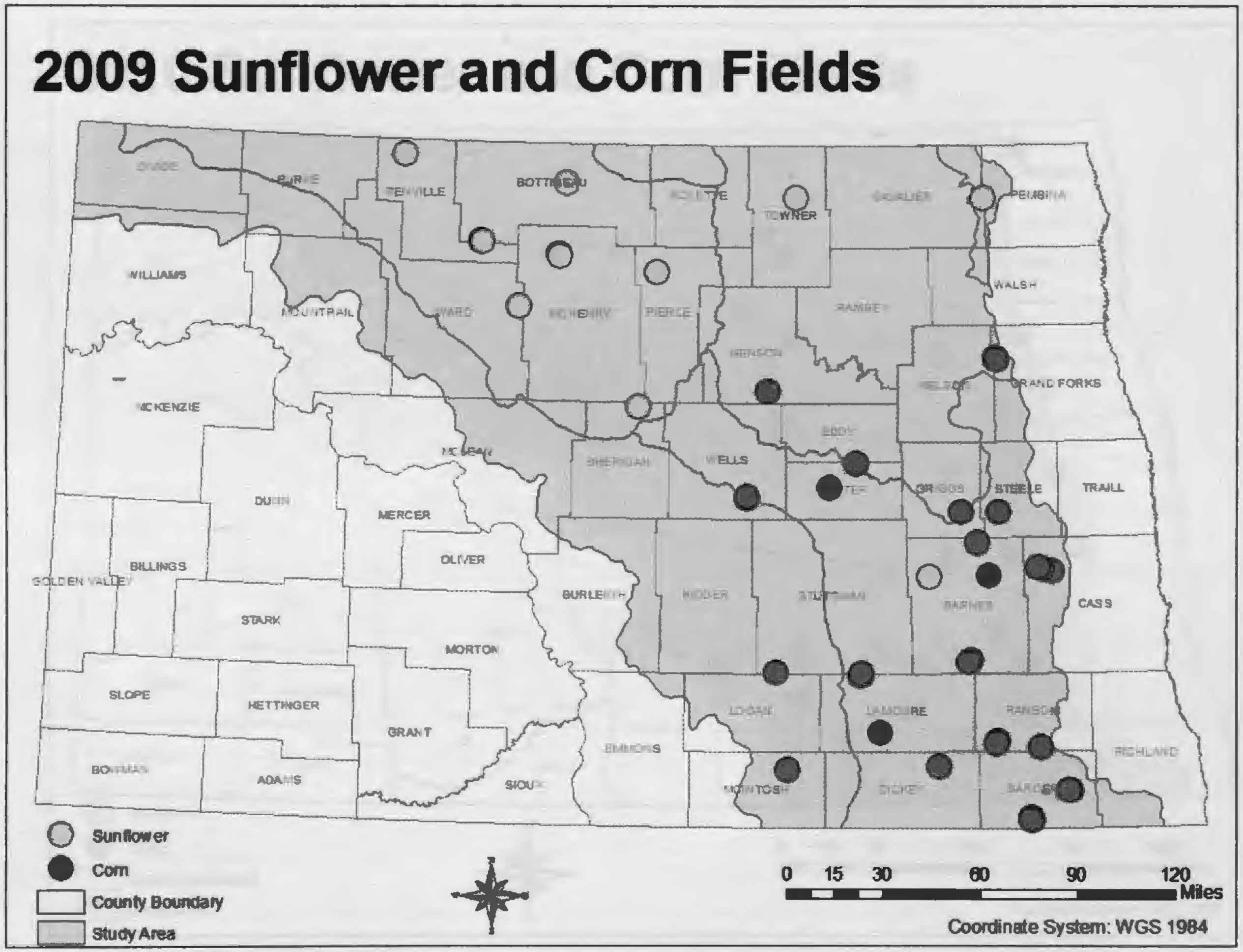

Figure 6. Field locations (corn: n=30, sunflower: n=15) for 2009 study fields in the Prairie Pothole Region of North Dakota.

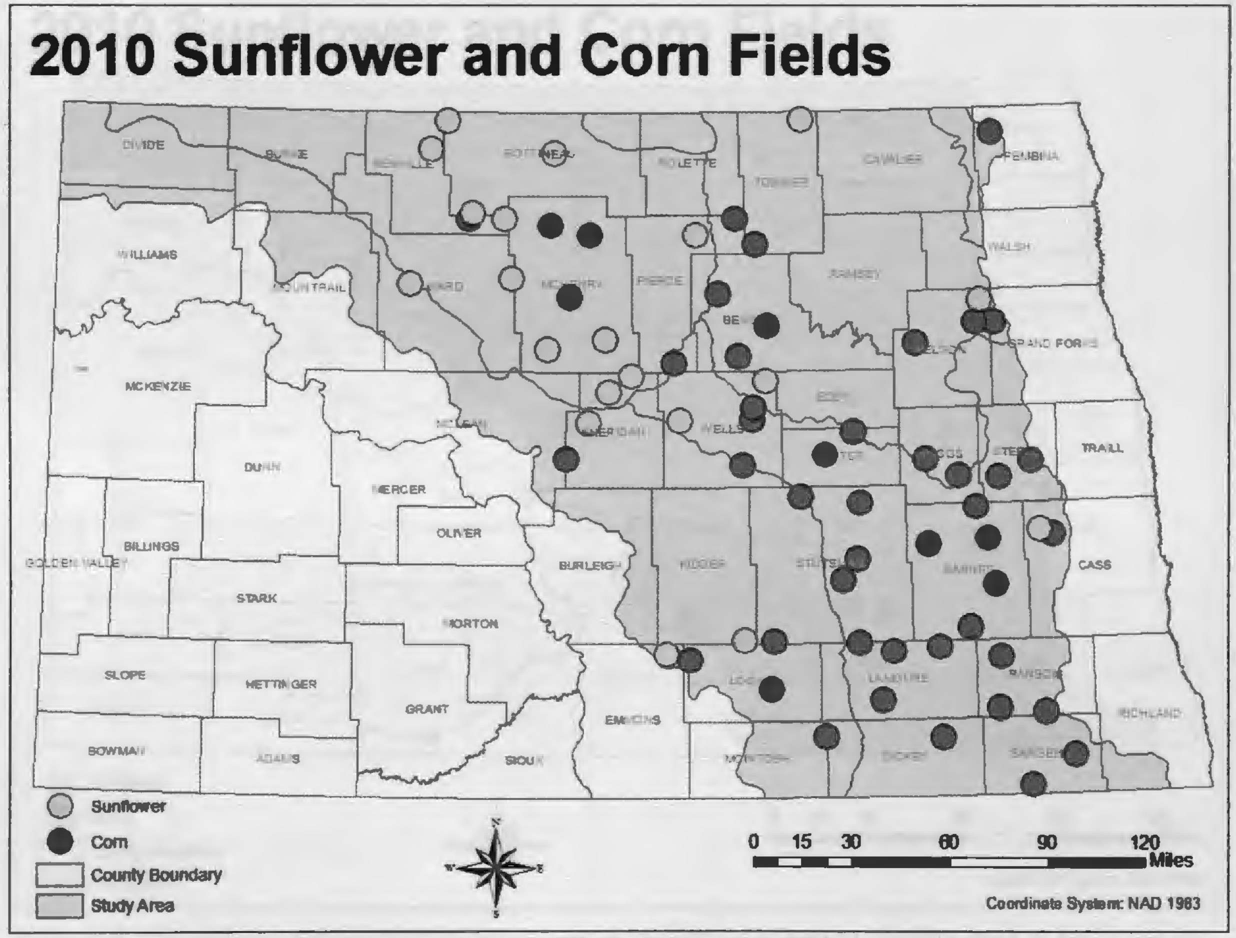

Figure 7. Field locations (corn: n=65, sunflower: n=23) for 2010 study fields in the Prairie Pothole Region of North Dakota.

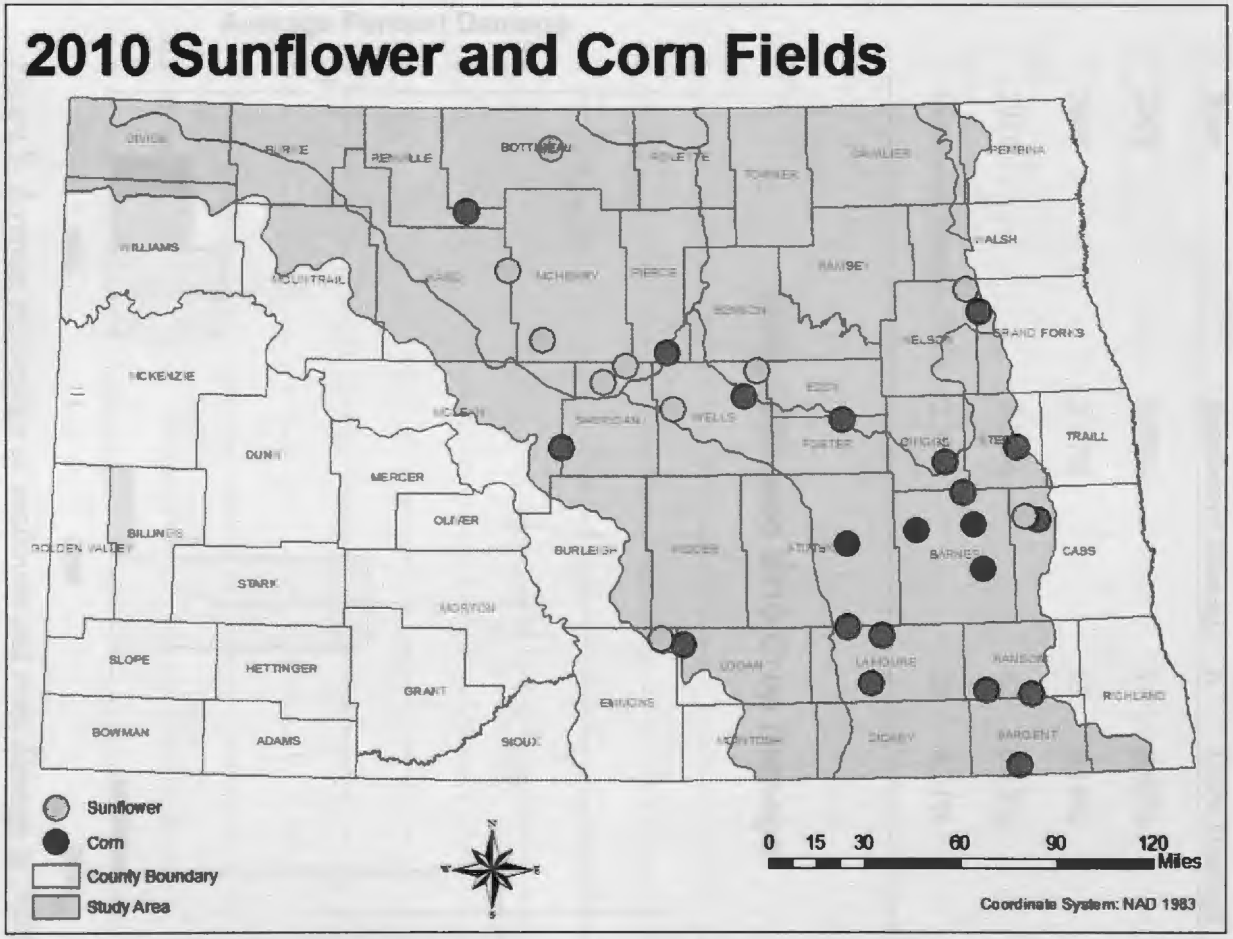

Figure 8. Locations of study fields (corn: n=38, sunflower: n=12), within the1.6-km^2 sample plot, within the Prairie Pothole Region of North Dakota in 2010. Sample size was augmented to improve the variance associated with damage estimates.

Table 2. Average percent of sunflower and corn damage for each year within the study period (15 Sept.-20 Oct.).

Year	Sunflower Damage	n	Corn Damage	n
2008	0.95%	14	0.69%	38
2009	2.17%	15	0.18%	30
2010	3.29%	12	0.13%	38
Expanded Sample 2010	2.32%	23	0.21%	65

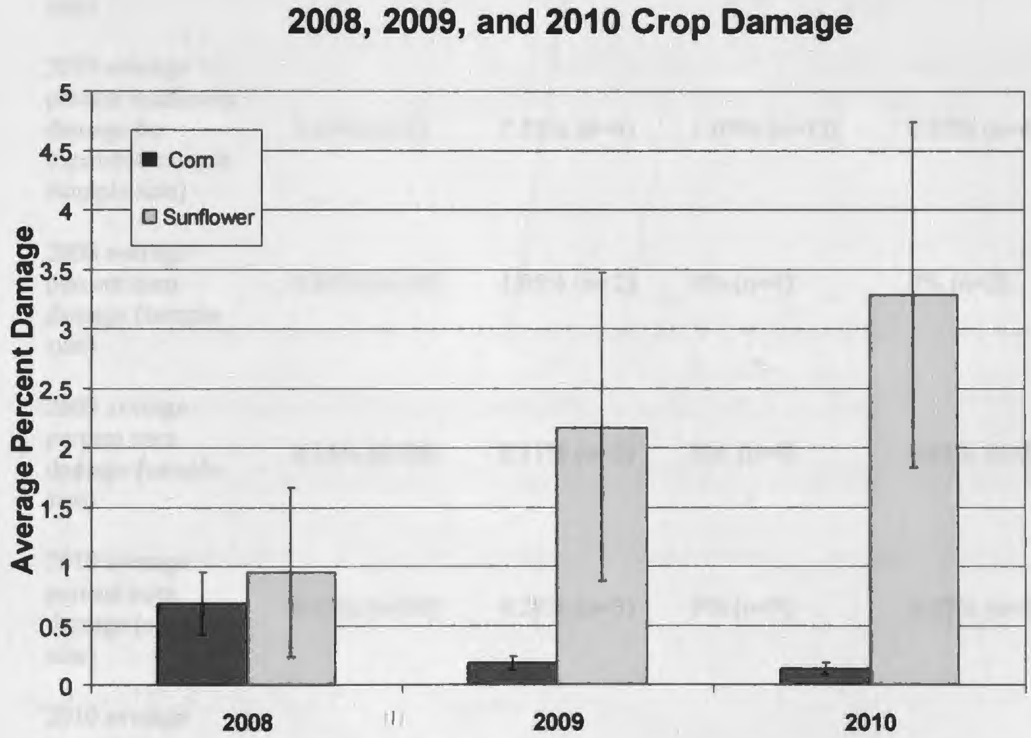

Figure 9. Average percentage of sunflower and corn damage in 2008, 2009 and 2010. Lines represent standard error for each crop per year.

Table 3. Average percent damage for sunflower and corn across four strata of the Prairie Pothole Region of North Dakota from 2008 to 2010.

	SDP	NEDP	NWDP	MC
2008 average percent sunflower damage (sample size)	10.16% (n=1)	0% (n=6)	0.38% (n=5)	0.64% (n=2)
2009 average percent sunflower damage (sample size)	19.79% (n=1)	1.52% (n=3)	0.75% (n=11)	NA (n=0)
2010 average percent sunflower damage (sample size)	3.38% (n=2)	9.59% (n=3)	0.65% (n=6)	0% (n=1)
2010 average percent sunflower damage for expanded sample (sample size)	3.38% (n=2)	7.53% (n=4)	1.09% (n=13)	0.57% (n=4)
2008 average percent corn damage (sample size)	0.80% (n=30)	1.05% (n=2)	0% (n=4)	0% (n=2)
2009 average percent corn damage (sample size)	0.14% (n=26)	0.11% (n=2)	NA (n=0)	0.81% (n=2)
2010 average percent corn damage (sample size)	0.13% (n=30)	0.28% (n=3)	0% (n=3)	0.07% (n=2)
2010 average percent corn damage for expanded sample (sample size)	0.12% (n=42)	0.59% (n=11)	0.09% (n=6)	0.31% (n=6)

Strata labeled as SDP= Southern Drift Plains, NEDP= Northeast Drift Plains, NWDP=Northwest Drift Plains, MC=Missouri Coteau.

Table 4. Cost of blackbird damage in the Prairie Pothole Region of North Dakota across crop types for each year of the study (15 Sept.- 20 Oct.) with standard error.

Year	**Cost of Sunflower Damage (Million)**	**Cost of Corn Damage (Million)**
2008	$US 3 (± 2.3)	$US 7.3 (± 2.8)
2009	$US 4 (± 2.6)	$US 1.25 (± 0.38)
2010	$US 8.9 (± 3.9)	$US 1.7 (± 0.66)
Expanded sample 2010	$US 6.3 (± 2.2)	$US 2.8 (± 0.8)
Average across years	$US 5.4 (± 1.8)	$US 3.4 (± 1.8)

Cost of damage is based on the total value of production for each crop type and each year in North Dakota in comparison to the average percent damage for each category.

$US 1.25 million (SE: ± $US 382 thousand) and $US 4 million (SE: ± $US 2.6 million) for corn and sunflower, respectively. In 2010, the cost was $US 1.7 million (SE: ± $US 664 thousand) for corn and $US 8.9 million (SE: ± $US 3.9 million) for sunflower. Using the expanded sample scheme, the cost of corn damage totaled $US 2.8 million (SE: ± $US 797 thousand) and sunflower damage totaled $US 6.3 million (SE: ± $US 2.2 million).

Overall average damage, across all years, totaled 0.33% (n=106, SE: ± 0.18) for corn and 2.14% (n=41, SE: ± 0.67) for sunflower (Tables 5, 6 and 7). The average overall cost of corn damage was $US 3.4 million. Sunflower damage

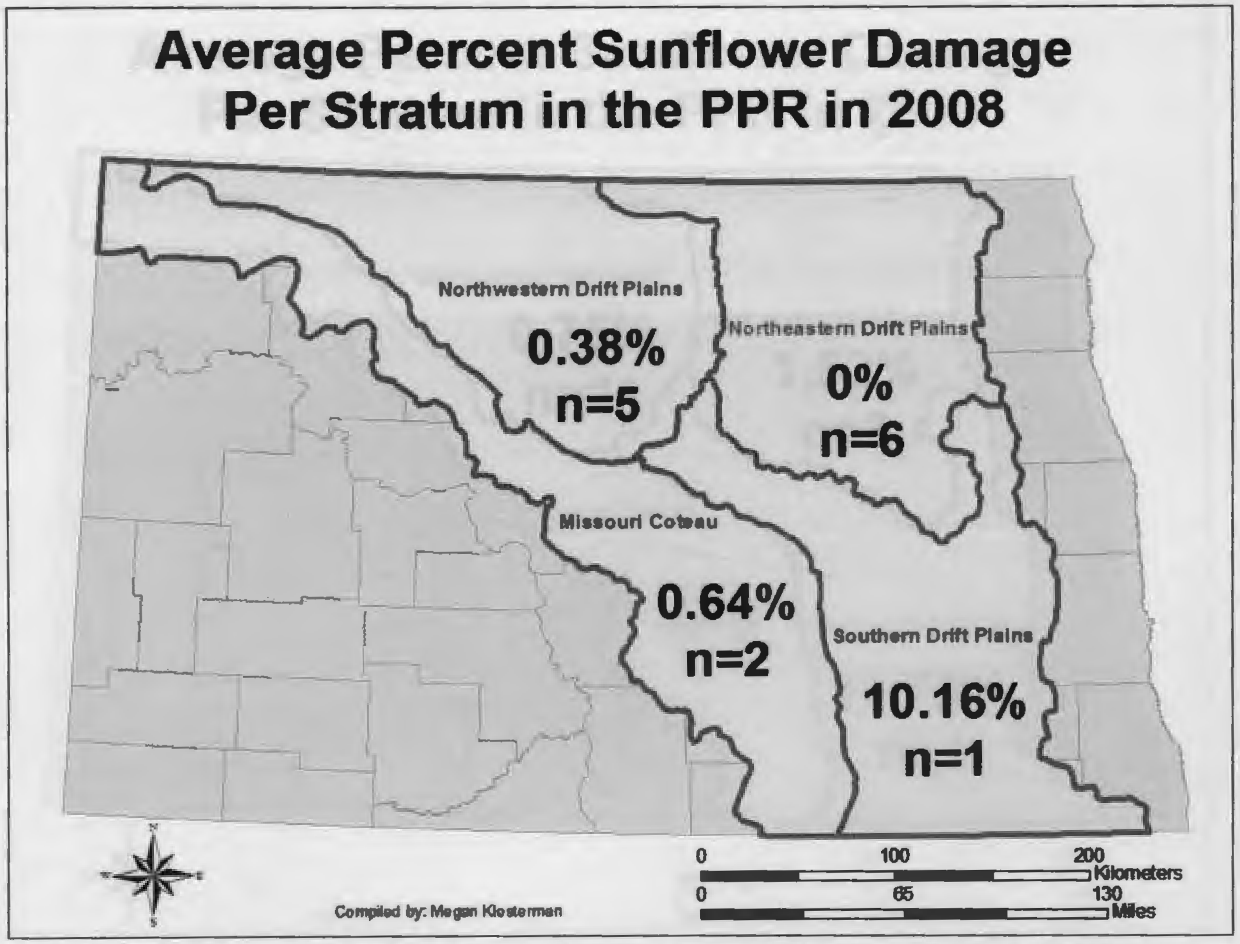

Figure 10. Average percent of sunflower damage across strata within the Prairie Pothole Region of North Dakota in 2008. Percentages based on only fields surveyed within each stratum for the year.

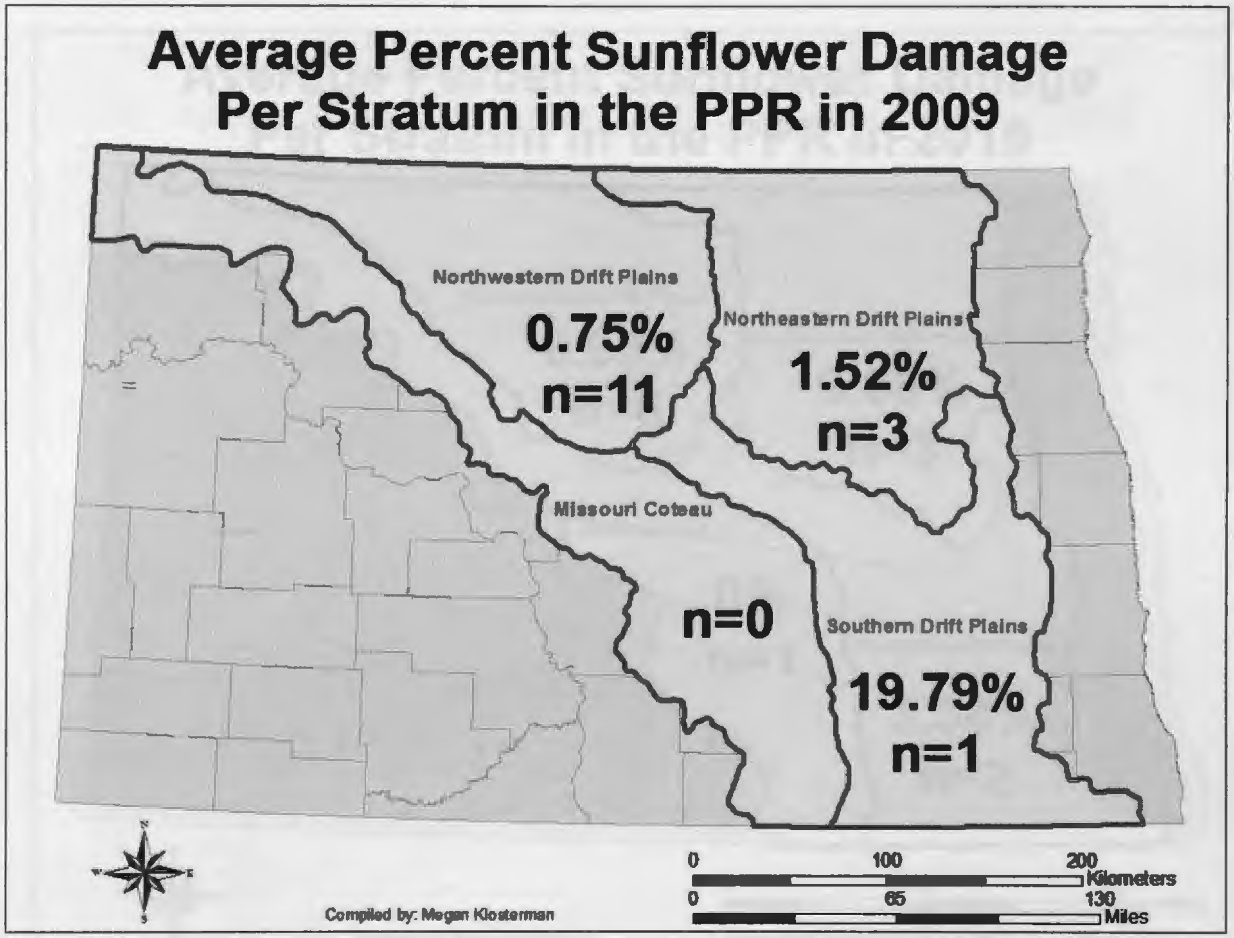

Figure 11. Average percent of sunflower damage across strata within the Prairie Pothole Region of North Dakota in 2009. Percentages based on only fields surveyed within each stratum for the year.

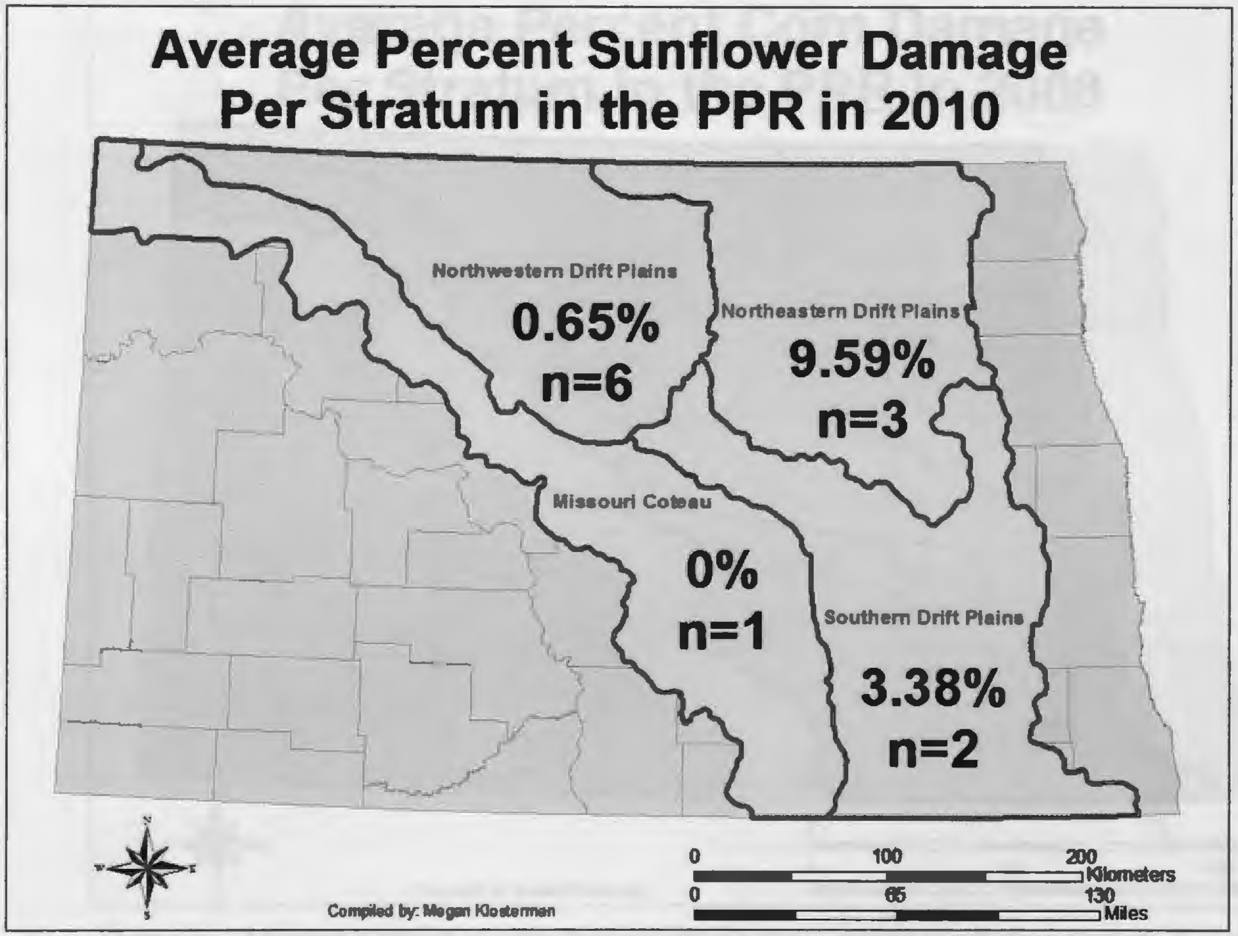

Figure 12. Average percent of sunflower damage across strata, within the 1.6-km^2 sample plots, within the Prairie Pothole Region of North Dakota in 2010.

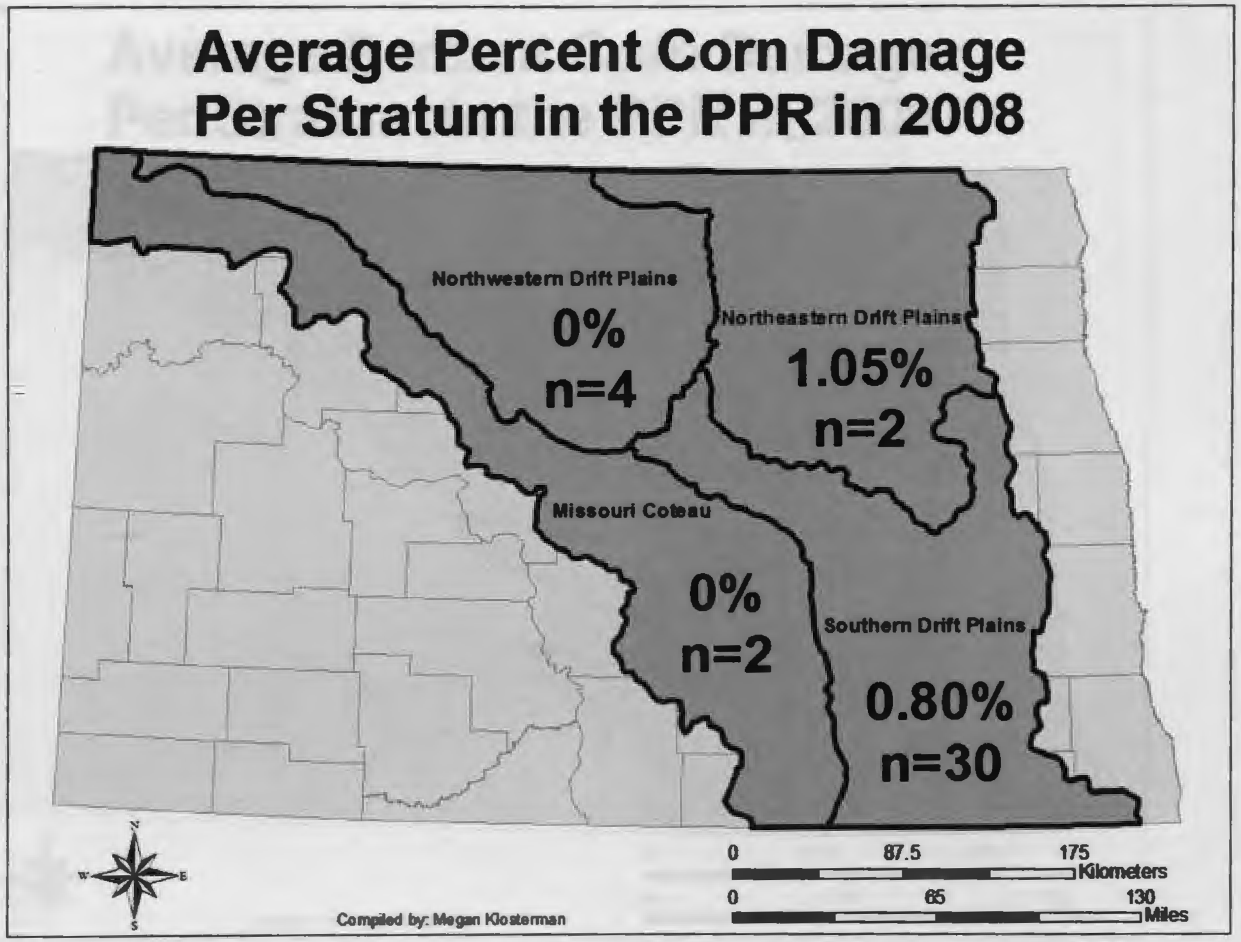

Figure 13. Average percent of corn damage across strata within the Prairie Pothole Region of North Dakota in 2008. Percentages based on only fields surveyed within each stratum for the year.

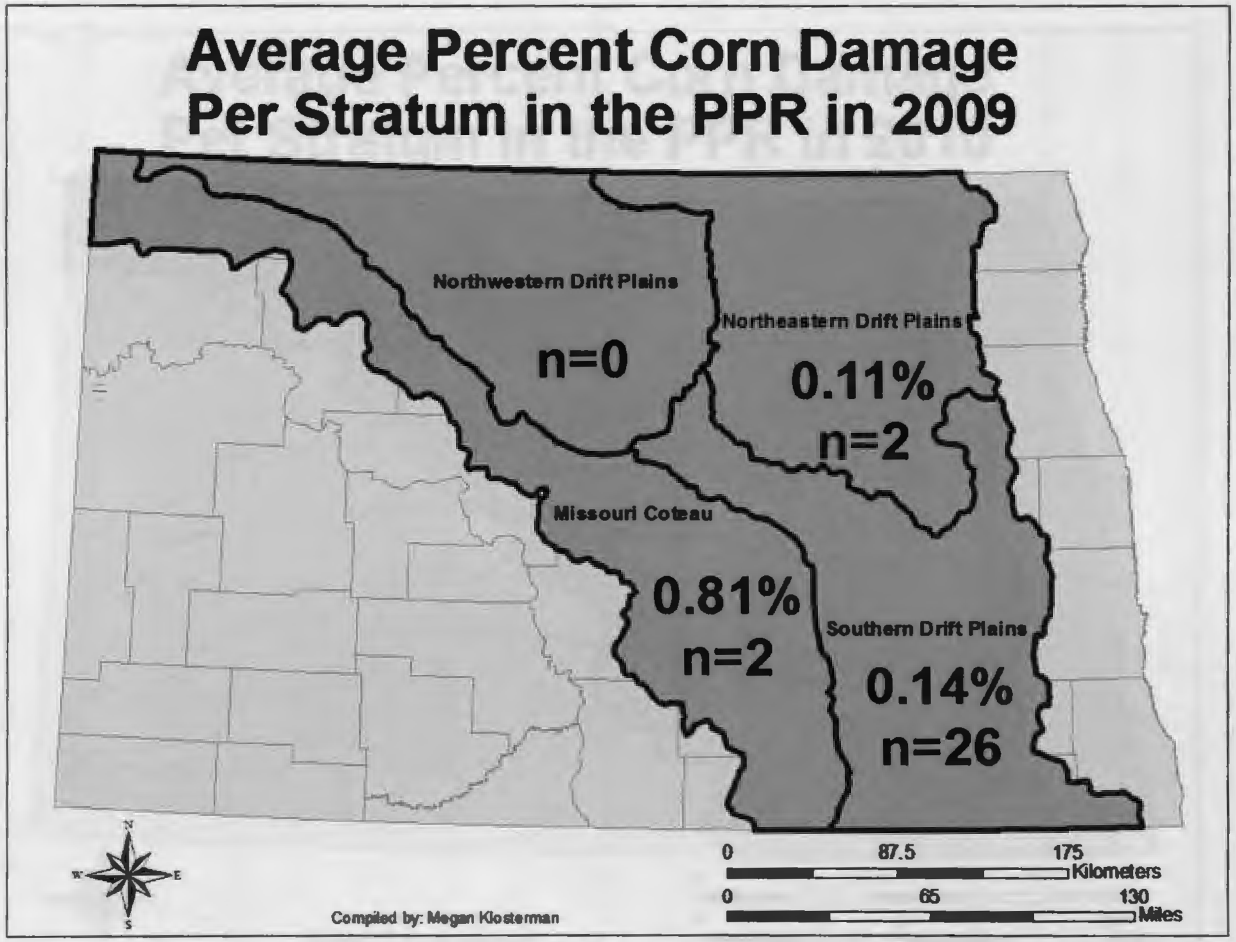

Figure 14. Average percent of corn damage across strata within the Prairie Pothole Region of North Dakota in 2009. Percentages based on only fields surveyed within each stratum for the year.

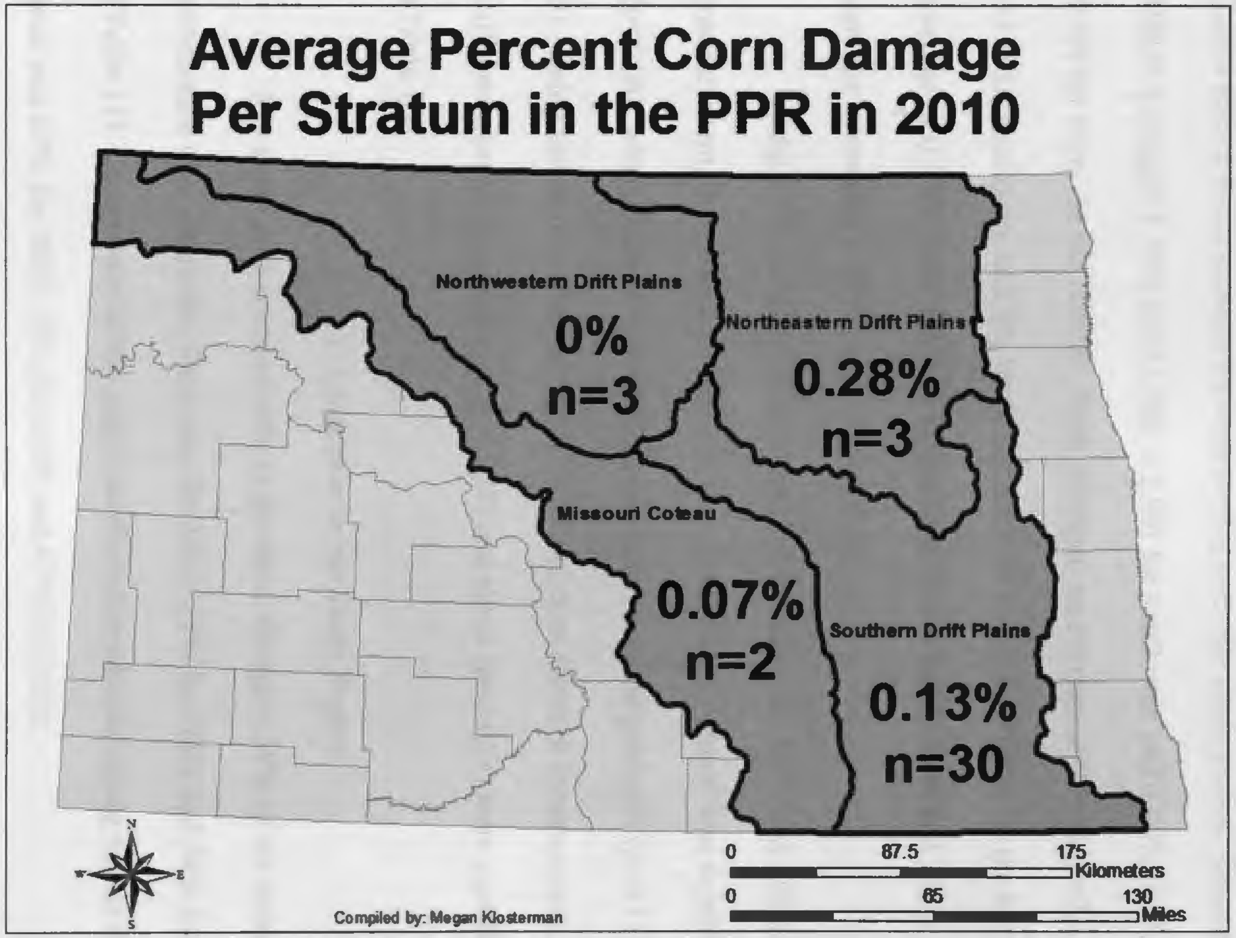

Figure 15. Average percent of sunflower damage across strata, within the 1.6-km^2 sample plots, within the Praire Pothole Region of North Dakota in 2010.

totaled $US 5.4 million, on average, across 2008, 2009 and 2010. Growers in the SDP lost an estimated 11.11% (SE: ± 4.76) damage in sunflower fields (n=4) and 0.36% (SE: ± 0.22) damage for corn (n=86) over the study period. Damage in the NEDP averaged 3.70% (n=12, SE: ± 2.98) for sunflower and 0.48% (n=7, SE: ± 0.29) for corn. In the NWDP, birds damaged an average of 0.59% (n=22, SE: ± 0.11) for sunflower and 0% (n=7, SE: ± 0) for corn. Sunflower in the MC had an average of 0.32% (n=3, SE: ± 0.32) damage across 2008, 2009 and 2010, with corn damage averaging 0.29% (n=6, SE: ± 0.26).

Using strata nested within crops (Table 8) and the Sorenson distance measurement, the difference between damage for each stratum was significant (p=0.04), whereas the difference between crops was insignificant (p=0.112) (Table 9). Using the same nested design with a Euclidian distance measurement, the difference between crop types (p=0.028) and strata (p=0.058) were significant (Table 10).

5.2. Landcover in the Study Region

My study area covered 46% of the state. Roughly 59% of the state's corn production was within the study area for 2008, 53% for 2009 and 54% for 2010 (Table 11). The percent of the state's sunflower production lying within the study area was 63% for 2008, 58% for 2009 and 47% for 2010.

Crosstab calculations showed varying accuracy between landcover types in the raster data provided by USDA NASS. Crop cover accuracy was provided

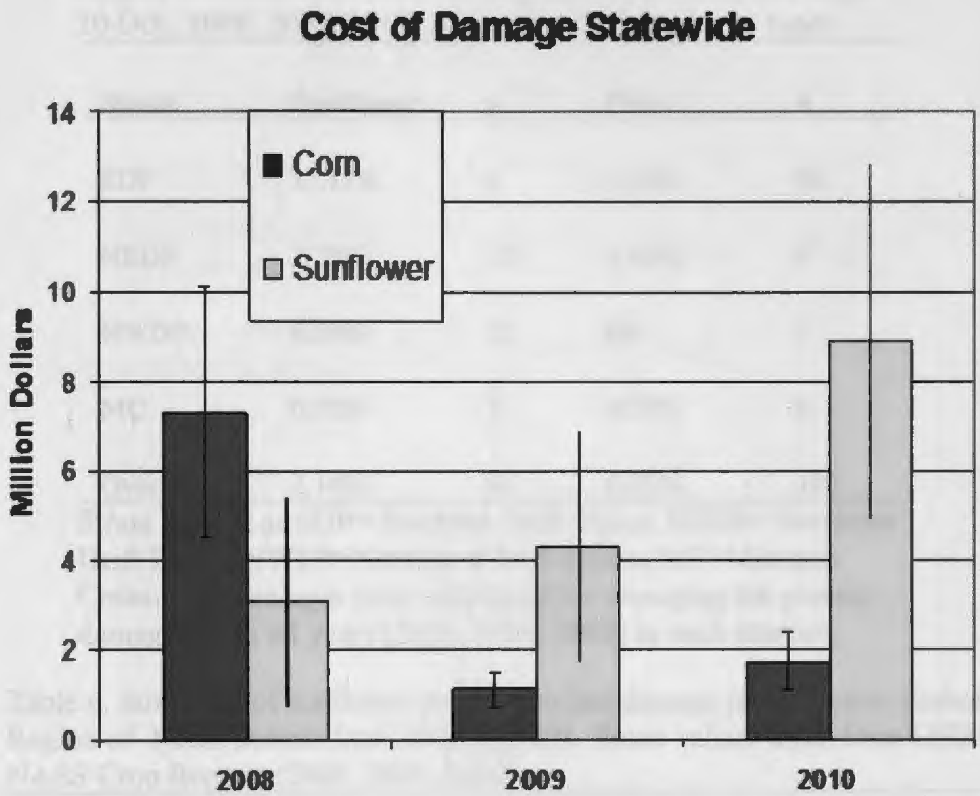

Figure 16. Estimate of economic losses associated with blackbird damage to sunflower and corn crops, in the Prairie Pothole Region of North Dakota, for 2008 and 2009. Lines represent standard error for each crop per year.

in the metadata. Crop cover accuracy in 2008 was recorded at 83.85% (error: 16.15%), 2009 accuracy was 82.70% (error: 17.30%) and 2010 was 80.50% (error: 19.50%) (USDA NASS, 2009, 2010, 2011). Non-agricultural landcover (open water, developed, wooded, wetlands) user's accuracy and producer's accuracy were calculated at 61.64% and 57.94%, respectively (commission error: 38.36%,

Table 5. Overall average percent damage in the Prairie Pothole Region of North Dakota across all years of the study (15 Sept.-20 Oct., 2008, 2009, 2010) and across strata and crop types.

Strata	**Sunflower**	**n**	**Corn**	**n**
SDP	11.11%	4	0.36%	86
NEDP	3.70%	12	0.48%	7
NWDP	0.59%	22	0%	7
MC	0.32%	3	0.29%	6
Overall	2.14%	41	0.33%	106

Strata labeled as SDP= Southern Drift Plains, NEDP= Northeast Drift Plains, NWDP=Northwest Drift Plains, MC=Missouri Coteau. Percentages were calculated by averaging the percent damages from all years (2008, 2009, 2010) in each stratum.

Table 6. Summary of sunflower production and damage in the Prairie Pothole Region of North Dakota from 2008 to 2010. Some values taken from USDA NASS Crop Reports (2008, 2009, 2010).

Category	**2008**	**2009**	**2010**
Sunflower (ha) in study area	517,558	181,846	144,394
Total production in North Dakota (lbs. 10^6)	1511.40	1317.20	1254.98
Total value of harvested sunflower in North Dakota ($US, 10^6)	324.55	197.88	270.80
No. of fields surveyed	14	15	12
Average (%) damage	0.95%	2.17%	3.29%
Average value of bird damage ($US, 10^6)	3.1	4.3	8.9

Table 7. Summary of corn production and damage in the Prairie Pothole Region of North Dakota across years. Some values taken from USDA NASS Crop Reports (2009, 2010, 2011).

Category	**2008**	**2009**	**2010**
Corn (ha) in study area	517,558	437,791	398,757
Total production in North Dakota (bushels, 10^6)	285.20	200.10	248.16
Total value of harvested corn in North Dakota ($US, 10^6)	1066.65	636.32	1327.66
No. of fields surveyed	38	30	38
Average (%) damage	0.69%	0.18%	0.13%
Average value of bird damage ($US, 10^6)	7.3	1.2	1.7

omission error: 42.06%) across 2008 and 2009 from the crosstab calculations (Table 12, Fig. 17). Crosstab calculations, comparing 2009 and 2010 raster data (Table 13, Fig. 18) maps, showed user's and producer's accuracies for non-agricultural landcover (open water, developed, wooded, wetlands) to measure 52.94% and 60.69%, respectively (commission error: 47.06%, omission error: 39.31%).

5.3. Landcover Analysis

5.3.1. Sunflower field analysis

The logistic stepwise regression showed both developed land (p=0.051) and open water (p=0.049) were significant variables, with open water showing slightly greater significance than developed land. Both variables produced

Table 8. Data used for perMANOVA, using a block design, to determine significance of damage data across four strata nested within two crop types. All zero values were converted to 0.01%, and missing values were found using methodology provided by Snedecor and Cochran (1980).

Plot	Damage	Crop	Stratum	Year
PC108	0.0080	1	1	2008
PC109	0.0014	1	1	2009
PC110	0.0013	1	1	2010
PS108	0.1016	2	1	2008
PS109	0.1979	2	1	2009
PS110	0.0338	2	1	2010
PC208	0.0105	1	2	2008
PC209	0.0011	1	2	2009
PC210	0.0028	1	2	2010
PS208	0.0001	2	2	2008
PS209	0.0152	2	2	2009
PS210	0.0959	2	2	2010
PC308	0.0001	1	3	2008
PC309	0.0001	1	3	2009
PC310	0.0001	1	3	2010
PS308	0.0038	2	3	2008
PS309	0.0075	2	3	2009

Table 8. (Continued)

Plot	Damage	Crop	Stratum	Year
PS310	0.0065	2	3	2010
PC408	0.0001	1	4	2008
PC409	0.0081	1	4	2009
PC410	0.0007	1	4	2010
PS408	0.0064	2	4	2008
PS409	0.0364	2	4	2009
PS410	0.0001	2	4	2010

Table 9. Significance of damage data using a PerMANOVA, two-level nested design (replicates within strata, within crops), with a Sorensen (Bray-Curtis) measurement of distance.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F	p
Crop	1	0.92	0.92	2.08	0.112
Strata	6	2.66	0.44	2.05	0.040
Residual	16	3.46	0.22		
Total	23	7.05			

Table 10. Analysis of damage data using a PerMANOVA, two-level nested design (replicates within strata within crops), with a Euclidian measurement of distance.

Source	**Degrees of Freedom**	**Sum of Squares**	**Mean Square**	**F**	**P**
Crop	1	0.38E-02	0.38E-02	2.68	0.028
Strata	6	0.84E-02	0.14E-02	2.77	0.058
Residual	16	0.81E-02	0.51E-03		
Total	23	0.20E-01			

negative stepwise model coefficients indicating that developed land (-0.00881) and open water (-0.00491) were related to the presence of damage in sunflower fields (Table 14). Negative coefficients represent a relationship to the presence of damage in logistic regressions due to the binomial configuration of the analysis ($1/(1+e^{-(a+bx)})$ (Statistix 9., 2008).

The best possible AIC model contained the variables bean, wetland, and wooded (AICc-Min AICc =0.57 Cp=2.8, R^2=0.4397). Regression analysis of this model showed wooded areas was insignificant (p=0.177), whereas beans and wetland had significant p-values of 0.000 and 0.035, respectively. Coefficients for these variables measured -2.490E-05, 3.332E-05 and 4.937E-05 for wooded, beans and wetland, respectively (Table 15). This model shows that beans and wetland are related to greater levels of damage due to a positive coefficient, and wooded land is related to less damage due to a negative coefficient.

Table 11. Stratification of the Prairie Pothole Region of North Dakota, crop cover distribution among strata,and sample field allocation within each stratum.

Category	Prairie Pothole Region of ND	Northeast Drift Plains	Northwest Drift Plains	Southern Drift Plains	Missouri Coteau
Area (km^2)	95,171	21,927	21,740	25,361	26,143
Area (ha)	9,517,100	2,192,700	2,174,000	2,536,100	2,614,300
Percent of North Dakota PPR	100%	23.1%	22.80%	26.60%	27.50%
Percent of Corn Crop of North Dakota PPR 2008 (area in ha)	100% (517,557)	12.86% (66,551)	4.73% (24,505)	72.12% (373,282)	10.28% (53,219)
% of Sunflower Crop of North Dakota PPR 2008 (area in ha)	100% (242,193)	17.41% (42,172)	52.68% (127,579)	13.19% (31,944)	16.72% (40,498)
% of Corn Crop of North Dakota PPR 2009 (area in ha)	100% (437,791)	16.23% (71,041)	4.79% (20,963)	67.48% (295,429)	11.50% (50,358)
% of Sunflower Crop of North Dakota PPR 2009 (area in ha)	100% (181,845)	12.04% (21,888)	59.90% (108,931)	11.16% (20,302)	16.90% (30,724)

Table 11. (Continued)

Category	Prairie Pothole Region of ND	Northeast Drift Plains	Northwest Drift Plains	Southern Drift Plains	Missouri Coteau
Percent of Corn Crop 2010 (area in ha)	100% (398,756)	12.76% (50,882)	5.77% (22,993)	69.78% (278,257)	11.69% (46,624)
Percent of Sunflower Crop 2010 (area in ha)	100% (144,393)	7.39% (10,674)	56.70% (81,875)	11.03% (15,926)	24.88% (35,918)
Sample Corn Fields 2008	38	2	4	30	2
Sample Sunflower Fields 2008	14	6	5	1	2
Sample Corn Fields 2009	30	2	0	26	2
Sample Sunflower Fields 2009	15	3	11	1	0
Sample Corn Fields 2010	38	3	3	30	2
Sample Sunflower Fields 2010	12	3	6	2	1

Table 12. Crosstab calculation results, comparing 2008 and 2009 USDA NASS landcover raster data maps.

Landcover Variables	**Commission Error**	**User's Accuracy**	**Omission Error**	**Producer's Accuracy**
Corn	0.84	0.16	0.83	0.17
Small Grains	0.56	0.44	0.55	0.45
Pasture	0.16	0.84	0.15	0.85
Wooded	0.42	0.58	0.41	0.59
Beans	0.76	0.24	0.77	0.23
Developed	0.36	0.64	0.35	0.65
Wetlands	0.58	0.42	0.66	0.34
Open Water	0.20	0.80	0.24	0.76
Sunflowers	0.99	0.01	0.99	0.01
Other	0.25	0.75	0.26	0.74
Overall Accuracy	0.62			
Sum (xi+ * x+i)	9.36E+14			
Khat Coefficient of Agreement	0.52			

Categories: Corn includes corn; Small Grains includes barley, durum wheat, spring wheat, winter wheat, other grains, rye, oats and millet; Pasture includes alfalfa, clover/wildflower, grassland herbaceous, pasture/hay, shrubland and other hay; Wooded includes mixed forest, woodland, evergreen forest and deciduous forest; Bean includes soybeans, dry beans and lentils; Developed includes developed/open space, developed/low intensity, developed/medium intensity and developed/high intensity; Wetlands include wetlands, woody wetlands and herbaceous wetlands; Open Water includes open water; Sunflowers include sunflowers; Other includes all other categories listed in the raster data for each year.

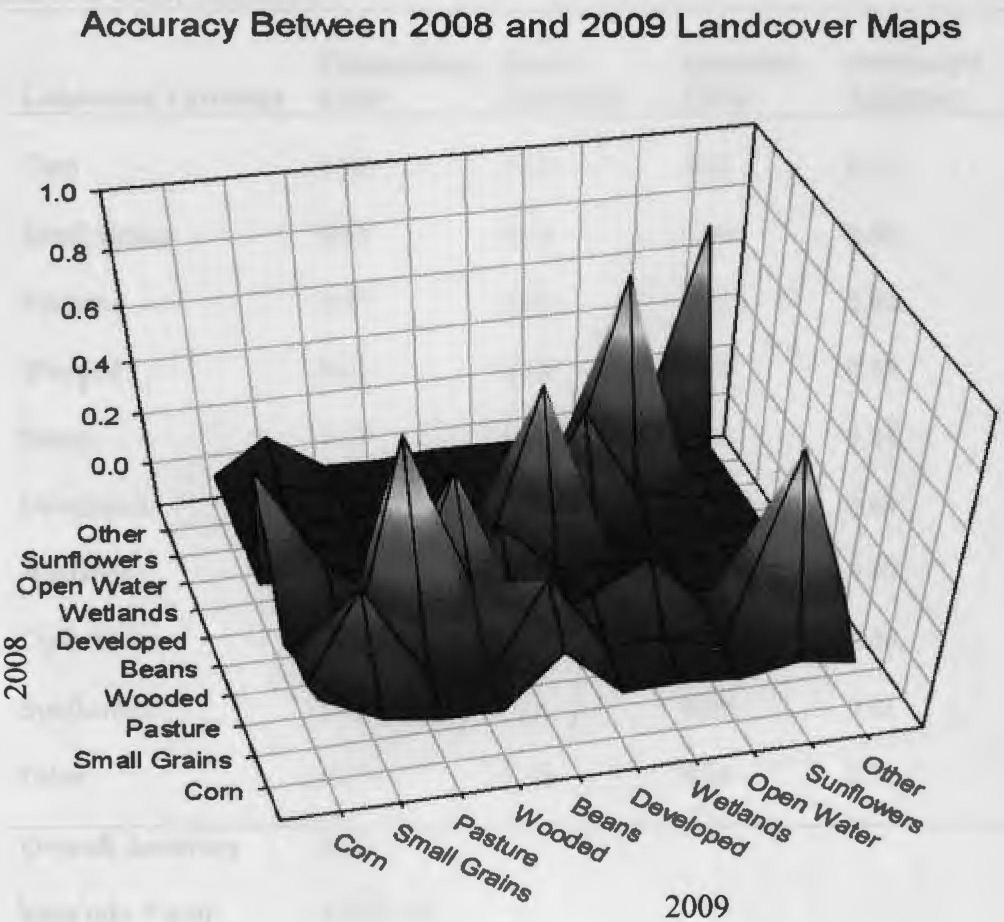

Figure 17. Landcover map accuracy using Sigmaplot software.

5.3.2. Corn field analysis

Using a backward logistic stepwise regression, significant variables were beans (p=0.012), pasture (p=0.008) and wetlands (p <0.001). All selected variables had positive coefficients (beans=0.001, pasture=9.31E-04, wetlands=0.004),

Table 13. Crosstab calculation results, comparing 2009 and 2010 USDA NASS landcover raster data maps.

Landcover Variables	Commission Error	User's Accuracy	Omission Error	Producer's Accuracy
Corn	0.90	0.10	0.89	0.11
Small Grains	0.63	0.38	0.60	0.40
Pasture	0.15	0.85	0.18	0.82
Wooded	0.41	0.59	0.41	0.59
Beans	0.73	0.27	0.76	0.24
Developed	0.54	0.46	0.36	0.64
Wetlands	0.64	0.36	0.60	0.40
Open Water	0.21	0.79	0.20	0.80
Sunflowers	0.99	0.01	0.99	0.01
Other	0.25	0.75	0.30	0.70
Overall Accuracy	0.61			
Sum (xi+ * x+i)	9.50E+14			
Khat Coefficient of Agreement	0.49			

Categories: Corn includes corn; Small Grains includes barley, durum wheat, spring wheat, winter wheat, other grains, rye, oats and millet; Pasture includes alfalfa, clover/wildflower, grassland herbaceous, pasture/hay, shrubland and other hay; Wooded includes mixed forest, woodland, evergreen forest and deciduous forest; Bean includes soybeans, dry beans and lentils; Developed includes developed/open space, developed/low intensity, developed/medium intensity and developed/high intensity; Wetlands include wetlands, woody wetlands and herbaceous wetlands; Open Water includes open water; Sunflowers include sunflowers; Other includes all other categories listed in the raster data for each year.

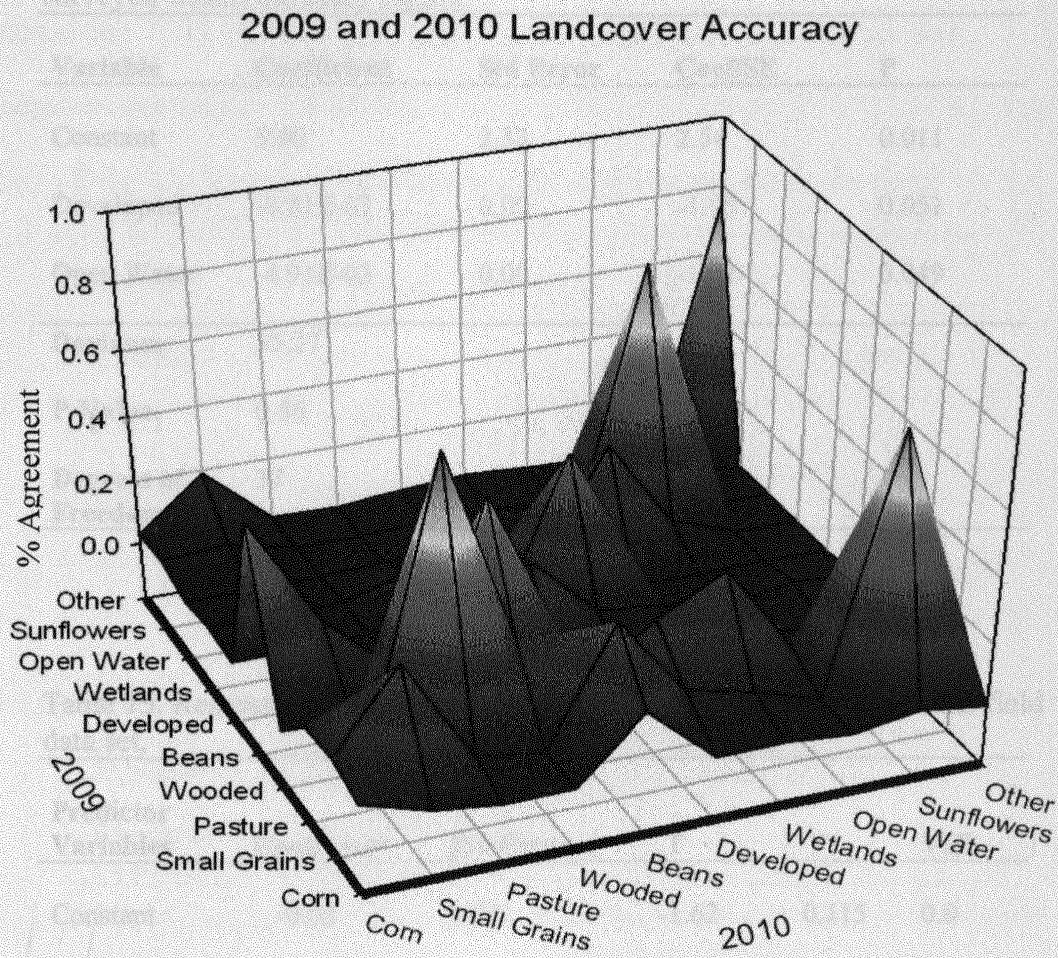

Figure 18. Landcover map accuracy using Sigmaplot software.

showing a relationship to the absence damage in corn fields (Table 16).

The AIC provided a model that included developed land, open water and pasture as significant variables. The regression showed developed land (0.132) was not a significant variable, whereas open water (0.022) and pasture (0.056)

Table 14. Backward logistic stepwise regression results for sunflower fields surveyed within the study region.

Variable	Coefficient	Std Error	Coef/SE	P
Constant	5.90	2.33	2.54	0.011
Developed	-8.81E-03	0.00	-1.95	0.051
Open Water	-4.91E-03	0.00	-1.97	0.049
Deviance	35.27			
P-Value	0.55			
Degrees of Freedom	37			

Table 15. Regression results of the selected AIC model for the sunflower field data set.

Predictor Variables	Coefficient	Std Error	T	P	VIF
Constant	-0.02	0.01	-1.62	0.115	0.0
Bean	3.33E-05	6.77E-06	4.92	0.000	1.0
Wetland	4.94E-05	2.25E-05	2.19	0.035	1.0
Wooded	-2.49E-05	1.81E-05	-1.38	0.177	1.0

were signficant. Coefficients for developed land and open water were positive measuring 3.282E-05 and 2.190E-05, respectively (Table 17). Pasture was negative, measuring -4.875E-06.

Table 16. Results of backward logistic stepwise regression for corn fields surveyed within the study region.

Variable	**Coefficient**	**Std Error**	**Coef/SE**	**P**
Constant	-6.42	1.73	-3.71	0.000
Bean	1.00E-03	4.52E-04	2.51	0.012
Pasture	9.31E-04	3.49E-04	2.66	0.008
Wetland	4.00E-03	0.00	4.08	0.000

Deviance	112.29
P-Value	0.228
Degrees of Freedom	102

Table 17. Regression results of the selected AIC model for the corn field data set.

Predictor Variables	**Coefficient**	**Std Error**	**T**	**P**	**VIF**
Constant	0.00	0.01	0.10	0.920	0.0
Developed	3.28E-05	2.13E-05	1.54	0.132	1.1
Pasture	-4.88E-06	2.47E-06	-1.97	0.056	1.2
Open Water	2.19E-05	9.15E-06	2.39	0.022	1.1

6. DISCUSSION

6.1. Sample Methods

I used 120 sample plots previously selected by Ralston et al. (2007). These sites were proportionately allocated among the four strata (Northeast Drift Plains (28), Northwest Drift Plains (27), Southern Drift Plains (32), Missouri Coteau (33)). Every site was visited each year to determine locations of survey fields. Thus, each stratum had a proportional chance of producing crop fields. Damage sampling was proportional per field; i.e, damage data were collected every 135 m along transects, which provided more samples for larger fields and fewer samples for smaller fields. The modification of sampling methods in 2010 resulted in a larger sample size for the final year of my study.

Although the number of sampled fields per strata was limited, sunflower damage was typically higher in the SDP. Most of the corn fields surveyed were from the SDP each year of the study. Across all years, there was no corn damage in the MC. Due to the limited number of fields distributed among strata, it is difficult to determine causes of significance among strata for both corn and sunflower.

Similar to Hothem et al. (1988) and Cummings et al. (1989), I used the Dolbeer et al. (1975) template method to measure damage to sunflower heads. The diameter of each sunflower head and the diameter of any undeveloped center were also measured in these studies to determine total area of developed sunflower (Hothem et al., 1988; Cummings et al., 1989).

Every year the National Sunflower Association (NSA) conducts a survey that assesses multiple forms of damage, including blackbird, to sunflower crops throughout several states. The results from this NSA survey showed blackbird damage was 4.2%, 2.4% and 5.6% for 2008, 2009 and 2010, respectively (Kandel, 2011). Kandel (2011) used visual estimates to calculate average bird damage, whereas I used the template method of damage estimation which provided calculations of 0.95%, 2.17% and 3.29% for 2008, 2009 and 2010, respectively. The visual damage estimation method provides results that tend to be skewed higher than actual levels of damage, whereas the template method tends to provide results that are lower than the actual level of damage (Dolbeer et al., 1975). Kandel (2011) also collected damage estimates in fields along roadsides rather than choosing a completely randomized survey set. My data provide estimates that may show slightly lower than average levels of damage found in North Dakota fields.

In many corn studies, such as Stone et al. (1972), damage measurements were estimated by calculating total weight of seed consumed by blackbirds. Initial measurements were taken by measuring the length of damage and the length of the total ear to determine percent damage (Stone et al., 1972). These initial measurements are similar to my methodology to determine percent damage of each corn ear within each sample. I did not determine the weight of the consumed corn kernels, although other studies calculated this measurement using the DeGrazio table (DeGrazio et al., 1969; Stone et al., 1972)

6.2. Accuracy of Raster Data

According to USDA NASS personnel, landcover variables such as developed and wooded land types on 2008 through 2010 rasters were developed from National Land Cover Data (NLCD) 2001 maps. Each year new random points were selected across the non-agricultural sites, and NLCD 2001 was used to determine the landcover at that site. According to Wickham et al. (2010), the Environmental Protection Agency (EPA) used frame cells (120 x 120 km), primary sample units (12 x 12 km) and pixels (30 x 30 m). One primary sample unit (PSU) was randomly selected from each frame cell without replacement in order to determine land cover using remote sensing techniques (Wickham et al., 2010). Wickham et al. (2010) showed that misclassifications were found in differing grass cover-types such as developed open space, grassland, pasture and cropland (3.5% in the west, 4.4% in the east). Developed open space was difficult to distinguish from other land types, and omission errors were typically higher in regions such as North Dakota (Region 5) due to the fact that these land types blend into their surroundings (Wickham et al., 2010). Woody wetlands were also a difficult land type to categorize because it is difficult to distinguish wet from dry forests using remote sensing software (Wickham et al., 2010).

The methods used in this study combined all developed landcover types into one variable (developed). Since developed urban space was difficult to distinguish from other grass type variables, mistakes in classification could have had a negative effect on the accuracy of the raster data. All wetland types were also combined to form one variable (wetlands), as were all wooded areas (wooded). It is difficult to distinguish between wet and dry woodlands which could have also had a negative effect on the raster accuracy. These data were then used by USDA NASS for the formation of their landcover raster data, and random sample points were selected each year. This methodology means landcover pixels could vary across years in the non-agricultural land types.

Agricultural land type accuracy for the NASS raster maps, using the crosstab analysis, was not accurate due to the change in crops planted across the study region each year. This analysis resulted in high error levels due to the inconsistency in cropland cover across years. Because of inconsistencies, the crop cover accuracy calculation provided in the metadata was used to analyze the raster suitability for this project.

6.3. Significance of Data

Both Sorensen and Euclidean distance measurements were used to determine the significance of the damage data. Overall, by using both the Sorenson and Euclidean distance measurements, I found that both the difference in damage between crops and across strata can be found to be significant to varying extents.

6.4. Landcover Analysis

A logistic stepwise regression was used to determine which landcover variables were significantly related to the presence or absence of damage within sunflower and corn fields. Damage values were modified so that 0 represented no damage in a field, and 1 represented the presence of damage in fields. Negative coefficients for these stepwise regressions mean that these variables are somehow related to the presence of greater damage in fields. These regressions showed that developed land and open water were related to the presence of damage in sunflower fields. In corn, however, the chosen variables (bean, pasture, wetland) produced positive coefficients which shows a relation to the absence of damage in corn fields.

For the AIC test, the best model included the variables beans, wooded and wetland for damage to sunflower fields. The regression based on this model showed that wooded land was not significantly related to damage. The best model for corn damage included the variables developed land, open water and pasture, and the following regression showed open water and pasture as being significant. The AIC analysis used actual damage measurements for all fields receiving damage and left out fields that contained an absence of damage. Since this analysis only included fields that received damage, the least square regression provides negative coefficients for variables related to less damage and positive coefficients for variables related to more damage, i.e., beans and wetland were found to be related to an increase in blackbird damage in sunflower.

7. MANAGEMENT IMPLICATIONS

7.1. Future Research

This research can be used as a base for future research. The last comprehensive damage survey for North Dakota was conducted in 1979 and 1980 (Hothem et al., 1988). This study added to the data collected by Hothem et al. (1988) study by providing damage in an era of high corn acreage in North Dakota. By using the results produced from each of these studies, one can determine a time line of damage in the state. Many other studies have been conducted in other states to determine possible methods of mitigating blackbird damage to crops such as sunflower and corn. By conducting damage surveys, it is possible to determine the possible effect of new management strategies and land use change.

This study included damage surveys for corn as well as sunflower. Since corn is a recent crop in North Dakota, it was important to determine the effect this crop has had on damage levels to sunflower in the region. This research provides baseline data for future damage surveys involving corn.

7.2. Cost of Blackbird Damage to Producers

My results show that corn producers experience a greater overall cost of damage than sunflower producers. However, blackbird damage to corn crops appears to be more proportionately allocated across the region. Corn producers tend to share the cost of damage on a more balanced level, with each producer experiencing on average $< 2\%$ damage. Sunflower producers typically experience damage on an irregular basis, with some producers experiencing near 20% damage and others experiencing 0% damage. Thus, a few select producers carry the cost of damage while other producers experience no damage. It is difficult for the producers who experience damage because it can dramatically decrease their profits.

7.3. Field Placement

Producers often spend considerable time and money on limiting blackbird damage to their fields. This expenditure adds to the initial cost of damage caused by direct predation on the crop. By determining areas of greater predation, it may be possible to limit the cost of mitigating this loss. Producers may be able to choose a different crop for a specified field or plant their sunflower or corn in a safer location.

Otis and Kilburn (1988) predicted that wetlands located near sunflower fields increased the probability of blackbird damage in the fields. An increase in blackbird populations near wetlands is due to RWBL and YHBL roosting in cattail stands in and around wetlands (Besser, 1978, 1985; Blackwell and Dolbeer, 2001; Peer et al., 2003). Because of higher populations residing in cattails, programs have been set up to remove cattail in certain regions, specifically near cropland (Blackwell et al., 2003; Linz et al., 1996). Wildlife damage insurance is typically not available for crop producers; therefore, these producers are vulnerable to devastating damage from blackbird species.

My data show that developed land and open water are typically located near damaged sunflower fields. Likewise, beans, pasture and wetlands are typically present when damage is absent from corn fields. The second analysis shows that increasing levels of wetland and bean coverage are related to increased levels of blackbird damage in sunflower fields. Increasing amounts of developed land and open water are related to increased damage in corn fields, with open water showing more significance than developed land. These results follow the previous evidence that nearby water is related to field damage. Based on these results, producers may decide to plant sunflower and corn fields in regions with limited levels of standing water in order to decrease economic losses to blackbird damage.

Wildlife conservation sunflower plots (WCSP) may be used around standing water and developed areas to lure blackbirds away from economically important production fields (Hagy, 2006; Hagy et al., 2010). These plots may shift the damage to this decoy sunflower in order to limit blackbirds in producers' sunflower and corn fields. These plots would also supply a buffer around the important landcover types to decrease the distance traveled by the depredating blackbirds in search of high caloric food.

Overall, my results show that producers should plant other crops, or decoy plots, near areas with high levels of water or beans. Sunflower and corn should be planted in drier regions, where alternative food sources are available.

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APPENDIX I. FIELD LOCATIONS: SUNFLOWER

Field	Year	Strata	County	Township	Range	Section	Ralston Site	Latitude	Longitude
F1S08	2008	NWDP	Burke	162	91	23	113	48.841	-102.454
F2S08	2008	NWDP	Ward	155	81	12	105	48.266	-101.030
F3S08	2008	NWDP	McHenry	154	78	2	90	48.180	-100.651
F4S08	2008	NWDP	McHenry	154	78	12	90	48.181	-100.645
F5S08	2008	NWDP	McHenry	152	76	9	87	48.000	-100.410
F6S08	2008	NEDP	Cavalier	161	60	11	77	48.786	-98.381
F7S08	2008	NEDP	Nelson	154	57	14	61	48.154	-97.941
F8S08	2008	SDP	Grand Forks	153	56	21	57	48.053	-97.855
F9S08	2008	NEDP	Grand Forks	153	56	28	57	48.046	-97.854
F10S08	2008	NEDP	Grand Forks	153	56	29	57	48.047	-97.867
F11S08	2008	NEDP	Grand Forks	149	55	5	56	47.753	-97.728
F12S08	2008	MC	Logan	136	73	32	17	-46.557	-99.879
F13S08	2008	MC	Logan	136	73	33	17	46.556	-99.868
F14S09	2009	SDP	Barnes	143	60	32	22	47.070	-98.317
F15S09	2009	NWDP	Sheridan	150	75	11	49	47.830	-100.236
F16S09	2009	NEDP	Grand Forks	153	56	29	57	48.048	-97.876
F17S09	2009	NWDP	Pierce	157	73	7	71	48.435	-100.127
F18S09	2009	NEDP	Pembina	161	56	18	75	48.767	-97.946

Field	Year	Strata	County	Township	Range	Section	Ralston Site	Latitude	Longitude
F17S09	2009	NWDP	Pierce	157	73	7	71	48.435	-100.127
F18S09	2009	NEDP	Pembina	161	56	18	75	48.767	-97.946
F19S09	2009	NEDP	Towner	161	66	15	84	48.771	-99.196
F20S09	2009	NWDP	McHenry	158	78	17	94	48.508	-100.774
F21S09	2009	NWDP	McHenry	158	78	18	94	48.506	-100.784
F22S09	2009	NWDP	McHenry	158	78	19	94	48.500	-100.779
F23S09	2009	NWDP	Bottineau	163	78	26	96	48.824	-100.741
F24S09	2009	NWDP	Bottineau	159	82	30	98	48.563	-101.306
F25S09	2009	NWDP	Bottineau	159	82	31	98	48.557	-101.306
F26S09	2009	NWDP	Bottineau	159	82	32	98	48.555	-101.292
F27S09	2009	NWDP	Renville	163	86	21	102	48.933	-101.836
F28S09	2009	NWDP	Ward	155	81	2	105	48.272	-101.043
F29S10	2010	NWDP	Ward	155	81	11	105	48.267	-101.041
F30S10	2010	NWDP	Bottineau	162	78	27	96	48.827	-100.756
F31S10	2010	NWDP	Bottineau	162	78	26	96	48.832	-100.750
F32S10	2010	NWDP	McHenry	152	79	32	88	47.946	-100.807
F33S10	2010	NEDP	Nelson	154	57	14	61	48.157	-97.940

Field	Year	Strata	County	Township	Range	Section	Ralston Site	Latitude	Longitude
F34S10	2010	NWDP	Sheridan	149	76	4	53	47.759	-100.406
F35S10	2010	NWDP	Sheridan	150	75	10	49	47.830	-100.246
F36S10	2010	SDP	Wells	148	73	14	48	47.634	-99.931
F37S10	2010	NEDP	Wells	150	68	22	47	47.799	-99.355
F38S10	2010	NEDP	Wells	150	68	22	47	47.800	-99.350
F39S10	2010	SDP	Cass	142	55	14	20	47.113	-97.606
F40S10	2010	MC	Emmons	136	74	20	18	46.588	-100.014
F41S10*	2010	MC	Ward	155	85	18	107	48.252	-101.653
F42S10*	2010	NWDP	Renville	162	84	29	101	48.828	-101.593
F43S10*	2010	NWDP	Renville	158	81	11	99	48.527	-101.100
F44S10*	2010	NWDP	Bottineau	159	83	35	98	48.557	-101.349
F45S10*	2010	NWDP	Bottineau	163	83	17	97	48.955	-101.470
F46S10*	2010	NWDP	Bottineau	163	83	18	97	48.956	-101.482
F47S10*	2010	NWDP	McHenry	152	76	8	87	48.004	-100.416
F48S10*	2010	NEDP	Towner	164	65	32	85	48.982	-99.104
F49S10*	2010	NWDP	Pierce	157	71	5	72	48.457	-99.856
F50S10*	2010	MC	Sheridan	147	77	8	51	47.572	-100.513

Field	Year	Strata	County	Township	Range	Section	Ralston Site	Latitude	Longitude
F51S10*	2010	MC	Kidder	137	70	22	33	46.663	-99.509

* denotes fields, additional to those found within the 1.6 km^2 sections, selected using the 2010 modified methodology.

APPENDIX II. FIELD LOCATIONS: CORN

Field	Year	Strata	County	Township	Range	Section	Ralston Site	Latitude	Longitude
F1C08	2008	SDP	Wells	149	69	26	46	47.691	-99.457
F2C08	2008	SDP	LaMoure	133	63	5	13	46.365	-98.636
F3C08	2008	NWDP	Renville	163	86	17	102	48.947	-101.850
F4C08	2008	NWDP	McHenry	158	78	17	94	48.508	-100.772
F5C08	2008	NWDP	McHenry	158	78	18	94	48.504	-100.784
F6C08	2008	NWDP	McHenry	158	78	18	94	48.506	-100.783
F7C08	2008	SDP	Wells	148	73	13	48	47.635	-99.923
F8C08	2008	SDP	Wells	148	73	24	48	47.630	-99.922
F9C08	2008	SDP	Wells	149	69	36	46	47.686	-99.443
F10C08	2008	SDP	Wells	148	69	22	45	47.628	-99.454
F11C08	2008	SDP	Wells	146	70	25	44	47.431	-99.524
F12C08	2008	SDP	Foster	146	65	18	41	47.469	-98.995
F13C08	2008	NEDP	Nelson	153	57	29	59	48.048	-97.992
F14C08	2008	NEDP	Grand Forks	153	56	29	57	48.046	-97.862
F15C08	2008	SDP	Griggs	145	58	19	39	47.361	-98.105

Field	Year	Strata	County	Township	Range	Section	Ralston Site	Latitude	Longitude
F16C08	2008	SDP	Griggs	145	58	18	39	47.371	-98.109
F17C08	2008	SDP	Steele	145	57	25	38	47.345	-97.863
F18C08	2008	SDP	Barnes	143	58	10	23	47.221	-98.011
F19C08	2008	SDP	Cass	142	55	14	20	47.115	-97.610
F20C08	2008	SDP	Cass	142	54	28	19	47.091	-97.517
F21C08	2008	SDP	Cass	142	54	21	19	47.098	-97.520
F22C08	2008	SDP	Stutsman	142	60	31	22	47.069	-98.321
F23C08	2008	SDP	Stutsman	142	57	29	21	47.084	-97.932
F24C08	2008	SDP	Barnes	142	57	31	21	47.077	-97.945
F25C08	2008	SDP	Barnes	139	57	9	25	46.873	-97.880
F26C08	2008	SDP	Stutsman	141	64	28	29	47.006	-98.791
F27C08	2008	SDP	Stutsman	141	64	21	29	47.013	-98.791
F28C08	2008	MC	Stutsman	142	67	8	31	47.125	-99.187
F29C08	2008	MC	Stutsman	142	67	9	31	47.129	-99.181
F30C08	2008	SDP	Stutsman	140	65	34	28	46.905	-98.879
F31C08	2008	SDP	Stutsman	137	64	32	15	46.634	-98.772
F32C08	2008	SDP	LaMoure	133	63	5	13	46.365	-98.636

Field	Year	Strata	County	Township	Range	Section	Ralston Site	Latitude	Longitude
F33C08	2008	SDP	LaMoure	134	63	32	13	46.374	-98.636
F34C08	2008	SDP	Ransom	133	57	17	4	46.330	-97.881
F35C08	2008	SDP	Dickey	132	60	31	6	46.201	-98.250
F36C08	2008	SDP	Dickey	132	61	36	6	46.203	-98.256
F37C08	2008	SDP	Sargent	130	54	3	1	46.099	-97.429
F38C08	2008	SDP	Sargent	131	54	34	1	46.112	-97.431
F39C09	2009	SDP	Sargent	130	54	2	1	46.106	-97.417
F40C09	2009	SDP	Sargent	130	54	3	1	46.105	-97.433
F41C09	2009	SDP	Sargent	129	56	14	2	45.984	-97.673
F42C09	2009	SDP	Sargent	129	56	23	2	45.975	-97.669
F43C09	2009	SDP	Sargent	129	56	22	2	45.975	-97.678
F44C09	2009	SDP	Ransom	133	55	28	3	46.300	-97.608
F45C09	2009	SDP	Ransom	133	57	17	4	46.329	-97.886
F46C09	2009	SDP	Ransom	133	57	19	4	46.318	-97.892
F47C09	2009	SDP	Dickey	132	61	25	6	46.218	-98.259
F48C09	2009	MC	McIntosh	132	68	31	9	46.204	-99.246
F49C09	2009	SDP	LaMoure	134	63	31	13	46.373	-98.646

Field	Year	Strata	County	Township	Range	Section	Ralston Site	Latitude	Longitude
F50C09	2009	SDP	LaMoure	136	64	5	15	46.627	-98.764
F51C09	2009	SDP	LaMoure	136	64	6	15	46.627	-98.772
F52C09	2009	SDP	Stutsman	137	64	33	15	46.634	-98.762
F52C09	2009	SDP	Cass	142	54	28	19	47.091	-97.518
F54C09	2009	SDP	Cass	142	55	24	20	47.100	-97.591
F55C09	2009	SDP	Cass	142	55	23	20	47.105	-97.610
F56C09	2009	SDP	Barnes	142	57	32	21	47.074	-97.931
F57C09	2009	SDP	Barnes	143	58	10	23	47.220	-98.006
F58C09	2009	SDP	Barnes	137	58	7	24	46.693	-98.054
F59C09	2009	SDP	Barnes	137	59	13	24	46.684	-98.067
F60C09	2009	MC	Stutsman	137	68	31	27	46.639	-99.321
F61C09	2009	SDP	Steele	145	57	24	38	47.358	-97.864
F62C09	2009	SDP	Griggs	145	58	19	39	47.362	-98.111
F63C09	2009	SDP	Foster	146	65	8	41	47.475	-98.975
F64C09	2009	SDP	Foster	147	64	2	42	47.580	-98.793
F65C09	2009	SDP	Wells	146	69	31	44	47.424	-99.517
F66C09	2009	SDP	Wells	146	69	30	44	47.431	-99.515

Field	Year	Strata	County	Township	Range	Section	Ralston Site	Latitude	Longitude
F67C09	2009	NEDP	Grand Forks	153	56	29	57	48.046	-97.867
F68C09	2009	NEDP	Benson	151	68	9	66	47.903	-99.378
F69C10	2010	NWDP	Renville	158	83	12	100	48.528	-101.325
F70C10	2010	NWDP	Pierce	151	73	24	70	47.888	-99.958
F71C10	2010	NEDP	Nelson	154	57	15	61	48.153	-97.949
F72C10	2010	NEDP	Nelson	154	57	15	61	48.155	-97.951
F73C10	2010	NEDP	Grand Forks	153	56	28	57	48.049	-97.853
F74C10	2010	MC	Sheridan	146	78	19	54	47.451	-100.666
F75C10	2010	NWDP	Sheridan	150	75	3	49	47.835	-100.250
F76C10	2010	SDP	Wells	149	69	35	46	47.686	-99.450
F77C10	2010	SDP	Foster	147	64	10	42	47.570	-98.804
F78C10	2010	SDP	Foster	147	64	3	42	47.581	-98.810
F79C10	2010	SDP	Griggs	145	58	18	39	47.371	-98.108
F80C10	2010	SDP	Griggs	145	59	13	39	47.370	-98.117
F81C10	2010	SDP	Steele	146	55	27	37	47.432	-97.647
F82C10	2010	SDP	Stutsman	141	64	22	29	47.009	-98.771
F83C10	2010	SDP	Stutsman	141	64	27	29	47.007	-98.770

Field	Year	Strata	County	Township	Range	Section	Ralston Site	Latitude	Longitude
F84C10	2010	SDP	Stutsman	141	64	22	29	47.011	-98.777
F85C10	2010	SDP	Barnes	139	57	4	25	46.882	-97.888
F86C10	2010	SDP	Barnes	139	57	9	25	46.874	-97.887
F87C10	2010	SDP	Barnes	139	57	8	25	46.873	-97.897
F88C10	2010	SDP	Barnes	143	58	3	23	47.227	-98.007
F89C10	2010	SDP	Barnes	142	60	5	22	47.049	-98.294
F90C10	2010	SDP	Barnes	142	57	29	21	47.085	-97.935
F91C10	2010	SDP	Barnes	142	57	31	21	47.078	-97.946
F92C10	2010	SDP	Cass	142	55	13	20	47.115	-97.589
F93C10	2010	SDP	Cass	142	54	21	19	47.098	-97.518
F94C10	2010	SDP	Cass	142	54	21	19	47.097	-97.523
F95C10	2010	SDP	Cass	142	54	27	19	47.091	-97.512
F96C10	2010	MC	Logan	136	73	29	17	46.562	-99.884
F97C10	2010	SDP	Stutsman	137	64	33	15	46.634	-98.785
F98C10	2010	SDP	LaMoure	136	64	6	15	46.628	-98.782
F99C10	2010	SDP	LaMoure	136	66	1	15	46.627	-98.796
F100C10	2010	SDP	LaMoure	134	63	32	13	46.373	-98.636

Field	Year	Strata	County	Township	Range	Section	Ralston Site	Latitude	Longitude
F101C10	2010	SDP	LaMoure	133	63	5	13	46.368	-98.638
F102C10	2010	SDP	LaMoure	136	63	13	12	46.589	-98.553
F103C10	2010	SDP	Ransom	133	57	18	4	46.328	-97.892
F104C10	2010	SDP	Ransom	133	55	33	3	46.296	-97.595
F105C10	2010	SDP	Ransom	133	55	27	3	46.299	-97.593
F106C10	2010	SDP	Sargent	129	56	23	2	45.978	-97.672
F107C10*	2010	NWDP	McHenry	158	77	8	94	48.532	-100.644
F108C10*	2010	NWDP	McHenry	157	76	17	93	48.427	-100.513
F109C10*	2010	NWDP	McHenry	154	78	11	90	48.176	-100.666
F110C10*	2010	NEDP	Towner	157	68	27	81	48.399	-99.418
F111C10*	2010	NEDP	Pembina	162	56	10	74	48.869	-97.874
F112C10*	2010	NEDP	Pierce	158	69	10	73	48.522	-99.538
F113C10*	2010	NEDP	Benson	155	70	28	69	48.213	-99.657
F114C10*	2010	NEDP	Benson	151	69	8	67	47.908	-99.528
F115C10*	2010	NEDP	Benson	153	67	19	65	48.061	-99.327
F116C10*	2010	NEDP	Nelson	152	60	21	60	47.970	-98.336
F117C10*	2010	SDP	Nelson	153	57	17	59	48.075	-97.992

Field	Year	Strata	County	Township	Range	Section	Ralston Site	Latitude	Longitude
F118C10*	2010	SDP	Wells	148	69	16	45	47.637	-99.464
F119C10*	2010	SDP	Wells	146	69	30	44	47.430	-99.503
F120C10*	2010	SDP	Foster	146	65	18	41	47.465	-98.981
F121C10*	2010	NEDP	Griggs	146	60	19	40	47.446	-98.356
F122C10*	2010	SDP	Steele	145	57	23	38	47.365	-97.897
F123C10*	2010	SDP	Stutsman	144	64	33	32	47.252	-98.790
F124C10*	2010	SDP	Stutsman	140	65	35	28	46.896	-98.856
F125C10*	2010	MC	Stutsman	137	69	35	27	46.644	-99.347
F126C10*	2010	MC	Stutsman	144	67	23	26	47.272	-99.131
F127C10*	2010	SDP	Barnes	137	59	13	24	46.683	-98.071
F128C10*	2010	MC	Logan	134	69	10	16	46.447	-99.349
F129C10*	2010	SDP	LaMoure	136	60	15	11	46.599	-98.216
F130C10*	2010	MC	Dickey	132	66	21	7	46.232	-98.962
F131C10*	2010	SDP	Dickey	132	60	31	6	46.198	-98.243
F132C10*	2010	SDP	Ransom	136	57	33	5	46.556	-97.860
F133C10*	2010	SDP	Sargent	131	53	30	1	46.125	-97.379

* denotes fields, additional to those found within the 1.6 km^2 sections, selected using the 2010 modified methodology.

APPENDIX III. LANDCOVER (HECTARES) SURROUNDING STUDY SUNFLOWER FIELDS

Field	Corn area	Small Grains area	Pasture area	Wooded area	Bean area	Developed area	Wetland area	Open Water area	Sunflower area	Other area
F1S08	2.5	2970.4	2877.6	2.5	0.6	464.1	201.6	19.8	74.3	712.2
F2S08	177.2	3103.7	1914.8	2.2	17.6	558.2	130.5	7.2	1122.7	291.0
F3S08	90.0	835.1	5179.7	89.4	16.0	337.7	511.2	24.1	111.3	131.4
F4S08	84.7	896.6	5132.7	88.4	16.0	332.1	516.8	24.5	98.5	131.1
F5S08	84.0	2107.1	3082.7	1.3	190.0	537.5	341.8	293.8	447.8	237.7
F6S08	32.6	3560.3	482.9	9.1	444.7	993.8	535.0	47.0	96.6	1122.1
F7S08	180.3	2818.3	1292.7	80.3	1107.0	524.0	583.6	10.3	231.1	493.9
F8S08	678.9	2384.9	1171.6	111.3	2053.5	488.6	266.2	31.7	130.8	2.8
F9S08	195.1	2765.3	1615.7	275.7	1232.4	468.2	257.5	16.0	439.4	56.1
F10S08	220.1	2831.5	1602.8	213.9	1105.4	479.2	329.9	28.5	406.7	104.4
F11S08	253.4	2702.3	1550.4	247.7	1290.8	491.1	280.7	17.6	436.2	55.2
F12S08	488.0	1936.5	3272.1	5.3	164.6	399.5	48.3	171.2	833.2	3.8
F13S08	492.7	1786.6	3323.8	5.0	166.8	385.4	47.7	180.3	928.9	3.8
F14S09	735.7	1485.2	833.9	46.1	2542.0	491.7	976.6	152.7	43.9	12.2
F15S09	83.4	2255.1	2382.7	3.4	218.3	484.5	452.5	584.6	763.0	96.6

Field	Corn area	Small Grains area	Pasture area	Wooded area	Bean area	Developed area	Wetland area	Open Water area	Sunflower area	Other area
F16S09	274.4	2642.4	1409.9	211.1	1628.2	463.8	236.1	32.6	223.0	198.5
F17S09	154.9	1745.5	2971.4	13.8	558.2	470.1	572.0	165.6	462.2	212.0
F18S09	111.0	1676.2	1540.4	1861.2	976.9	512.7	241.5	44.2	217.3	138.3
F19S09	6.6	2203.4	2337.6	23.8	384.2	458.5	1165.7	85.3	97.5	562.9
F20S09	87.5	1692.5	4178.7	26.0	64.6	405.8	369.7	28.9	220.5	247.1
F21S09	75.6	1580.9	4321.7	25.7	67.4	403.3	374.1	26.0	233.0	218.0
F22S09	58.6	1303.3	4780.8	28.5	55.5	366.6	314.9	21.3	213.6	183.1
F23S09	63.0	4042.3	412.7	2.2	138.3	587.1	96.9	21.3	1095.7	865.5
F24S09	41.1	3329.5	982.2	1.3	43.6	545.4	354.4	8.5	1516.3	498.3
F25S09	42.6	3220.7	1091.0	2.5	74.6	549.4	361.9	8.5	1466.7	507.7
F26S09	52.4	3231.0	914.5	2.5	139.2	553.8	363.8	8.5	1517.8	539.4
F27S09	27.3	3956.4	1015.4	8.2	23.5	558.5	124.5	15.1	480.7	1111.7
F28S09	34.5	3107.5	2230.6	3.8	18.2	533.7	246.8	5.3	530.6	610.3
F29S10	60.5	2545.5	2815.5	0.6	254.6	371.6	194.4	3.4	639.1	437.2
F30S10	44.8	3763.5	746.7	2.5	401.1	376.3	90.6	21.0	330.2	1545.7
F31S10	46.4	3614.6	782.1	2.2	413.3	384.2	80.6	19.4	373.8	1605.9
F32S10	169.7	2045.3	2762.8	23.8	440.6	269.7	647.0	86.6	369.7	506.5

Field	Corn area	Small Grains area	Pasture area	Wooded area	Bean area	Developed area	Wetland area	Open Water area	Sunflower area	Other area
F33S10	343.4	2066.3	1588.4	97.5	1667.1	306.7	662.3	9.7	111.6	468.2
F34S10	201.3	1924.2	2335.1	1.3	411.4	297.0	375.4	473.5	541.9	763.6
F35S10	93.1	1797.2	2966.0	2.5	423.4	292.0	408.9	535.3	583.9	222.7
F36S10	439.0	2243.2	2123.1	12.9	1811.4	381.3	155.2	4.7	108.5	45.8
F37S10	78.1	1672.1	2850.6	9.7	1526.0	261.9	445.9	376.9	45.5	56.1
F38S10	78.4	1713.5	2815.8	7.5	1537.9	264.4	436.2	368.8	45.5	52.7
F39S10	1907.0	321.8	1073.1	15.4	3267.7	322.1	101.0	11.0	207.6	96.9
F40S10	443.4	1499.6	3204.1	4.1	210.1	224.2	144.3	729.1	804.1	61.8

APPENDIX IV. LANDCOVER (HECTARES) SURROUNDING STUDY CORN FIELDS

Field	Corn Area	Small Grain Area	Pasture Area	Wooded Area	Bean Area	Developed Area	Wetland Area	Open Water Area	Sunflower Area	Other Area
F1C08	538.8	3380.3	677.7	23.5	1798.2	478.6	115.1	67.1	154.9	87.5
F2C08	1793.8	506.5	2241.6	45.2	1734.8	487.0	127.0	12.5	372.9	1.3
F3C08	39.5	3902.8	854.9	1.3	4.1	533.4	118.2	13.5	798.1	1059.7
F4C08	319.6	1176.0	4215.4	17.2	19.8	411.4	245.9	27.6	466.6	422.4
F5C08	250.6	1060.6	4471.6	17.6	19.8	410.8	232.7	24.5	482.0	350.9
F6C08	267.5	1126.5	4321.4	16.9	20.4	417.7	239.0	25.4	494.9	392.3
F7C08	404.9	2809.9	1759.3	15.4	1257.8	552.2	320.2	17.2	169.3	15.4
F8C08	380.1	2870.1	1766.8	13.5	1220.5	543.2	307.0	15.7	184.4	19.4
F9C08	513.7	3401.3	616.9	19.4	1931.8	476.7	110.7	60.8	93.8	99.4
F10C08	1055.6	2180.5	202.6	6.6	3057.0	510.5	66.2	2.8	174.4	68.4
F11C08	744.5	1949.0	1482.4	22.6	2058.2	461.3	235.2	104.4	156.8	107.3
F12C08	1592.1	1480.8	882.5	48.3	2258.5	513.7	276.0	25.1	180.0	66.8
F13C08	244.6	1900.4	1412.5	40.1	898.8	547.2	1700.3	236.8	90.3	251.5
F14C08	236.1	2786.6	1576.8	231.8	1140.9	492.4	321.1	25.7	412.1	99.4
F15C08	901.6	1051.8	2352.6	113.5	1823.9	450.0	421.8	152.4	14.1	38.9
F16C08	856.8	1144.3	2301.2	115.1	1845.8	450.0	408.0	157.7	16.3	28.9

Field	Corn Area	Small Grain Area	Pasture Area	Wooded Area	Bean Area	Developed Area	Wetland Area	Open Water Area	Sunflower Area	Other Area
F17C08	2136.2	1253.5	311.1	65.2	2792.3	436.8	254.3	73.1	2.2	0.3
F18C08	489.8	352.5	3529.3	81.8	1426.9	407.1	362.2	666.1	1.3	9.4
F19C08	1567.7	978.7	491.4	17.9	2529.2	528.1	697.4	8.8	195.4	308.9
F20C08	2380.9	1047.1	259.0	61.5	2875.4	447.5	126.1	5.3	90.6	27.9
F21C08	2580.3	961.8	227.4	65.9	2763.1	462.2	124.8	4.4	33.9	101.3
F22C08	1305.2	1037.4	669.5	32.0	2960.1	470.7	498.0	142.1	209.8	2.2
F23C08	1140.6	1308.0	1171.3	50.5	2498.1	376.9	423.0	349.0	3.8	3.4
F24C08	1052.4	1427.5	1205.8	60.2	2344.2	410.5	465.4	346.5	3.8	4.1
F25C08	1381.7	1106.7	612.1	49.9	3374.3	428.7	250.9	70.9	45.2	0.9
F26C08	1346.0	568.2	1782.2	43.0	2013.9	553.5	240.5	617.2	132.0	27.9
F27C08	1387.1	570.8	1676.5	41.4	2198.0	561.0	227.7	498.6	133.0	27.9
F28C08	334.9	351.9	4177.2	21.6	530.9	360.3	275.0	1189.5	69.6	13.8
F29C08	468.8	366.3	3982.1	22.6	583.9	379.1	278.8	1153.4	72.1	14.1
F30C08	1229.9	329.0	1589.3	36.1	2898.3	664.2	430.6	124.2	21.3	3.1
F31C08	950.5	671.7	1685.3	24.5	2947.5	573.3	396.7	54.6	12.5	4.7
F32C08	1717.9	706.2	2109.3	54.3	1807.0	427.1	118.9	12.5	371.9	0.9
F33C08	1986.3	595.5	2043.4	48.3	1713.2	430.3	121.4	11.9	372.9	0.9

Field	Corn Area	Small Grain Area	Pasture Area	Wooded Area	Bean Area	Developed Area	Wetland Area	Open Water Area	Sunflower Area	Other Area
F34C08	1601.6	795.3	1525.4	43.6	2397.5	395.4	526.2	31.7	2.5	1.6
F35C08	1585.6	347.5	2633.0	81.2	1669.6	264.4	405.2	327.7	1.9	5.6
F36C08	1642.0	341.2	2578.4	76.2	1670.9	280.7	397.3	327.7	1.9	5.6
F37C08	1180.1	714.1	1296.1	62.7	2121.2	427.8	945.5	566.4	2.5	4.1
F38C08	1173.5	753.6	1268.2	61.5	2220.6	404.5	899.7	533.7	2.5	2.8
F39C09	1364.5	612.8	1413.1	58.0	2113.4	427.4	857.7	472.3	0.9	3.8
F40C09	1281.1	498.0	1590.0	56.1	1856.5	405.8	985.6	648.2	0.6	2.2
F41C09	1301.4	377.9	1556.7	35.8	2726.4	399.8	732.6	189.4	0.6	1.6
F42C09	1258.8	355.0	1431.9	31.0	2903.9	414.3	666.1	149.3	1.6	109.8
F43C09	1318.1	316.1	1429.1	38.3	2960.1	385.4	642.9	121.0	1.9	113.2
F44C09	1657.7	664.2	2332.6	43.9	1673.4	379.5	527.2	26.3	2.8	17.9
F45C09	1616.9	598.3	1316.8	53.9	2419.4	402.0	792.2	119.5	0.3	1.9
F46C09	1693.4	567.0	2357.6	49.9	1586.5	358.4	622.2	29.8	2.8	55.5
F47C09	1166.0	444.7	3015.0	48.3	1387.1	286.0	562.0	260.3	4.7	151.2
F48C09	120.7	698.4	4489.5	10.7	628.8	257.5	57.7	1008.5	0.6	50.8
F49C09	1286.4	428.7	2938.4	52.4	1980.1	482.6	87.8	7.5	53.3	4.1
F50C09	754.8	299.5	2141.9	30.1	2980.1	546.6	428.4	74.0	6.0	59.9

Field	Corn Area	Small Grain Area	Pasture Area	Wooded Area	Bean Area	Developed Area	Wetland Area	Open Water Area	Sunflower Area	Other Area
F51C09	737.9	371.9	2174.2	28.5	2967.3	500.2	400.8	63.0	24.1	57.1
F52C09	719.7	268.8	2144.4	23.8	3074.8	556.3	411.8	61.5	3.1	62.4
F52C09	2247.9	517.1	165.9	72.1	3499.5	457.2	127.6	6.3	165.6	65.9
F54C09	2271.7	482.0	267.2	24.5	3005.5	514.6	329.6	15.7	407.7	2.5
F55C09	2162.0	635.7	451.6	18.8	2625.5	484.8	443.1	14.4	484.2	2.5
F56C09	1206.4	942.1	721.0	89.4	3013.1	408.9	558.8	379.1	0.9	0.6
F57C09	320.5	665.8	3530.8	113.8	1206.1	402.0	413.3	666.1	0.3	5.3
F58C09	728.8	651.3	3042.5	80.0	2064.4	428.7	273.8	51.1	0.0	3.4
F59C09	927.0	430.6	2854.7	74.0	2228.8	451.0	296.7	51.7	0.0	6.3
F60C09	221.1	775.5	3625.8	2.2	1250.0	518.7	139.6	772.4	5.0	9.7
F61C09	1595.9	1129.6	357.2	74.3	3242.9	419.0	421.2	71.5	7.8	1.3
F62C09	442.2	1063.4	2419.1	101.3	2218.1	451.3	495.8	127.0	1.3	5.0
F63C09	615.9	1745.5	1021.1	32.9	2150.7	497.1	1127.4	114.8	6.6	13.5
F64C09	521.8	769.6	3663.2	38.6	1130.2	408.6	543.5	96.9	1.9	149.9
F65C09	1057.5	2016.4	1310.5	31.0	1979.8	413.3	308.9	97.5	55.8	52.7
F66C09	1013.2	1956.2	1499.0	30.1	1933.7	431.5	286.0	46.1	78.1	51.4
F67C09	269.4	2566.8	1376.4	236.8	1669.6	494.9	220.8	21.0	231.1	233.3

Field	Corn Area	Small Grain Area	Pasture Area	Wooded Area	Bean Area	Developed Area	Wetland Area	Open Water Area	Sunflower Area	Other Area
F68C09	342.5	1890.7	2686.3	25.4	1289.5	313.6	262.2	42.0	92.2	377.3
F69C10	232.4	3327.6	1621.0	4.7	185.0	376.0	395.8	9.1	477.6	692.1
F70C10	87.5	1358.8	3402.2	25.1	1007.0	328.3	779.6	148.6	52.7	131.4
F71C10	297.9	2013.3	1577.7	93.1	1659.9	290.1	746.1	15.7	96.3	532.5
F72C10	286.6	2070.1	1548.6	96.0	1661.1	285.1	742.3	16.3	90.9	523.4
F73C10	389.8	2286.5	1668.0	267.8	1748.9	328.3	303.9	18.5	186.6	127.6
F74C10	138.3	1200.1	4630.3	18.5	34.5	258.1	419.6	377.9	50.5	196.3
F75C10	67.1	1664.0	3139.4	2.8	408.9	314.2	414.6	514.3	539.4	259.3
F76C10	554.1	2444.2	898.5	13.5	2601.3	277.2	155.9	16.6	169.7	188.8
F77C10	802.8	1069.1	3223.8	40.1	977.5	319.6	581.1	77.8	28.5	201.6
F78C10	863.0	1039.6	3387.5	38.9	850.8	285.7	526.5	108.8	4.7	218.9
F79C10	507.7	1252.8	2432.0	52.7	2102.7	308.3	521.8	140.2	1.6	6.9
F80C10	504.6	1274.2	2403.7	61.2	2092.3	297.6	545.0	134.5	3.4	7.2
F81C10	1593.4	789.3	805.6	160.6	3530.5	270.0	112.6	2.5	21.0	34.2
F82C10	1306.8	912.6	2016.8	42.3	1758.4	396.1	331.2	541.3	0.0	15.7
F83C10	1232.8	864.6	2092.7	42.0	1674.3	374.8	355.3	673.3	0.0	12.5
F84C10	1230.3	894.4	2097.4	41.7	1715.1	386.0	340.6	604.3	0.0	12.5

Field	Corn Area	Small Grain Area	Pasture Area	Wooded Area	Bean Area	Developed Area	Wetland Area	Open Water Area	Sunflower Area	Other Area
F85C10	1701.9	732.9	1053.7	41.1	3254.2	286.3	149.9	32.9	70.2	3.1
F86C10	1803.5	811.9	969.3	39.8	3124.1	284.1	164.0	41.4	84.4	2.5
F87C10	1876.0	755.8	1022.6	47.7	2987.7	331.5	169.0	47.7	84.7	3.1
F88C10	425.9	368.8	3889.9	75.3	1371.1	265.3	312.0	606.2	0.6	9.4
F89C10	593.6	899.1	1534.1	36.1	2998.0	281.6	737.6	220.5	1.9	19.1
F90C10	741.4	1349.1	1447.6	58.6	2664.3	280.0	454.7	318.0	0.6	10.0
F91C10	897.5	1110.8	1385.5	52.4	2872.6	243.4	424.0	328.0	0.3	6.6
F92C10	2338.2	281.0	878.4	24.1	3146.0	348.7	103.8	11.6	178.8	11.6
F93C10	2490.0	568.2	375.7	46.4	3375.0	311.7	50.2	14.1	34.2	55.8
F94C10	2677.8	465.1	349.0	47.4	3284.6	326.5	44.8	6.6	48.6	72.4
F95C10	2630.8	519.0	364.4	48.3	3271.5	314.2	45.5	6.6	44.5	80.3
F96C10	328.3	1559.2	2917.7	1.6	536.3	261.5	149.0	493.6	937.4	139.9
F97C10	823.8	378.5	2491.6	27.9	2826.2	303.6	408.9	19.1	22.6	18.5
F98C10	853.9	363.5	2577.5	30.4	2701.7	299.2	436.5	20.1	22.0	15.1
F99C10	863.0	371.3	2514.1	27.9	2783.5	307.3	413.0	20.4	0.3	20.4
F100C10	1481.4	485.8	3076.7	38.6	1800.7	284.4	94.4	3.4	53.6	0.9
F101C10	1616.9	481.7	3002.4	40.8	1724.2	286.3	108.8	6.3	53.6	0.6

Field	Corn Area	Small Grain Area	Pasture Area	Wooded Area	Bean Area	Developed Area	Wetland Area	Open Water Area	Sunflower Area	Other Area
F102C10	709.0	326.8	3330.1	88.1	2258.9	296.0	218.3	32.0	60.8	4.4
F103C10	1472.7	578.9	2739.6	38.9	1828.0	266.2	370.7	22.6	0.0	2.8
F104C10	1060.9	364.1	1897.6	49.5	2699.8	231.8	887.5	119.5	5.3	4.4
F105C10	1023.6	433.1	1795.7	51.7	2755.9	229.2	901.9	124.5	5.3	2.5
F106C10	1145.6	517.8	2472.1	30.7	2124.0	256.5	621.2	137.7	2.5	17.6

APPENDIX V. PERCENT DAMAGE IN SUNFLOWER FIELDS

Field	Damage
F1S08	0.55%
F2S08	1.02%
F3S08	0.24%
F4S08	0.10%
F5S08	0.00%
F6S08	0.00%
F7S08	0.00%
F8S08	10.16%
F9S08	0.00%
F10S08	0.00%
F11S08	0.00%
F12S08	0.15%
F13S08	1.13%
F14S09	19.79%
F15S09	0.26%
F16S09	0.19%
F17S09	1.28%
F18S09	0.03%
F19S09	4.34%
F20S09	0.05%
F21S09	0.11%
F22S09	0.45%
F23S09	0.00%
F24S09	0.90%

Field	Damage
F25S09	0.24%
F26S09	0.28%
F27S09	1.49%
F28S09	3.15%
F29S10	1.18%
F30S10	1.87%
F31S10	0.39%
F32S10	0.22%
F33S10	2.22%
F34S10	0.00%
F35S10	0.25%
F36S10	0.06%
F37S10	12.99%
F38S10	13.57%
F39S10	6.71%
F40S10	0.00%
F41S10*	0.02%
F42S10*	0.05%
F43S10*	6.54%
F44S10*	0.39%
F45S10*	0.46%
F46S10*	0.05%
F47S10*	1.89%
F48S10*	1.35%
F49S10*	0.86%

Field	Damage
F50S10*	1.55%
F51S10*	0.70%

* denotes fields, additional to those found within the 1.6 km^2 sections, selected using the 2010 modified methodology.

APPENDIX VI. PERCENT DAMAGE IN CORN FIELDS

Field	Damage
F1C08	0.00%
F2C08	0.00%
F3C08	0.00%
F4C08	0.00%
F5C08	0.00%
F6C08	0.00%
F7C08	0.00%
F8C08	0.00%
F9C08	0.00%
F10C08	0.00%
F11C08	0.00%
F12C08	0.00%
F13C08	2.10%
F14C08	0.00%
F15C08	0.00%
F16C08	0.00%
F17C08	0.00%
F18C08	0.03%
F19C08	0.00%
F20C08	0.00%
F21C08	0.00%
F22C08	0.33%
F23C08	0.66%
F24C08	4.07%

Field	Damage
F25C08	0.00%
F26C08	0.00%
F27C08	1.46%
F28C08	0.00%
F29C08	0.00%
F30C08	5.27%
F31C08	0.00%
F32C08	0.00%
F33C08	0.00%
F34C08	0.00%
F35C08	0.55%
F36C08	0.66%
F37C08	6.33%
F38C08	4.64%
F39C09	0.53%
F40C09	0.21%
F41C09	0.65%
F42C09	0.75%
F43C09	0.00%
F44C09	0.00%
F45C09	0.13%
F46C09	0.09%
F47C09	0.00%
F48C09	1.52%
F49C09	0.00%

Field	Damage
F50C09	0.00%
F51C09	0.04%
F52C09	0.14%
F52C09	0.00%
F54C09	0.30%
F55C09	0.00%
F56C09	0.00%
F57C09	0.00%
F58C09	0.10%
F59C09	0.00%
F60C09	0.10%
F61C09	0.00%
F62C09	0.11%
F63C09	0.29%
F64C09	0.25%
F65C09	0.00%
F66C09	0.00%
F67C09	0.00%
F68C09	0.21%
F69C10	0.00%
F70C10	0.00%
F71C10	0.84%
F72C10	0.00%
F73C10	0.00%
F74C10	0.00%

Field	Damage
F75C10	0.00%
F76C10	0.00%
F77C10	0.28%
F78C10	0.03%
F79C10	0.13%
F80C10	0.02%
F81C10	0.45%
F82C10	0.00%
F83C10	0.00%
F84C10	0.00%
F85C10	0.00%
F86C10	0.00%
F87C10	0.00%
F88C10	0.00%
F89C10	0.13%
F90C10	1.21%
F91C10	0.11%
F92C10	0.00%
F93C10	0.00%
F94C10	0.00%
F95C10	0.00%
F96C10	0.15%
F97C10	0.26%
F98C10	0.05%
F99C10	1.28%

Field	Damage
F100C10	0.00%
F101C10	0.00%
F102C10	0.00%
F103C10	0.00%
F104C10	0.00%
F105C10	0.00%
F106C10	0.05%
F107C10*	0.52%
F108C10*	0.00%
F109C10*	0.00%
F110C10*	2.85%
F111C10*	0.00%
F112C10*	0.00%
F113C10*	0.01%
F114C10*	0.00%
F115C10*	1.85%
F116C10*	0.48%
F117C10*	0.38%
F118C10*	0.01%
F119C10*	0.03%
F120C10*	0.00%
F121C10*	0.49%
F122C10*	0.52%
F123C10*	0.01%
F124C10*	0.00%

Field	Damage
F125C10*	1.17%
F126C10*	0.04%
F127C10*	0.00%
F128C10*	0.24%
F129C10*	0.00%
F130C10*	0.24%
F131C10*	0.00%
F132C10*	0.00%
F133C10*	0.00%

* denotes fields, additional to those found within the 1.6 km^2 sections, selected using the 2010 modified methodology.

APPENDIX VII. PRECIPITATION IN NORTH DAKOTA

Average Annual Precipitation

City	Avg. Annual (cm)*	1930s (cm)*	1990s (cm)*
Fargo	54.1	38	68.6
Jamestown	47.6	38	58.4
Bismarck	41.2	30.5	53.3
Minot	42.7	33	50.8
Oakes	49	38	66

* Values taken from North Dakota State Climate Office

APPENDIX VIII. MODELS: LANDCOVER SURROUNDING SUNFLOWER FIELDS

(3 BEST MODELS FROM EACH SUBSET SIZE LISTED)

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
2	Beans	5.8	0.36	2.80	0.05
2	Wetland	22.6	0.11	16.28	0.07
2	Corn	22.8	0.10	16.42	0.07
3	Beans Wetland	2.6	0.43	0	0.04
3	Beans Wooded	5.5	0.38	2.96	0.04
3	Beans Open Water	5.7	0.38	3.16	0.04
4	Beans Wetland Wooded	2.8	0.44	0.57	0.04
4	Beans Open Water	3.0	0.44	0.74	0.04

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Wetland				
4	Beans	4.2	0.42	2.08	0.04
	Developed				
	Wetland				
5	Beans	3.5	0.45	1.81	0.04
	Open Water				
	Wetland				
	Wooded				
5	Beans	4.4	0.43	2.82	0.04
	Corn				
	Wetland				
	Wooded				
5	Beans	4.5	0.43	3.02	0.04
	Developed				
	Wetland				
	Wooded				
6	Beans	4.9	0.44	4.09	0.04
	Corn				
	Open Water				

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Wetland				
	Wooded				
6	Beans	5.3	0.43	4.59	0.04
	Corn				
	Small Grains				
	Wooded				
	Pasture				
6	Beans	5.5	0.43	4.72	0.04
	Open Water				
	Small Grains				
	Wetland				
	Wooded				
7	Beans	6.9	0.42	7.16	0.04
	Corn				
	Open Water				
	Small Grains				
	Wetland				
	Wooded				
7	Beans	6.9	0.42	7.20	0.04
	Corn				
	Open Water				

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Wetland				
	Wooded				
	Pasture				
7	Beans	6.9	0.42	7.21	0.04
	Corn				
	Developed				
	Open Water				
	Wetland				
	Wooded				
8	Beans	8.8	0.41	10.43	0.04
	Corn				
	Open Water				
	Small Grains				
	Sunflower				
	Wetland				
	Wooded				
8	Beans	8.9	0.41	10.49	0.04
	Corn				
	Developed				
	Open Water				
	Small Grains				
	Wetland				

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Wooded				
8	Beans	8.9	0.40	10.51	0.04
	Corn				
	Open Water				
	Other				
	Small Grains				
	Sunflower				
	Wooded				
9	Beans	10.8	0.39	13.98	0.04
	Corn				
	Developed				
	Other				
	Small Grains				
	Sunflower				
	Wooded				
	Pasture				
9	Beans	10.8	0.39	14.01	0.04
	Corn				
	Open Water				
	Other				
	Small Grains				
	Wetland				

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Wooded				
	Pasture				
9	Beans	10.8	0.39	14.01	0.04
	Corn				
	Developed				
	Open Water				
	Small Grains				
	Wetland				
	Wooded				
	Pasture				
10	Corn	12.8	0.37	17.79	0.04
	Developed				
	Open Water				
	Other				
	Small Grains				
	Sunflower				
	Wetland				
	Wooded				
	Pasture				
10	Beans	12.8	0.37	17.81	0.04
	Corn				
	Developed				

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Open Water				
	Other				
	Small Grains				
	Sunflower				
	Wooded				
	Pasture				
10	Beans	12.8	0.37	17.81	0.04
	Corn				
	Developed				
	Other				
	Small Grains				
	Sunflower				
	Wetland				
	Wooded				
	Pasture				
11	Beans	11.0	0.42	17.05	0.03
	Corn				
	Developed				
	Open Water				
	Other				
	Small Grains				
	Sunflower				
	Wetland				

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Wooded				
	Pasture				

APPENDIX IX. MODELS: LANDCOVER SURROUNDING CORN FIELDS

(3 BEST MODELS FROM EACH SUBSET SIZE LISTED)

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
2	Developed	3.5	0.08	2.68	0.01
2	Pasture	4.7	0.06	3.83	0.01
2	Water	4.8	0.05	3.94	0.01
3	Pasture Water	0.8	0.17	0	0.01
3	Developed Open Water	2.1	0.14	1.55	0.01
3	Open Water Wetland	3.6	0.10	3.14	0.01
4	Developed Pasture Water	0.6	0.20	0.05	0.01
4	Pasture Sunflower	1.9	0.17	1.6	0.01

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Open Water				
4	Pasture	2	0.17	1.71	0.01
	Open Water				
	Wetland				
5	Developed	1.9	0.19	1.9	0.01
	Pasture				
	Sunflower				
	Open Water				
5	Developed	2.1	0.19	2.21	0.01
	Pasture				
	Open Water				
	Wetland				
5	Developed	2.2	0.18	2.38	0.01
	Pasture				
	Open Water				
	Wooded				
6	Developed	3.3	0.19	4.11	0.01
	Other				
	Pasture				
	Sunflower				

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Open Water				
6	Beans	3.4	0.18	4.26	0.01
	Developed				
	Pasture				
	Sunflower				
	Open Water				
6	Developed	3.6	0.18	4.52	0.01
	Pasture				
	Sunflower				
	Open Water				
	Wetland				
7	Developed	5.2	0.16	7.12	0.01
	Other				
	Pasture				
	Sunflower				
	Open Water				
	Wooded				
7	Beans	5.2	0.16	7.13	0.01
	Developed				
	Other				

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Pasture				
	Sunflower				
	Open Water				
7	Beans	5.2	0.16	7.14	0.01
	Corn				
	Pasture				
	Small Grain				
	Sunflower				
	Wetland				
8	Beans	7.1	0.14	10.3	0.01
	Corn				
	Developed				
	Pasture				
	Small Grain				
	Sunflower				
	Wetland				
8	Beans	7.1	0.14	10.32	0.01
	Corn				
	Other				
	Pasture				
	Small Grain				
	Sunflower				

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Wetland				
8	Developed	7.1	0.14	10.32	0.01
	Other				
	Pasture				
	Sunflower				
	Open Water				
	Wetland				
	Wooded				
9	Beans	9	0.12	13.67	0.01
	Corn				
	Other				
	Pasture				
	Small Grain				
	Sunflower				
	Water				
	Wetland				
9	Beans	9	0.12	13.69	0.01
	Corn				
	Developed				
	Other				
	Pasture				
	Small Grain				

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Sunflower				
	Wetland				
9	Beans	9	0.12	13.73	0.01
	Corn				
	Developed				
	Other				
	Small Grain				
	Sunflower				
	Open Water				
	Wetland				
10	Beans	11	0.09	17.43	0.01
	Corn				
	Other				
	Pasture				
	Small Grain				
	Sunflower				
	Open Water				
	Wetland				
	Wooded				
10	Beans	11	0.09	17.44	0.01
	Corn				
	Developed				

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Other				
	Pasture				
	Small Grain				
	Sunflower				
	Open Water				
	Wetland				
10	Beans	11	0.09	17.46	0.01
	Corn				
	Developed				
	Other				
	Pasture				
	Small Grain				
	Sunflower				
	Wetland				
	Wooded				
11	Beans	11	0.12	18.84	0.01
	Corn				
	Developed				
	Other				
	Pasture				
	Small Grain				
	Sunflower				
	Open Water				

Subset Size	Variables	Cp	R^2	Change AICc	Residual SS
	Wetland				
	Wooded				