2021

A Joint Estimation of Pheasant Hunting Parameters

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A JOINT ESTIMATION OF PHEASANT HUNTING PARAMETERS

BY

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A thesis submitted in partial fulfillment of the requirements for the

Master of Science

Major in Economics

South Dakota State University

2021

THESIS ACCEPTANCE PAGE

Rama Khadka

This thesis is approved as a creditable and independent investigation by a candidate for the master's degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest and most sincere gratitude to my research supervisor Dr. Matthew Diersen for giving me the opportunity and providing invaluable guidance throughout this research. He taught me from the beginning to carry out the research and to present the work as clearly as possible. It was great privilege and honor to work and study under his guidance. I would also like to thank the other members of my thesis committee, Dr. George Langelett, and Dr. David Davis for their advice and support. My sincere appreciation goes to Dr. David Davis for helping me understand the econometric concepts and being willing to provide help and advice whenever and wherever I needed. I would like to thank my graduate school representative, Dr. Michele Dudash for her willingness to serve on my committee.

I would also like to thank Sprih Harsh for her support, and Dr. Robert Lonsinger for his suggestions with kindness and enthusiasm to carry out my thesis. I am thankful to Travis Runia and his colleagues for helping me get pheasant data for my research. My sincere appreciation also goes to my fellow graduate students for their friendship and support, all other faculty members in the Ness School of Management & Economics Department for their care and willingness to help.

Finally, I am extremely thankful to my parents and my family for their love, support and encouragement to pursue my dreams. My special and profound thanks to my brother for being there for me in every situation I faced and my friends for their time and support throughout this journey.

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ABSTRACT

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The decreasing pheasant population from 2008 to 2019 across South Dakota is a concern as it may lead to decreased hunting activity and consequently reduced economic activity. Past studies have shown that changes in the landscape (e.g., from changing agricultural practices) is a major factor responsible for decreasing the bird population. However, these studies lack a clear understanding of how the fluctuating crop mixes impact the pheasant population together with harvest volume. The goal of this study was to analyze the pheasant population and the quantity of harvested birds during 2008 to 2019 in South Dakota to understand how variations in some of the key crop areas were associated with pheasant population. The study focused on understanding how bird population and number of hunters influence the pheasant harvest volume. To achieve this goal, a simultaneous equation model was employed to estimate both bird population and harvest volume jointly. The study showed that wheat, alfalfa and Conservation Reserve Program (CRP) acres were positively related with pheasant population. Similarly, the number of hunters and bird population were positively related with the number of harvested birds. There was a negative relation of corn/soybean and other hay acres with both variables. It was also found that wheat and alfalfa acres were strong determinants over CRP acres and winter wheat was more likely than other crops to enhance pheasant

population and harvest volume. Efforts to increase small grains and forage crops, including CRP acres, may be necessary to maintain and increase pheasant population and harvest volume.

CHAPTER ONE

1. Introduction

There have been ups and downs in the pheasant population in the U.S. since its establishment. Various factors such as landcover and land-use, weather, agricultural practices and crop mixes have played roles influencing the condition of habitat for these birds and consequently the population of the birds. Being a game bird, pheasants play a role in economic activity in various states across the country. Therefore, understanding the demand for and supply of pheasants, a major goal of this research, becomes vital for policy makers at the state and federal levels.

Establishing a pheasant population in the U.S. was a challenging undertaking. A number of attempts were made more than 150 years ago. It was reported that a release of Chinese ring-necked pheasants (*Phasianus colchicus*) in the late 18th century in the Willamette Valley of Oregon was the first successful attempt at establishing the population in North America. Though early growth and spread was slow, the pheasant population was established quite well by the late 1930's. Most of the range where pheasants are found today was established as pheasant habitat by that time, leading to pheasants being nationally prominent birds for recreational and gaming purposes (Hallett et al., 1988). These gaming activities contributed substantially to state economies around the country. It was reported that more than $502 million of economic impact was achieved in 25 states annually between 2006 and 2009. The primary source of economic impact was the hunting license fee, which was estimated to be $68 for resident hunters and $118 for non-resident hunters (combined average of $83) per harvested bird (Midwest Pheasant Study Group 2013).

When it comes to South Dakota, ring-necked pheasants were introduced in the early 1900s. Some of the earliest successes in introducing pheasants in South Dakota were observed in the James River corridor (Flake et al., 2012), which still remains an area with a strong pheasant population and consequently higher levels of hunting activities. Ever since, populations in the state have fluctuated between 16 million birds in the mid 1940s to 2 million birds in 1986 (Past Pheasant Statistics, SDGFP). Introduction of the Conservation Reserve Program (CRP) in 1985 by the United States Department of Agriculture (USDA), a provision of the Federal Food Security Act of 1985 (i.e., the Farm Bill) (Eggebo et al., 2003), was an important step towards improving pheasant habitat around the country, including in South Dakota. This program contributed to reversing the trend in South Dakota and increased the pheasant populations over the following decades. Pheasant population was found, in general, to be increasing in South Dakota during 2000s as well, though there were annual fluctuations, leading to an estimated population of 11.9 million birds in 2007, which was the highest between 1986 and 2018. As shown in figure 1.1, the bird population started to decline from 2008 onward, going down to 7.1 million in 2018 (Past Pheasant Statistics, SDGFP). Another important indicator of pheasant health and population is the harvest statistics, which also showed a similar trend between 2000 to 2018. Pheasant population was estimated using an annual survey conducted along a number of survey routes. The number of birds counted per mile of the survey routes was extrapolated to estimate the total population. The survey data (pheasant population per survey route mile) plotted in figure 1.1 clearly depicts such a trend in the pheasant population from 1993 to 2018. Figure 1.1 shows the average pheasant population per mile across 58 counties in South Dakota from 1993 to 2019. Even though there are 66 counties in SD, only 58 counties were included in this study, because no pheasant per survey route mile data was available for the remaining 8 counties.

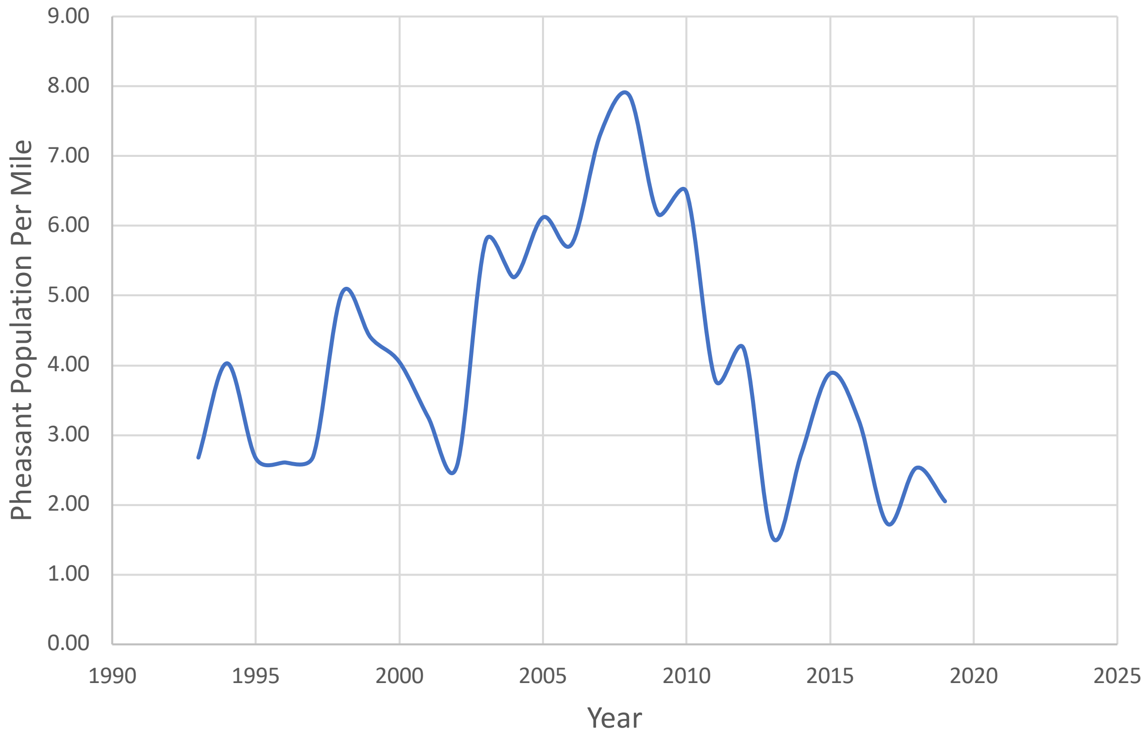

Figure 1.1 Trend of pheasant population (per mile) over the entire study area (58 counties) from 1993 to 2019 (Source: SD Game Fish & Parks).

South Dakota is considered as one of the most important states for ring-necked pheasants. Therefore, a large number of hunters visit South Dakota from many other states and other countries. Pheasant hunting activity plays an important role in the State's economy through purchasing licenses, fuel, food and accommodations. Although the license sale is a key source for generating revenue, pheasant hunting is facilitated by several other factors (hotels, restaurants and other business) that produce income for rural communities. As per the U.S. Department of Interior, an estimated nationwide economic impact of pheasant hunting was $154.5 million in 2014 (Runia et al., 2016). It was estimated that resident and non-resident hunters contributed approximately $202.4 million in 2019 in the state, while Brown County generated the highest level of $12.8 million among all counties, followed by Brule County with $11.4 million and Tripp County with $10.3 million (2019 Pheasant Economics, SDGFP). The level of economic activity (and the economic impact) in each county generally was proportional to the bird population in those counties.

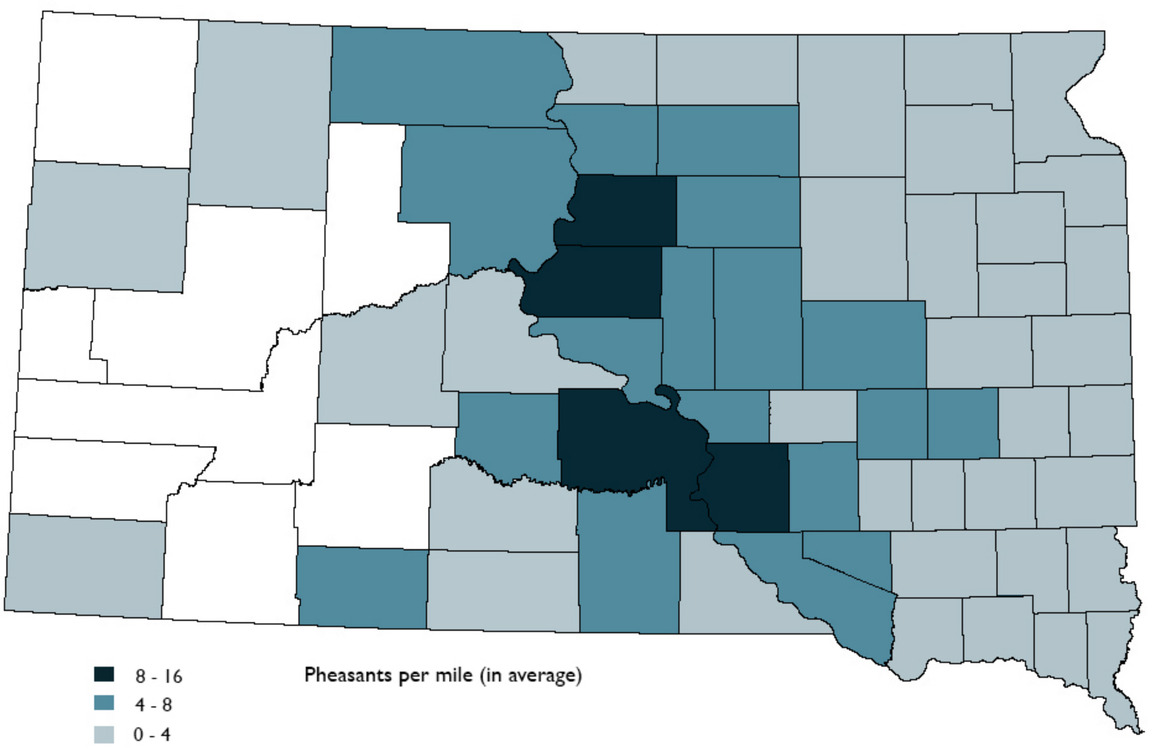

Figure 1.2 County-wide average pheasant population (per mile) over 2008 to 2019 (Source: SD Game Fish & Parks).

As can be seen from figures 1.2 and 1.3, Lyman (15.66) and Brule (13.82) counties had the highest number of birds counted per mile of the survey routes and

Brown (76,815) and Tripp (73,843) had the highest number of birds harvested, which is proportional to the amount of dollars generated by hunting activities in those counties. On average, 1.3 million pheasants were harvested annually in South Dakota from 2008-2019, which is a measure of the value of bird hunting and hunters in the state's economy (Past Pheasant Statistics, SDGFP).

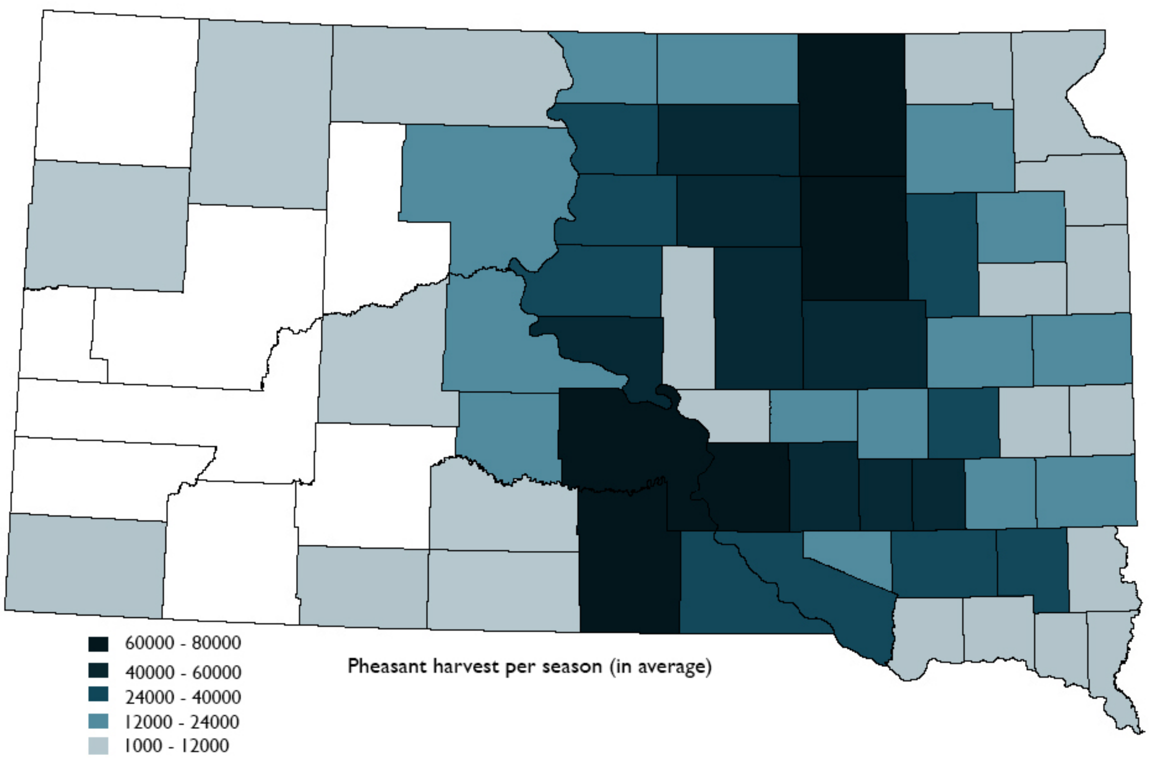

Figure 1.3 County-wide average pheasant harvest (per season) over 2008 to 2019 (Source: SD Game Fish & Parks).

Even though pheasant hunting has played an important role over the decades, there are specific challenges to maintain it in this rural state. There has been significant fluctuation in pheasant populations over the years. Low, unpredictable and unstable pheasant populations are a great problem for maintaining and increasing the economic impact of bird hunting in South Dakota. Some of the specific important factors causing population variation are crop production systems, farm size, and availability of grasslands (Hansen et al. 1999). As shown by prior studies, swamps, mixed croplands, dense vegetation and grasslands are desirable to maintain a healthy pheasant population. Schmitz and Clark (1999) and Leif (2005) emphasized the importance of mixed crops fields and grasslands for the pheasant population to flourish. As indicated above, there have been dramatic changes in farming methods, crops, and farming equipment in the past century, which have negatively affected the habitat and food supplies for pheasants (Flake et al. 2012). In addition, there has been an increased consolidation of smaller fields with mixed crops into larger fields with one kind of crop, which also caused a negative impact to pheasant habitat and population levels. These changes in agriculture have led to a net reduction in grassland, increased monocrop agriculture, increased number of relatively larger agricultural fields, and loss of annual weeds in the last two decades, leading to reduction in pheasant abundance across much of South Dakota (Flake et al. 2012).

It is important that land use (e.g., farming, grassland, swamps) should be maintained to create a good mix and diversity of cover desirable for healthy habitat and therefore, a healthy population of pheasants. It was found, through historical data analysis, that a severe decline in pheasant population is generally linked to changes in land use and weather (Laingen 2008, Labisky 1976; Trautman 1982). However, there are different parameters believed to have affected the bird population. A couple of examples would be climate shifts and predators that can play a role in how well birds can maintain their population. In many circumstances, healthy habitat created by good cover types and availability of intensified grassland is important. In the past, CRP maintained millions of acres of land in undisturbed grassland, which contributed significantly to maximizing the pheasant population (Riley, 1995; Nielson et al., 2008). As per Ryan, Burger, Kurzejeski (1998), initiation of CRP and coincidental milder weather led to a significant increase in the pheasant population and hunting activities in South Dakota. Researchers also reported that an increased bird population led to an increased economic benefit to many communities around a number of states caused by increased hunting activities (Bangsund et al., 2004). Later, as the land area enrolled in CRP continued to decrease, pheasant populations continued to decline throughout several states (USDA-FSA, 2007, 2015).

Moreover, there has been an increase of transformation in the land use system, such as conversion of agricultural lands near larger cities to urban development over the past century, that has negatively impacted bird habitat, leading to a decline in pheasant production. It is noted that the major landscape changes caused by modern agriculture and transportation infrastructure had a more significant influence on the pheasant population than any other changes since the initial efforts to establish pheasants in South Dakota (Flake et al. 2012).

There have been studies in the past focused generally on understanding the impact of some factors, such as CRP or similar conservations programs, and agricultural intensification on pheasant population in different parts of the U.S., including various counties in South Dakota. However, no specific studies have been reported in recent years that focus on understanding how the fluctuation of specific major crop-mix acres impact the pheasant population and how the harvest volume is influenced by other key factors in South Dakota counties where pheasant brood survey routes are available.

Because bird population and quantity of harvested birds are key aspects that affect the state's economy, where harvested volume is a suitable proxy for bird density, it is important to analyze both parameters together. Furthermore, no study has investigated the relationship between some specific crop-mix acres and harvested number of birds during recent years. This study was conducted to understand how variation on these crop and grassland acreages, including CRP, impact the bird population and how pheasant population and hunters impact the harvest volume, along with the relationship of these mix-crop acres and harvested birds during 2008 to 2019. Such a study will be crucial for further planning to maintain suitable habitat and an increase or a stabilization of the pheasant population so that states may continue to maintain or increase the economic activity related to pheasant hunting including license sales to hunters.

Research Objectives

The purpose of this study is to analyze the pheasant population and overall harvest of birds during 2008 to 2019 using the empirical data of 58 counties across South Dakota. The study will use the joint estimation of pheasant population and harvested bird equations. The relationship of crop-mix acreages and harvest volume will be examined by employing a reduced equation estimation separately. Moreover, the county variables used in the study will specify the population density and magnitude of harvested birds specific to each county. The following are the specific objectives of the study:

1. Examine the impacts of land use changes (corn, soybeans, wheat, alfalfa, other hay and CRP) on pheasant population,

2. Investigate how pheasant population and hunter numbers determine the pheasant harvest,
3. Study the relationship between major land uses and pheasant harvest, and
4. Analyze the population density and harvest volume specific to each county.

The study includes four chapters beside this one. Chapter two is a review of literature on impact of landcover changes, limitations of CRP, impact of weather, other factors and economics of pheasant hunting. The research materials and methods used in the study is explained in chapter three. Chapter four discuss the empirical results found in this analysis. Chapter five delivers summary and limitations of this study, including management implications and recommendations for further research.

CHAPTER TWO

2. Literature Review

A number of studies have been conducted in the U.S. and around the world in understanding various aspects of health and well-being of the pheasant population. These studies span from understanding the effect of various land/natural resource conservation programs managed by government agencies (e.g., CRP) to changing crop mixes to extreme weather conditions. Studies have found that pheasants like habitats with herbaceous vegetation, which allow sufficiently open ground for broods to walk around (Hill, 1984). The vegetation should also be sufficiently tall to protect birds from predators. It has also been found that crops such as winter wheat, oats, and other small grains can provide good nesting cover, thus encouraging an increased bird population (Snyder 1984, Warner et al. 1999).

Impact of Landcover Changes

Past studies show that maintaining grassland would be beneficial to improve pheasant habitat (particularly nest covering) and therefore their population. Both quantity and quality of grassland play an important role in increasing pheasant production. Frank and Woehler (1969) studied the potential of habitat manipulation to maintain and enhance ring-necked pheasant populations and hunting success. The study focused on food and cover manipulation and its impact on pheasants and other wildlife to pre-management conditions of the habitats. The study was conducted in the Waterloo Wildlife Area in Southern Wisconsin consisting of 2,400 acres of state-owned game land and 13,600 acres of privately-owned farmland, which began in 1963 and was continued over 6 years. The study found that planting canary-grass, Blackwell switchgrass and brome-grass produced the most satisfactory type of residual nesting cover on upland sites, whereas planting canary-grass and timothy gave the best results on peat soils. The study also found that pure stands of alfalfa and red clover provided poor residual cover due to lodging and over-winter leaf loss. Forage sorghums and sorghum-sudan grass hybrids were established annually, which provided the best winter cover on upland areas during a single growing season. In addition, it was found that lodging of nesting cover was a problem on organic soils and on fertile uplands during excess rainfall in May and June.

One of the ways landcover changes over time is the changes in farming practices. Hanson and Progulske (1973) analyzed the pattern of movement and ground cover preferences of 13 ring-necked pheasant hens, 8 of which had broods. The study was conducted in 640 acres of private farmland in east-central South Dakota using radio-telemetry technology from June to October in 1969 and 1970. It was observed that both nesting and non-nesting hens moved to nearby standing cover such as alfalfa, rye or oats when they were disturbed by harvesting or by field plowing. The study concluded that pheasants preferred alfalfa fields much more than other widely available natural covers, as it was good for nesting and brooding.

Over the last several decades, the agricultural landscape has been changing with larger commercial farms that prefer larger, contiguous acreage of single crop types leading to less diverse landcover mixes (Wimberly et al., 2017). This change can negatively impact pheasant habitants (Warner 1989, Hiller et al. 2009). Coates et al. (2017) analyzed Breeding Bird Survey (BBS; annual survey by U.S. geological survey) data collected during 1974-2012, Christmas Bird Count (CBC) data collected during

1914-2013, and hunter data from Annual Game Take Survey (AGTS) collected during 1948-2010. They used a joint response abundance index to integrate these three types of data and found that there was a significant decline in ring-necked pheasant population in agricultural environments in California. The authors argued that the decrease in bird population was caused by major changes in agricultural practices over the last three decades leading to a loss of preferable habitat for birds.

Conservation Reserve Program (CRP)

In this context, Conservation Reserve Program (CRP) and other similar land conservation efforts by state and federal governments have been playing a key role in changing the land-cover at local and at landscape levels, which can then play a significant role in the well-being of pheasants. CRP has been viewed as the most effective program for improving the field age and cover type in several northern states including South Dakota, which has a positive impact on pheasant abundance and productivity. CRP grasslands became even more important in recent decades to maintain ring-necked pheasant populations because of the loss of native grasslands around bird habitats (Eggebo et al., 2003).

One important study to understand the effect of CRP on ring-necked pheasants was conducted by Nielson et al. (2008). They analyzed ring-necked pheasant population and CRP land cover data across a number of states using datasets available from federal agencies. The study was conducted with data from 1987 to 2005. The study used Breeding Bird Survey (BBS) data along 388 BBS routes in nine states. The study was limited to the areas within these states where the BSS survey recorded at least one bird during the study period. Geographic Information System (GIS) data for land cover classes (National Land Cover Dataset, NLCD) and CRP land use maps (FSA and USDAERS) were also collected from direct sources. CRP land use maps were available at the county-level for nine states used in the study. In terms of CRP practices, they grouped CRP practices into five categories to represent the variations in vegetation structures. The study used the program called FRAGSTATS to calculate an index of interspersion-juxtaposition (McGarigal and Marks 1995) for the land-use categories. A statistical method was then used to analyze the dataset over the study period and study site to assess the relationship of pheasant counts along BBS routes and CRP landscape data (discussed above). The authors used a Bayesian hierarchical modeling approach, which was capable of providing different levels of relationships between bird population and CRP land area. Markov Chain Monte Carlo (MCMC) analysis (Link et al. 2002) was used to model BBS counts of pheasants in specific regions. This model was capable of incorporating the spatial heterogeneity present in the NLCD and CRP cover types and the multilevel sampling design of the BBS route survey. These models were employed in WinBUGS software (version 1.4.1, Spiegelhalter et al., 2003). The study found that an increased number of pheasants were because of not only the presence of herbaceous-vegetation category, but also because of other CRP and agricultural practices leading to a better mix of agricultural crops, and woody and herbaceous vegetation.

Similarly, Taylor et al. (2018) studied the effect of improved landcover mix created by conversion of agricultural land to grassland through CRP on pheasants. They reported that birds preferred landscapes with a mix of cropland and grassland cover types as they found waste grain as a good source of food and herbaceous cover for nesting and hiding from predators. A study done in eastern South Dakota by Eggebo et al. (2003) also noted that CRP made a large positive impact on pheasant abundance and productivity. In this study, the authors graded CRP grasslands by CRP stand age; old (10 to 13 years) vs new (1 to 3 years) and cover type CP1 (cool-season grasslands) vs. CP2 (warm-season grasslands) and found that combination of old (10-13 years of age) and cool-season CRP grassland provided the best pheasant habitat among all evaluated cases. Other studies, however, found that the benefit of CRP in providing good habitat for nesting and brood-rearing of pheasants can decline after initial establishment of the CRP land because habitat quality can decrease with field age, which can impact pheasants negatively.

Rodgers (1999) found that interspersion of grass–legume strips on intensively farmed croplands could be helpful to improve the pheasant habitat in addition to CRP lands. In addition, they found that habitat of established CRP can be enhanced by strip-disking a small strip of land around margins of fields. This process can help control burning and hinder broad-leaved plants. In agreement with this finding, a mandatory requirement was established by the United States Department of Agriculture on CRP land. Starting 2004, for new CRP contracts, farmers would need to alter grass and field management in the mid-contract period, which can be fulfilled by discing/ploughing the land and inter-seeding with new legumes. In addition, to fulfill the gap of whether this kind of mid-contract management improves the habitats and population of pheasants. Matthews et al. (2012) studied the response of pheasant population to cropland conversion program with mid-contract management practices. The study was conducted during 2005-2006 in 12 fields in Stanton County, Nebraska to investigate how such practices impacted pheasant hens, especially in the nesting and brood-rearing stages.

They also investigated pre-nesting movements of hens as impacted by management. One of the methods used in this study was radio telemetry to track the birds and locate the habitat. They completed the study at two levels, macro (topographic level) and micro (crop structure level), which is important to understand the overall impact of these mid-contract management practices to the wellbeing of this species. It was found that disced and interseeded CRP (DICRP) fields had greater vegetation density and structural heterogeneity compared to monotypic grasslands found in unmanaged CRP and pasture fields. Pheasant hens could produce higher percentages of chicks and rooster production was also more than doubled in DICRP fields.

Similarly, Matthews et al. (2012) found that pheasant hens preferred dense and tall nesting cover and greater forb composition along with managed portions of CRP fields for both nesting and brood-rearing. Interseeded grasslands, such as alfalfa and sweet clover fields, were shown to be effective for increasing the use of CRP fields by pheasants as these grasses have dense vegetative structure and rapid growth rates compared to other fields.

One key indicator of healthy habitat for pheasants would be their success in nesting and brooding. Some studies have examined how pheasant nests were affected by habitat characteristics and its use. For example, hay harvesting can cause the destruction of pheasant hens and embryos. Warner et al. (1989) analyzed the survival of female pheasants and embryos in the time of forage harvesting. The objective was also to consider the implications of harvest dates for pheasant management. The study analyzed 1,104 ring-necked pheasant nests in harvested and unharvested hayfields which covered a

9,393 ha Sibley Study Area (SSA) from 1962-1972 in Ford County, Illinois. This research found that mortality rates of female pheasants and embryos were high during hay harvesting; specially when it coincided with the late stages of incubation. The study suggested that there was a potential for increasing the quantity and quality of nest cover through CRP like programs by diverting farmland production of key commodities, especially, to set-aside programs with annual contracts. Similarly, Pauly et al. (2018) studied pheasants on their selection of successful nesting sites in relation to land-use type and other landscape level habitat characteristics (e.g., patch size, shape, and juxtaposition). A total of 123 pheasant nests were studied during 2011-2012 in a 65,546-ha area located in Lyman County, South Dakota. The study found that pheasants were 66% more likely to select CRP grassland than winter wheat for nest sites and used spring wheat and other land-use types at a lower rate. However, the study found the nest success and nesting chronology was similar in both CRP and winter wheat.

Limitations of CRP

As discussed before, CRP and other conservation programs have been found to be helpful to covert farmland into grassland and other landcover that has helped improve pheasant habitat and increase the population. However, the potential expiration of CRP contracts could result in the loss of critical habitat. To understand the impact of CRP expiration, Geaumont et al. (2017) compared the ring-necked pheasant response on four CRP land types that may potentially be converted back to crop production: 1) season-long grazing, 2) hay land, 3) no-till corn (Zea mays), and 4) no-till barley (Hordeum spp.). The study used a randomized complete block design where each block (study site) was replicated and was assigned five treatments. The study showed that maintaining CRP grasslands that provide nesting cover would be beneficial to increase pheasant production. It was also found that expiration of CRP contracts that changed the CRP grasslands to crop production negatively impacted pheasant population in a study site in North Dakota, because crop production caused low nest densities. They suggested that conversion of CRP to livestock production might be a helpful option if vertical structures with visual obstructions are available for secure nesting.

Taylor et al. (2018) recommended to continue CRP programs with current characteristics, but also to increase the acreage and quality simultaneously. It is also noted that there has been increasing change from grassland to croplands in the last few decades, and therefore the effect of CRP and other conservation program on habitant improvement is being neutralized by the expansion of cropping systems, which can be problematic for maintaining pheasant population if new policies are not implemented (Wimberly et al., 2017). Rodgers (1999) studied the distributional population changes in ring-necked pheasants over time using existing survey data and RMC index (p/100) methods (Warner, 1981). Expected values for Chi-Square analysis was determined by comparing proportions of independent pheasant observations. The study used paired – field experimental design to compare CRP (a habitat gained) and weedy wheat stubble (a habitat being lost). They found that the population dropped by an average of 65% from 1966-1975 to 1986-1995 in western Kansas and have not recovered even after a large area of CRP grasslands was added. This effect was primarily because the sharp decline in the quality of wheat stubble habitats could not be compensated for by CRP grassland. In addition, benefits from CRP were also found to be limited because of insufficient plant diversity and poor stand maintenance. Similarly, Nielson et al. (2008) also found that some regions they studied saw declining bird populations even with increasing CRP enrollment, which was related to the loss of habitat and increased mortality of chicks.

To summarize, CRP and similar programs enacted before CRP have played a critical role in increasing the quantity and enhancing the quality of habitats for pheasants (especially by increasing nest cover and reducing interferences) by diverting some crop/fields into dedicated grasslands. Diverse vegetation and grassland cover save pheasants from several obstacles, such as extreme winters and predators. In addition, these programs have helped increase biodiversity that have the potential to increase food supplies while enhancing habitats. These features have benefited pheasants leading to an increased population of these birds in the areas where enrolment in CRP is at a reasonable level including the study area used in this research. Such benefits, however, were found to erode over the age of the CRP stand, and therefore, new mandates on mid-contract reseeding were put in place for the CRP program starting in the mid 2000's.

Impact of Weather on Pheasant Population

Harsh winter weather is a key factor that may cause a decline in pheasant population in a large number of U.S. states (including Northern Great Plains states) that have generally colder winters. One way to protect birds from winter damage is to provide good cover in their habitats. Frank and Woehler (1969) reported that the average mortality rate among hens was found to be 51% during winter in east-central Wisconsin over a 7-year period. Gabbert et al. (1999) studied the impact of severe winter on survival and habitat use of pheasants during one of the most severe winters in eastern South

Dakota. The study chose three sites (~1,035 ha) in western Moody County. They analyzed data from 58 radiomarked hen pheasants during 1995-1996 and 48 hen pheasants at the beginning of 1996-1997 winter at the same sites. It was found that survival of hen pheasants was higher in 1995-1996 than 1996-1997. The study observed a higher death rate of hen pheasants because of predation than weather in both winters. It was because extreme weather made them weak and vulnerable and were easily killed by predators. In addition to severe winters, wet springs have also caused substantial decreases in pheasant populations (Laingen, 2008).

One way the impact of severe winters can be minimized is to provide tall and strong vegetation around the pheasant habitat that can withstand heavy snowfalls and provide continuous cover for the birds. Gabbert et al. (1999) found that shelterbelt and corn food plots worked the best in helping pheasant survival during extreme winter conditions and concluded that habitats with shelterbelts and food plots were important for maintaining the pheasant population in eastern South Dakota. As per Robertson (1996), another landcover that helps with winter weather is emergent wetland vegetation and shrublands as they provide good shelter from extreme winter weather while also providing cover for avoiding predators.

Other Factors

Changes in agricultural programs and practices can affect pheasant populations and its hunting value, not just because of land-cover changes, but also due to changes in chemicals usage. For example, increased use of insecticide due to more intensive agricultural practices can cause nesting and chick bearing problems and thus can lead to reduced pheasant populations (Hansen et al., 1999). Coates et al. (2017) also found negative impacts on pheasant populations in states like California that was related to high levels of pesticide application in farming. Similar impact of insecticide on pheasant habitat was also reported by Rodgers (1999) in Kansas.

Another factor that plays a role in pheasant population is availability of insects as food for broods. It was found that some mix of broad-leaved plants can be a good component in the habitat to produce insect foods for broods (Doxon and Carroll 2010, Smith et al. 2015). Another factor that is playing a role is the long-term climate pattern. It has been reported that climate change has led to changing landscapes (in terms of landcover), which, as discussed before, impacts the pheasant population (Laingen, 2008).

Economics of Pheasant Hunting

Pheasants are one of the gaming birds with great economic impact. While the hunting population is generally decreasing, it was found that population of pheasant hunters in South Dakota (both in-state and out of state) increased by more than 30% between 1960 to 2005 (Laingen, 2008). Taylor et al. (2018) stated that "since 1991 and likely many decades prior, more hunters have pursued pheasants than any other upland game bird in the United States". Economic activity from hunting was approximately $585 million in 2015 when some 850,000 hunters participated in pheasant hunting (U.S. Fish and Wildlife Service and Bureau of the Census 2011). Another study by Hansen et al. (1999) analyzed the value of hunting pheasants to individuals. Using such analysis, they estimated overall economic value of pheasant hunting and how changes in agricultural practices can change economics of pheasant hunting. In this work, first a random utility model (RUM) was used to estimate the hunting site value for individuals based on travel distance to the hunting sites. Then, a participation model was used to estimate the level of participation of individuals in hunting. Behavioral data (behavior of hunters) for the study was acquired from a survey whereas field/habitat related data was collected from census data and other federal databases. They found that, using GIS-based modeling and analysis, the benefit of CRP programs would be enhanced if more distributed approach is taken. This approach, however, was estimated to negatively impact the hunting income by about $10 million because hunters would have to travel longer distance. The study found that, such loss in hunting benefit would be more than compensated by other direct and indirect benefits such as increasing activity of other wildlife and availability of water recreation. It is noted that, in addition to South Dakota, the economic benefit of this industry is also substantial in North Dakota and other surrounding states (Laingen, 2008).

CHAPTER THREE

3. Research Materials and Methods

The pheasant population (measured in terms of number of pheasants per mile of the survey routes) and the amount of pheasant harvest (total number of pheasants harvested by resident and non-resident hunters per year in the study area) are the dependent variables of interest in this study and will be modeled to determine their relationship with imperative explanatory variables. Supply (pheasant population) and demand (pheasant harvest) models are developed based on independent variables such as major crop and grassland acres and number of hunters, factors likely to affect the dependent variables the most. The selection of these independent variables is based on findings reported in previous studies (Coates et al., 2017, Geaumont et al., 2017, Matthews et al., 2012) and other types of data available.

In the following four major segments, this chapter describes the materials collected, and methods used to study this relationship. The first section (Sec. 3.1), conceptual framework, explains the factors that have a potential to substantially influence pheasant abundance and the harvest volume. The second section (Sec. 3.2) describes the structure of the study area. The data collection methods used, and the data collected and used in the study are discussed in Sec. 3.3. Sec. 3.4 explains the model that is used to determine the relationship among these variables.

3.1 Conceptual framework

A healthy habitat is crucial for a healthy pheasant population. As a ground nesting bird, pheasants need both higher quantity and quality of grasslands providing good nesting cover than other species. Some of the major features of good quality pheasant habitat include idle farmland, low-intensity farming, and protected grasslands (Trautman, 1982). Pheasant populations can fluctuate significantly due to changes in the landscape-level habitat over time. For example, fluctuations of pheasant populations in South Dakota since the establishment of the bird has been attributed to changes in the habitat (Flake et al., 2012). Both local and federal level changes in policies and practices toward ground/cover (such as crop types) can make a huge impact in habitat quality and quantity and, therefore pheasant population.

One important federal policy, the establishment of the Conservation Reserve Program (CRP), has made a great positive impact on pheasant population around the country. The policy established high quality ground/cover (e.g., undisturbed herbaceous plants) for nesting and brood rearing through federal land-retirement programs (Trautman, 1982). This program, its positive impact, and its limitations have been discussed in the literature review.

There were other voluntary conservation programs designed to aid pheasant population growth before initiation of CRP) including the Soil Bank (1956 Soil Bank Act) and Cropland Adjustment Program (1965 Food and Agriculture Act). These programs produced thousands of acres of grassland habitat hospitable for pheasants by enrolling agricultural lands. These programs increased the mixture of crop/land and grasslands, which played a significant role in enhancing pheasant populations (Flake et al., 2012).

3.1.1 Features of Pheasant Habitat

As many studies have shown, pheasants need structural diversity in vegetation in their habitat, which is of prime importance for nesting and brood-rearing. In a study conducted by Hanson and Prougulske (1973), both nesting and non-nesting hens preferred standing cover such as alfalfa, rye or oats when they were disturbed by harvesting or by other field work. Thus, standing cover like alfalfa is important during the nesting period and also for brood rearing and roosting. Moreover, it has been found that pheasant hens prefer tall grass (>75 cm), cattail (Typha spp.) wetland, and corn as food plots in the landscape. Maintaining these habitat features through various efforts like CRP is also important to protect pheasants from severe winter and help them adapt to changing climate and land use (e.g., caused by changes in agricultural practices as discussed in Chapter 2; Laingen, 2008). Smaller patches of land (a few acres) with winter cover around agricultural or other open fields, as well as introduction of shelterbelts, would also be helpful (Frank and Woehler, 1969; Gabbert et al., 1999) to minimize negative impacts on bird population by climate and weather conditions.

3.1.2 Conservation Reserve Program (CRP)

CRP is the most recent and most comprehensive voluntary program for improving land cover mix. CRP is one of the largest private land conservation programs in the United States administered by Farm Service Agency (FSA). CRP has been instrumental in preserving ‘environmentally sensitive and fragile lands’ by maintaining more land cover with grass and trees for long terms since the beginning of this program. Through this program, private landowners can enroll their acreage into CRP and are compensated by the government for such voluntary participation. Specifically, highly erodible and other crop lands are enrolled into CRP creating idle conservation land (Flake et al. 2012). Some studies (e.g., Laingen, 2008) have found that some landowners can achieve higher returns through either farming or renting the land to other crop producers than by enrolling the land in CRP programs. Therefore, it is important to review and update CRP programs to provide similar or higher returns to landowners who are willing to enroll in CRP. Important features of CRP program on conserving natural habitat are briefly summarized below. More detailed discussion on the impact of CRP on pheasant population can be found in Chapter 2.

Among a large number of benefits to wildlife, CRP program can provide restoration of native vegetation and wetlands and supply more abundant food sources (Barbarika et al., 2004). Past studies have also shown that variations in undisturbed herbaceous cover offered by CRP have been creating significant changes in the pheasant population over the years providing support to birds in all seasons (Nielson et al., 2008). However, it was found that the most significant increase in pheasant population is associated with CRP habitat covers with large patches enrolled for longer term contracts like 10 to 15 years (Laingen, 2008).

The expiration of CRP contracts can lead to converting CRP grasslands to crop production, negatively impacting pheasant populations, because nesting hens try to avoid crop fields leading to lower nest densities (Geaumont et al., 2017). In addition, the benefits of CRP program acres can decline over the years after the initial enrollment because habitat quality can decrease with field age (Eggebo et al., 2003). To minimize the impact, altering grasses and field management in the mid-contract period has been mandated (Matthews et al, 2012).

3.1.3 Factors Influencing Habitat and Hunting Practice

Ring-necked pheasant hunting has produced a significant economic benefit for the public and private sectors across the northern great plains. However, the future benefits of pheasant hunting are uncertain as the hunter participation for ring-necked pheasant is continuing to decline (Erickson and Wiebe, 1973). The data indicated a large downward trend of hunting participation, which is a critical threat for economic benefits the region has been enjoying. Along with pheasant management, it is also crucial to facilitate hunting and hunter participation. The potential solution to stabilize and expand hunter participation could include identification of the factors that affect this activity. A key factor to understand the cause of hunter participation would be the satisfaction level of hunters. Hunters' expectation for the hunting environment and their experiences during the hunting period drive their satisfaction level; and thus, influences future hunting participation (Oliver 1980, Manfredo et al. 2004, Brunke and Hunt 2007, Wszola et al., 2020). The amount and location of approachable hunting lands for hunters impacts the hunting experience, site choice of hunter, game encounter rate and satisfaction, which is created by the social and ecological interactions (Enck et al. 2000, Stedman et al.2008). As per Tomeček et al. (2015), variations in the ecological landscape and game/bird abundance have a great influence on the hunting experience.

Previous studies also suggest that harvest success determines the satisfaction level of the hunters. However, hunting satisfaction may be influenced even more heavily by the type of pheasant habitat and the species available. In a study conducted in Utah, Frey et al. (2003) found that the most significant factor (~35% contribution) influencing hunting experience and satisfaction was the number of roosters seen by hunters. The study also found that simply presenting the chances for the hunters to be in the field with a frequent presence of pheasants would help increase their satisfaction. Another factor to consider is the solitary hunting preference of hunters (Thomas et al., 1973). It was argued that a high density of hunters in a given area might negatively impact hunters experience and satisfaction level and might deter them in the future (Frey et al., 2003).

Wszola et al. (2020) found that hunter demographics together with social and ecological characteristics of hunting locations affects hunting decisions, upshots and perceptions. They found that hunter satisfaction was positively influenced by the number of pheasant hunters, hunting areas and also the number of youths in the hunting teams. This study suggested that hunter satisfaction could be improved by increasing the diversity of hunters and the hunting environment, which can lead to increased hunting activities. As indicated before, abundance of pheasants is important to provide positive experiences to hunters. CRP grasslands are positively associated with high pheasant abundance (Eggebo et al. 2003, Taylor et al. 2018, Matthews et al. 2012); hence, hunters are more likely to hunt in CRP grasslands. Hence, maintaining and increasing CRP grasslands is crucial to bring an increased pheasant population, and give higher satisfaction to hunters, which eventually helps increase hunting activities and makes hunting sustainable and economically beneficial activity in South Dakota and the Great Plains.

3.2 Study Area

This study was conducted in an area covering 58 counties in South Dakota, particularly in the eastern and central parts of the state where the pheasant population is substantial. Some counties in the state were excluded from the study due to unavailability of pheasant per survey route mile data. South Dakota is located in the Northern Great Plains of the United States. The state gets a varying amount of precipitation with around 15 inches per year, on average, in the northwest part of the state. The southeast part gets the highest precipitation of about 28 inches, on average, per year. Average precipitation for the state varied between 10.9 inches and 28.0 over the last 100 years (https://statesummaries.ncics.org/chapter/sd/#:~:text=Average%20annual%20total%20precipitation%20ranges,of%2027.97%20inches%20in%201915). The state sees a wide variation in temperature with average January temperate of about 12°F in the northeast to more than 24°F in the southwest. Average July temperature ranges from about 64°F to 75°F in different parts of the state (https://statesummaries.ncics.org/chapter/sd/#:~:text=Average%20annual%20total%20precipitation%20ranges,of%2027.97%20inches%20in%201915). The major landcover (used in this study) classes for the state included 51.77% of grass/pasture, 10.9% of corn, 9.7% of soybeans, 2.3% of winter wheat, 2.4% of spring wheat, 1.6% of alfalfa, 5.4% of other hay, and 2.2% of CRP, on average (https://nassgeodata.gmu.edu/CropScape/).

3.3 Data Collection

Various kinds of data were collected from secondary sources to meet the research objectives. The major variables employed in the study included the crop-mixture (corn, soybean, wheat, alfalfa and hay) acres, CRP acres, pheasant population, number of harvested birds and number of pheasant hunters. Agricultural land use and CRP are expected to have the highest impact on pheasants in South Dakota. An effect on this upland gamebird population due to fluctuation on leading agricultural crops and CRP grasslands acres influences the number of hunters (license sales) and revenue generated from hunting activities.

3.3.1 Pheasant Parameters

The major dependent variable used in this study is the ring-necked pheasant population. As mentioned before, pheasant population was defined in terms of number of pheasant per mile (PPM) of the survey routes within the study area (58 counties in South Dakota) for last 12 years (2008-2019). The pheasant population data was collected from the South Dakota Game, Fish & Parks (SDGFP) department. The SDGFP conducts pheasant brood survey counts each summer focusing on estimating pheasant reproductive success, population trends, and relative densities throughout the state where information on population trends and densities, agricultural harvest status, and historical hunting pressure are some of the important variables that were used to predict hunter success and satisfaction (Runia et al., 2016).

The brood count survey included 110 routes, each 30-miles long, which were spread across South Dakota where pheasants are prevalent. The survey was conducted in the mornings between July 25 to August 15 each year using standardized methods considering the favorable weather for observing pheasants. The survey also took into account the young pheasant broods when possible. Using these surveys, a pheasants-per-mile (PPM) variable was estimated by summing the product of mean brood sizes and broods along with number of cocks and hens observed in each route (Runia et al., 2016). In addition to the population survey, a hunter harvest survey is conducted annually to estimate the number of birds harvested by hunters. The survey was used to estimate the number of hunters (both residents and non-residents), hunting duration, total birds harvested as well as hunter satisfaction level (Runia et al. 2016).

Since the pheasant brood survey was started in 1949, the statewide highest and lowest pheasant per mile (PPM) recorded was 11.38 per mile in 1961 and 1.03 per mile in 1976. Similarly, a low of ~200 pheasants were harvested in 1919 whereas ~7.5 million pheasants were harvested in 1945 by an estimated 1,000 hunters in 1919 and 212,000 hunters in 1963 (Runia et al. 2016). In 2019, an estimated 145,797 licenses were issued (78,355 resident and 67,442 nonresident) to hunt pheasants, where approximately 111,204 (47,403 resident and 63,801 nonresident) pheasant hunters participated harvesting approximately 829,495 (354,742 by residents, 474,754 by nonresidents) pheasants in South Dakota (South Dakota annual game report, 2019).

The data for harvested birds and number of hunters were collected from the South Dakota annual game report, which is made available by SDGFP. This dataset reported the number of birds harvested by each hunter in each of the counties they hunted in. However, the dataset included estimated birds with the unknown county as well. In such a case, the number of birds with an unknown county were proportionally allocated to the counties with known number of birds harvested by the corresponding hunters. When it comes to the brood count survey in the study area, the SDGFP department is the vital agency predicting pheasant populations each year in South Dakota. The estimated population is then used by state agencies to make decisions about the number of hunting licenses to be granted each year. As discussed, the survey data already collected and preserved by SDGFP department was acquired for this study. The data was obtained in both spreadsheet and pdf (later converted to spreadsheet) formats.

3.3.2 Crop-mix Acreages

The publicly available landcover data of the study area was acquired from USDA National Agricultural Statistics Service (NASS) from the years 2008 through 2019 to analyze the impact of landcover mix on the pheasant population. This dataset included the Cropland Data Layer (CDL), which provided an annual land cover classification map that allows identification of different types of vegetation. The map was available in a raster form (a resolution of 56 m) and was geo-referenced that utilizes orthorectified imagery to accurately and geospatially identify field crop types (Boryan et al., 2011).

The crop type classification provided by this data was about 90% accurate for major crops like corn, soybeans, wheat, alfalfa and hay (USDA-NASS-RDD Spatial Analysis Research Section, 2016), which was considered to be sufficient for this study. This data source was selected for landcover because it provided comprehensive spatial information and there is an increasing community of users providing necessary knowledge and experience on this dataset and its applicability (Lark et al., 2017). It was found that the CDL program covered numerous different crops with larger number of acreages from 2006. However, one of the important land use class, the non-alfalfa hay crop, was covered only starting in 2008. Production acreage of non-alfalfa hay is large in South Dakota, and therefore this study analyzed the dataset starting 2008. As discussed above, the state has a much higher production acreage of corn and soybeans compared to other grains, and expansion of these crop acres may have a high influence on pheasants. Corn and soybeans planting acreage expanded by 27% (3.8 million ha) from 2010 to 2012 in eastern Dakotas (Johnston, 2014). Combined acreage of these two crops increased from 8.3 to 10.4 million acres in the South Dakota during the 10 year period from 2004 to 2014 (Wimberly et. al., 2017). A similar trend was reported by USDA National Agricultural Statistics Service, showing an increase from about 8.5 million to about 11.4 million acres during the 2008 to 2018 timeframe. These studies showed a dramatic increase in corn and soybeans acres over the years indicating a potential loss of grassland habitats. It was crucial to include both grain production acres in the analysis because, as reported by past studies, pheasant prefer tall, dense, long-term and undisturbed grasslands, and therefore a larger proportion of these crop acres may cause damage to pheasant abundance. Besides, these crops are harvested annually and disturbances from farming activities may destroy the pheasants, especially hens and embryos. Hence, it is expected that these crops have an inverse relationship with the pheasant population.

The wheat acres have a somewhat different story. Although, the share of wheat acres was not as high as that of corn and soybeans, this landscape was thought to be beneficial as a winter cover in severe winter. This land use type has the potential of supplying annual nesting and brood-rearing habitat for pheasants. Between 2004 and 2014, it was found that the combined area of wheat planting and CRP land decreased from 2.7 million to 2.0 million acres in South Dakota (Wimberly et. al., 2017). Following the similar trend, the winter wheat acres decreased from about 1.7 million to 856 thousand acres and spring wheat decreased from about 1.4 million in 2008 to 656 thousand acres in 2019 (USDA National Agricultural Statistics Service). The other factors believed to have a large contribution in pheasant habitat are alfalfa and other hay crops. There was a significant rise in alfalfa acres during the 1940s and 1950s reaching to about 2.5 million acres and staying around there for the past 35 years (Runia et al., 2016).

Similarly, land use of other hay crop remained relatively flat for over 50 years (Runia et al., 2016). However, there was a gradual increase in alfalfa planting from 792 thousand to 1.1 million acres and in other hay from 1.6 million to 2.1 million during 2008 to 2019 period (USDA National Agricultural Statistics Service). Considered a substantial habitat use (based on the previous findings) by pheasants besides the high quantity of coverage, the wheat, alfalfa and other hay were essential predictor variables to be included in the study.

3.3.3 Conservation Reserve Program (CRP)

It was important, as discussed before, to examine the variations of CRP acres over crop production and the impact of crop mix on pheasant population. The CRP program introduces specific land cover desirable for environmental conservation for 10-15 years (Nielson et al. 2008). The past study (Nielson et al., 2008, Eggebo et al., 2003) showed that there was a strong relationship between CRP acres and the pheasant population. The CRP acreage in South Dakota grew rapidly in the 1980s and remained quite level until 2007. However, CRP acreages in the state were going down since 2007 due to changes in the policy (Runia et al., 2016). South Dakota had about 1.3 million acres of CRP (highest across years used in the analysis) which was 6.5% of total cropland acres enrolled in CRP in 2008 (Janssen et al. 2008) and stood at about 1.1 million acres at the end of FY 2019 (FSA, 2020). The continuous loss of CRP acres has the potential to affect pheasant abundance drastically in South Dakota and in the Northern Great Plains. A total of 556,000 CRP acres expired during 2007-2014 and approximately 257,000 CRP acres expired during 2015-2019, a majority of which was converted into row-crop production (Runia et al. 2016). A USDA report shows that 110,695, 137,972, 78,377, 55,565, 71,456, 81,005, 109,374 and 706,050 of CRP acres will be expiring respectively from 2021 to 2028 (and beyond) (FSA, 2020). There is a continual renewal and new enrollment into the program going on, which is guided by various factors including CRP program funding and landowners' preferences (Janssen et al, 2008). However, it is not certain if these efforts will match the retiring land area in the next 5 to 10 years. As expected, the conversion of CRP grassland acres to cropland has negative outcomes for pheasants; hence, including CRP acres in estimating pheasant population is worthwhile. The empirical data for CRP acres were obtained from the USDA, Farm Service Agency. The data are available in a spreadsheet format and were downloaded from USDA Farm Service Agency on 7/1/2020 and 12/7/2020.

Figures 3.1 and 3.2 show the trends on pheasant population (number per mile) along with number of hunters (resident and non-resident) and harvested birds by resident and non-resident hunters for 58 counties and Beadle county in South Dakota for the years 2008-2019. The vertical axis in figure 3.1 represents the average of the corresponding variables for 58 counties covered in the study area. These figures show that the pheasant population fluctuated highly than other variables and followed a declining trend over the study period. Number of harvested birds was also fluctuating to some extent and was deceasing over the study period. There was a relatively smoother, gradual decline in the number of hunters over the study period. The pheasant population declined sharply in 2013 reaching the lowest level over the study period, which rose again in 2015 followed by another sharp fall in 2017. The harvest showed strong correspondence with the total population and decreased together with it. The average number of hunters were comparatively steady, which indicates stability in license sales. To provide a county level view, figure 3.2 was plotted with the same variables for Beadle County. This county was selected because it is in the middle of the main pheasant hunting area in South Dakota. The patterns for Beadle County display highly similar negative trends as seen in the average over the counties.

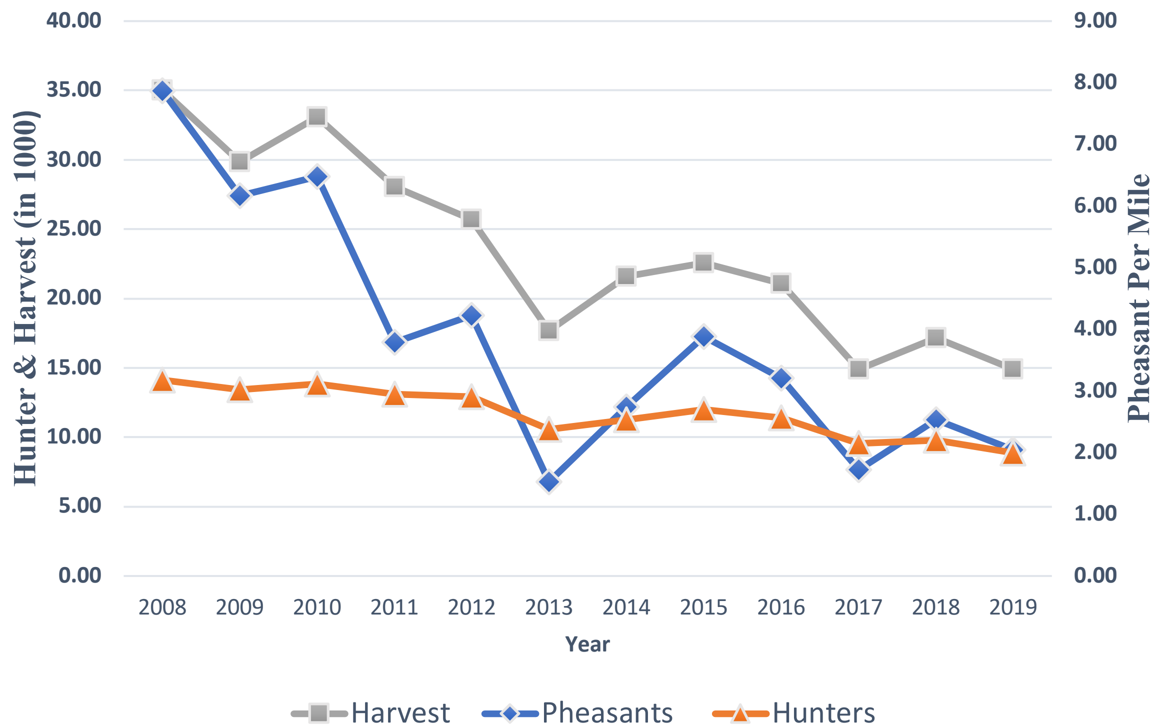

Figure 3.1 Average pheasant population (per mile), number of hunters and total harvest (in 1000) over the entire study area (58 counties) from 2008 to 2019 (SD Game Fish & Parks).

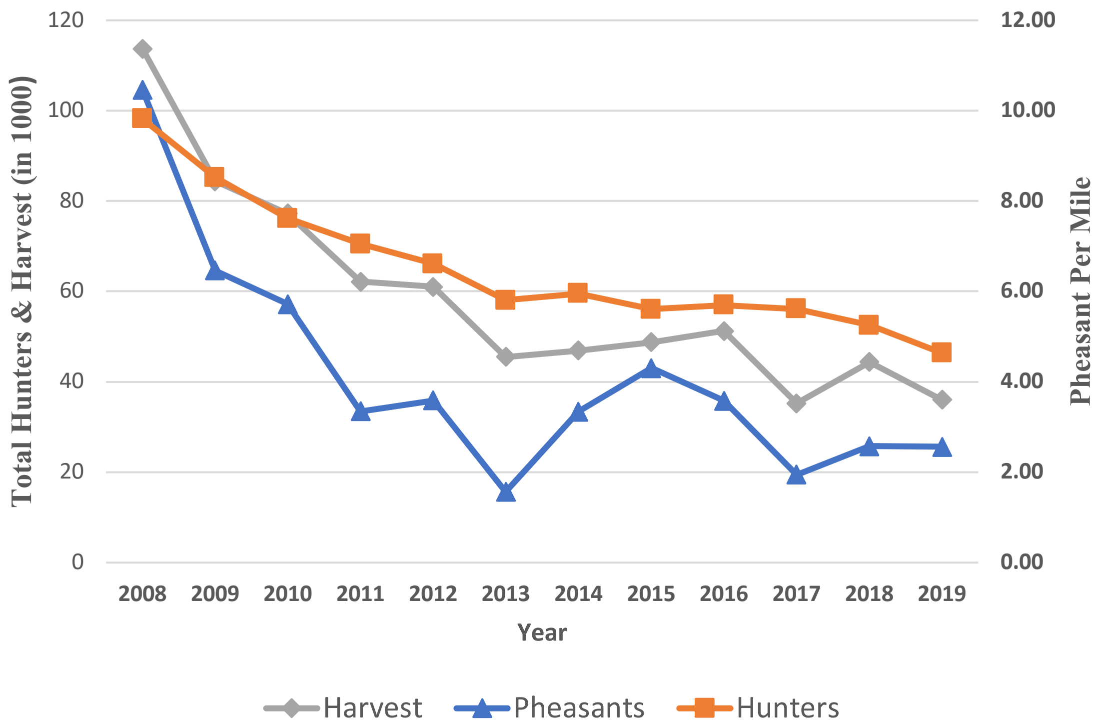

Figure 3.2 Average pheasant population (per mile), number of hunters and total harvest (in 1000) for Beadle County over 2008 to 2019 (Source: SD Game Fish & Parks).

Figures 3.3 and 3.4 show the variation on crop-mix acres over the study period. The average of combined corn and soybeans acres went up gradually until 2018 and dropped sharply in 2019. The average wheat acres (average of winter and spring) decreased continuously from 2008 to 2013. The average wheat acres fluctuated over the study period but followed a decreasing trend overall. Alfalfa planting, on the other hand, remained relatively steady during the study period whereas the other hay cropping increased modestly from 2009 to 2014 and was steady in the rest of the years. The CRP acres dropped slightly until 2015 as contracts expired. However, CRP acres were relatively steady after 2015 until 2019. The crop-mix acres of Beadle County showed a comparatively similar pattern relating to average crop-mix for the 58 counties covered in the study area.

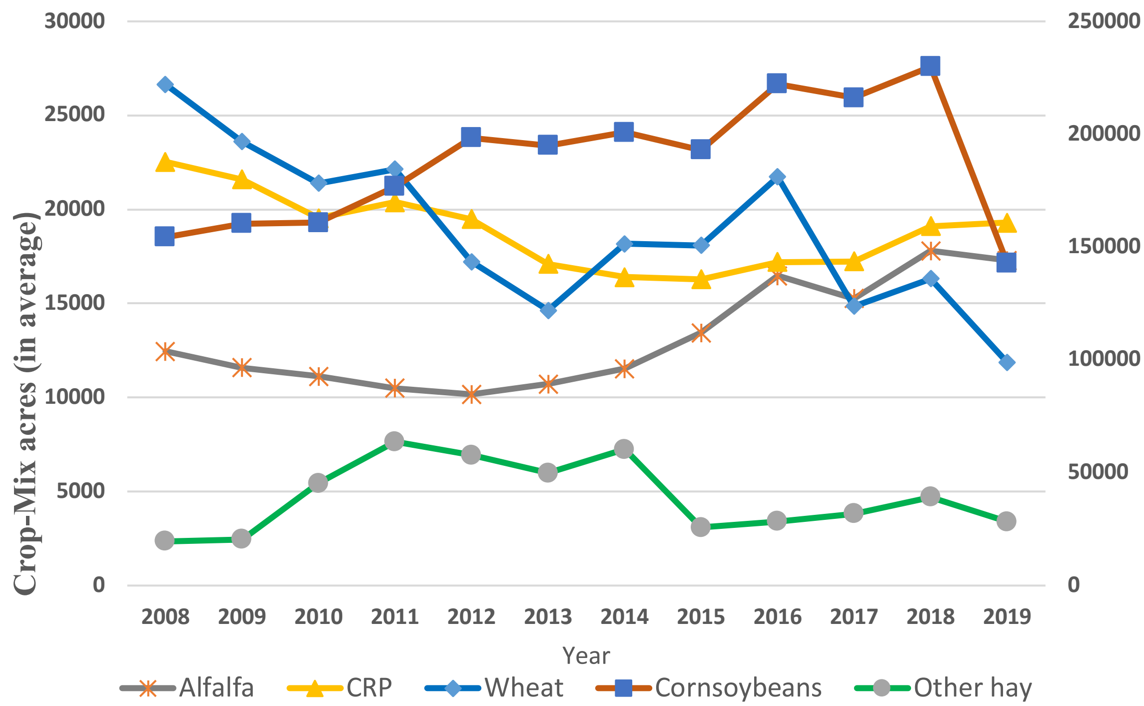

Figure 3.3 Crop-mix trend over the study area (58 counties) from 2008 to 2019 (Source: USDA NASS FSA)

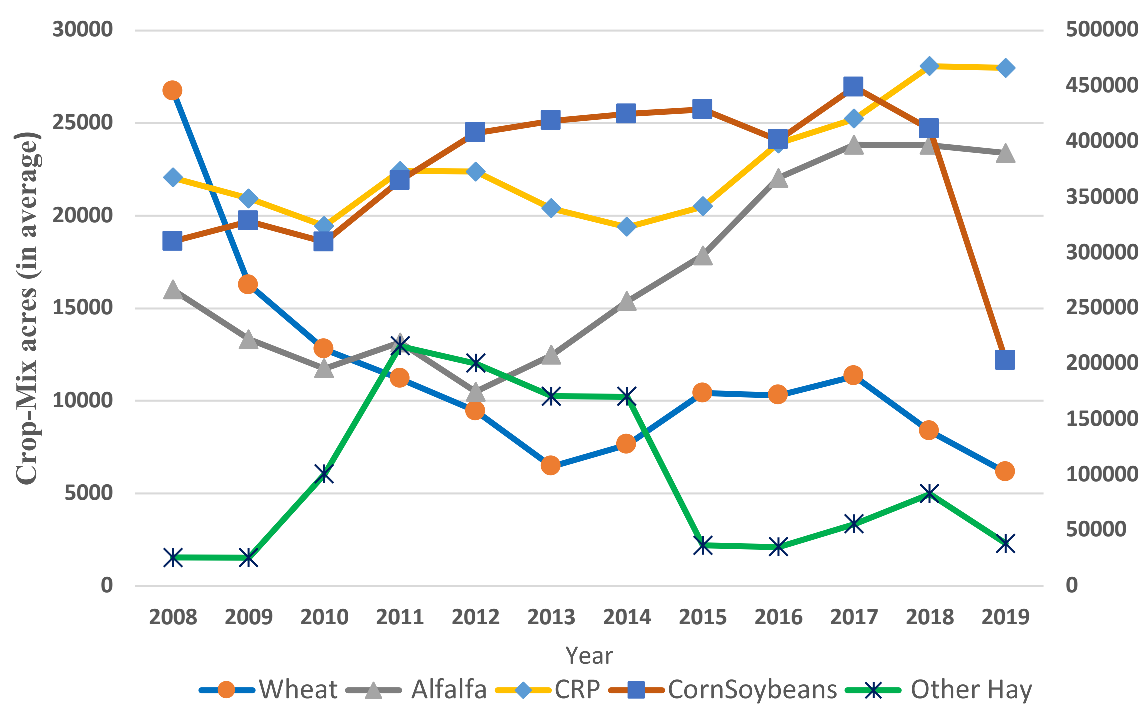

Figure 3.4 Crop-mix trend of Beadle County from 2008 to 2019 (Source: USDA NASS).

Summary descriptive statistics for each of the variables used in the models developed in this work are shown in Table 3.1. The table includes number of observations, mean, standard deviation, minimum value, and maximum value for each variable used. The variability apparent in the previous figures can also be seen in the standard deviations presented in this table. For example, a high standard deviation around the mean pheasant harvest indicates the highest variability this variable showed among all the variables included in the table. It is noted that the number of hunters were used as a proxy for revenue generated from pheasant hunting.

Table 3.1 Summary of descriptive statistics for variables used in the study

Variable	**No. of Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Pheasant Population (number per mile of the survey route)	660	3.824	4.517	0	36.934
Corn/Soybeans (acres, in 10,000)	660	18.758	15.816	0	168.532
Winter Wheat (acres, in 10,000)	660	1.777	2.499	0	18.531
Spring Wheat (acres, in 10,000)	660	2.002	2.532	0	14.217
CRP (acres, in 10,000)	660	1.885	1.554	.021	8.797
Other Hay/Non-Alfalfa (acres, in 10,000)	660	3.92	3.838	0	22.555
Pheasant Harvest (number)	660	23469.964	22626.823	359	127026
Total Hunters (number)	660	2641.85	2175.4	83	11807

3.4 Model Specification

The main objective of this study is to analyze the pheasant population and level of harvested birds. Therefore, two regression equations (supply and demand) are specified to address the study objective. Pheasant population in the supply equation primarily depends on the CRP acreage along with crop mix acres. The model illustrates how changes in land use of these crops impact the pheasant population over time. The demand equation explains the relationship between number of harvested pheasants, number of resident and non-resident hunters and pheasant population.

The pheasant population is the desired dependent variable in the supply model. As mentioned earlier, peasant population was expressed in terms of number of birds per mile (PPM) of survey routes across South Dakota. Using the brood count survey data (Runia et al., 2016), the sum of cocks, hens and multiple of broods and brood size was divided by length of the route (PPM = (CO + HE + (BD*BDSZ))/30) to estimate the pheasant population. This estimation was then averaged over all survey routes in a given county.

The corn and soybeans acres were combined in this study because of a collinearity issue, as collinearity between any explanatory variables leads to inaccurate estimation (Greene 2018, Stewart and Davis, 2005). Moreover, both (corn and soybeans) acres have had a strong negative correlation (based on past studies) with bird population and for both crop habitat was unwelcomed by pheasants. Considering the similar trend of both crops, it was assumed that combining these two crop acreages would not create bias in estimating bird population. The other variables of potential importance to estimate the bird population was grass/pastures because the land space covered by grass/pastures was the highest among all included in this study. However, this landscape was likely to be associated with CRP and it created collinearity issues even after excluding CRP acres; so, it was treated as residual.

The winter and spring wheat acres were explained separately because each was planted and harvested in different seasons. The agricultural landscape with cereal grains, especially winter wheat, was beneficial for pheasants in winter (Pauly et al., 2018) as it can provide cover during severe winters and can reduce mortality. Therefore, it was hypothesized that winter wheat was associated positively with the bird population. Based on the finding by Hanson and Progulske (1973), it was expected that perennials such as alfalfa and other hay have a positive association with pheasant population as alfalfa fields were the most preferred by the pheasants than other widely available natural covers. As discussed already, several studies found CRP as a significant and healthy habitat for increasing pheasant population. So, this study included CRP grasslands as an explanatory variable assuming a potential for positive association with the pheasant population. The crop acres included in this study were either planted or likely to be planted to the corresponding crops. All of these mix-crop acres were converted to ten thousand of acres (crop acres/10,000) for appropriate interpretation of the coefficients.

Demand (pheasant harvest) was hypothesized to have a positive association with the pheasant population and number of hunters. The pheasant population, pheasant harvest and the pheasant hunters are substantially correlated (Runia et al., 2016). Generally, an increase in pheasant population causes an increase in hunters and therefore increases in harvested number of birds. The pheasant population and number of hunters are the independent variables in the second model.

As explained before, this analysis includes 58 counties where 3 counties are combined as they were connected by the same survey routes. Further, county level dummy variables were created. For example, Aurora County observations are assigned a value of 1, otherwise a value of 0. Dummy variables were defined because agricultural practices can be different between counties and the dummy variable would result in county specific shifts in the intercept term. In addition, other factors such as soil fertility and precipitation may change over the study area. Therefore, including the dummy variables ensures that any kind of interactions would be constant across the state. However, interaction between the dummy variable and the predictor variables such as

CRP was assumed to be negligible as there was no reason to be suspicious of that. The CRP program, on the other hand, is national, and its state-level implementation does not have any unique characteristics. Therefore, it was assumed that change in CRP acres in a given county would not cause shifts in hunting practices or other specific activities. On the other hand, some agricultural policies might vary at the county level that influences corn/soybeans production and other crop-mix. The statewide total of number of hunters, crop acres and CRP acres may influence the entire study area and all the habitats. These factors are in contrast to any special event or variable that takes place at a local scale to influence bird population at the county level. It may happen in any county and dummy variables may control the shifting of the intercept corresponding to specific counties. Therefore, including dummy variables in both of the equations shifts the number of birds available or harvested specific to that county and it would implicitly represent the average differences across the counties.

3.4.1 Simultaneous Equation Model

The two equations consisting of supply and demand aspects work together to determine pheasant population and the harvested birds. Therefore, these two variables are endogenous variables as they are determined at the same time. Following Greene (2018) and Stewart and Davis (2005), a simultaneous equation model was created, which is an extension of the seemingly unrelated regression (SUR) model. The simultaneous model was used to address such a set of triangular equations in which some of the right-hand side variables are endogenous. The pheasant population, which is the dependent variable in first equation, represents an independent variable in second equation and is assumed to be correlated with the disturbances.

It was assumed that there is a linear relationship between variables in this study. The specific structural form of the model having pheasant population and pheasant harvest as a dependent variable are depicted by the following equations:

$$PP = \alpha_0 + \alpha_1 CS + \alpha_2 WW + \alpha_3 SW + \alpha_4 Alfalfa + \alpha_5 OH + \alpha_6 CRP + \alpha_7 Year + \sum_{i=1}^{n} \gamma_i d_j + \varepsilon_1, \quad (1)$$

$$PH = \beta_0 + \beta_1 TH + \beta_2 PP + \beta_3 Year + \sum_{i=1}^{n} \gamma_i d_j + \varepsilon_2, \quad (2)$$

where PP is total pheasants per mile. Crop-mix variables are the total acres of specific crops identified to be important for this study including corn/soybeans (CS), winter wheat (WW) and spring wheat (SW) along with grasses like alfalfa (Alfalfa) and other hay (OH). Similarly, CRP represents area covered by CRP contracts at the end of each fiscal year. PH is the total number of harvested birds (by resident and non-resident hunters). TH represents the total number of hunters (resident and non-resident) recorded by the hunter harvest survey as discussed in Sec. 3.3.1. $\sum_{i=1}^{n} \gamma_i d_j$ is the set of dummy variables created in the analysis where n represents the number of counties and j represents Aurora to Yankton County.

For solving the two structural equations, (1) and (2), by expressing the endogenous variables PP and PH as functions of all exogeneous variables, the following reduced form equation can be derived that specifies each endogenous variable as a function of all exogenous variable (Stewart and Davis, 2005):

$$PH = \pi_0 + \pi_1 TH + \pi_2 CS + \pi_3 WW + \pi_4 SW + \pi_5 Alfalfa + \pi_6 OH + \pi_7 CRP + \pi_8 Year + \sum_{i=1}^{n} \gamma_i d_j + v, \quad (3)$$

where pheasant population (PP) does not appear as a separate explanatory variable. The reduced model/equation can be estimated consistently by OLS (Stewart and

Davis, 2005) because the explanatory variables are determined outside of the structural equations and these variables are not correlated with the error terms. The error term has a constant variance and zero covariance. As explained above, pheasant harvest increases with increasing pheasant population as they have a strong positive correlation. Using this equation, it may be identified how much of an impact crop-mix acreage has on pheasant population and consequently on pheasant harvest. As mentioned before, the reduced form of the model represents the equilibrium between supply and demand. For example, if there is more expansion of CRP acres, then it will probably cause the pheasant harvest to go up, which then shifts the supply curve that puts an ease on pheasant harvest. As demand and supply models were integrated properly into this reduced form, there is no endogeneity and source of bias between these variables.

The structural equations to develop an empirical model are preferred because the system equations are more interesting. The first (supply) equation in the system does not have any endogeneity issues from the independent variables; so, it can be estimated by ordinary least square (OLS) estimation. But the second (demand) equation is expected to have endogeneity problem associated with evaluating the impact of exogeneous variables on pheasant harvest. As the variable is expected to be corelated with an error term, using OLS estimation with endogeneity causes bias and inconsistent estimation where the error term determines the magnitude of the estimated coefficient for that variable. For example: if pheasant population is correlated to errors in equation (2) than any external shock causes such errors to change, and induces a shift in the demand curve and causes the equilibrium points. If this issue is not addressed, this may result in inaccurate interpretations of the effects of a variable on the harvest volume (Abdallah et al. 2015).

A Hausman test is performed to test the endogeneity for pheasant population in the second equation. Following Stewart and Davis (2005), CS, WW, SW, alfalfa, OHNA and CRP were employed as instruments of endogenous variables (PP) presuming that PP and these variables were corelated, but none of the linear combinations of those variables were to be exogeneous to PH. The null hypothesis (P value < 0.01) was rejected and remained with the assumption that OLS does not estimate parameters consistently for equation (2).

Besides, it is also assumed that the error terms in the two equations are correlated at the same point in time. Since two dependent variables are similar in many regards; it is likely that the effects of any absent factors on pheasant population will be similar to harvest. In such a case, error 1 and error 2 will be correlated detaining similar effects (cov $(\varepsilon_{pp,t}, \varepsilon_{ph,t}) = \sigma_{pp,ph},\ \sigma_{pp,ph} \neq 0$, Hill et al, 2011)). A Breusch-Pagan (BP) test of independences was used to check whether there is a correlation between the errors of two equations. The result rejected the null hypothesis at 1% (chi2(1) = 6.831, P < 0.01). The significant result indicated they do have correlation.

To address such issues stated above, simultaneous equation model is used in the study to estimate the parameters of equations (1) and (2). This approach estimates the triangular equations jointly, accounting for the fact that the variance of the error terms is different for two equations and that there is endogeneity in the equation (2). In addition, this technique accounts for the contemporaneous correlation between the errors of both equations and it comes up with a consistent and efficient estimation of parameters (Grene, 2018). The data were statistically analyzed using STATA/SE 16.1.

CHAPTER FOUR

4. Results

In this chapter, results from regression analysis of pheasant population and pheasant harvest models are described. Results based on both ordinary least squares (OLS) method (for each equation) and conditional mixed process method (for joint estimation) are included. The conditional mixed process was considered as it is a broader method of estimating simultaneous equations models and is consistent in the presence of heteroskedasticity in linear models.

4.1 Pheasant Population

Table 4.1 presents estimation results for the supply model or the pheasant population model. The OLS estimation for this model independently was coherent for the single equation. However, the OLS method is inconsistent to estimate the structural equations. Therefore, both models (pheasant population and pheasant harvest) are estimated jointly to address the endogeneity issue and contemporaneous errors to obtain consistent and efficient results. Hence, the analysis will emphasize the joint estimation for interpretation of the regression results. The variables chosen in this model showed significant impact of changing land use acres on the pheasant population.

The merged corn and soybean acres were significant at the 1% level ($p < 0.01$) and negatively associated with the number of birds in both estimation approaches. This was expected because planting more corn and soybeans in a given year may reduce some of the best habitat and birds may be forced to move further away to find nesting sites and food. The result indicates that a reason for the falling bird population across the state may be due to the considerable increase of corn and soybean acres. However, in addition to increasing corn and soybean acres, there could be several other factors causing the drop in bird population. In terms of marginal impact of the crop-mixed acres on pheasant population, the elasticity would be more straightforward to interpret. Keeping all other variables constant, when corn-soybean acres increase by 10%, the pheasant counts decreased by 5.74% per mile of the survey routes.

The table also shows that other hay (non-alfalfa) ground cover is significant at the 1% level ($p < 0.01$) in the OLS estimation and at the 10% level ($p < 0.1$) in joint estimation. The outcome in the combined estimation model indicates that a 10% increase in other hay acres would cause a decrease of 0.76% of pheasants per mile. The hypothesis made in the analysis was that a rise in other hay grassland acres would cause the bird population to increase because grasses normally would make good pheasant habitat and be good for nesting. However, the results turned out to be negative and failed to support the hypothesis in this study. One reason behind this unexpected result could be weather-related factors over the study duration of 2008 and 2019. For example, dry conditions observed during those periods might have led to increased grazing pressure by domestic animals disturbing the habitat for pheasants. Farmers might also hay the grasses for animal feed, which would minimize the cover and food for birds, including pheasants, forcing them to move to areas more favorable to them. This situation, called livestock demand, can pressure pheasants and may cause a reduction in the population. However, the inverse relation may also be caused by other factors. The year variable coefficient is negative and significant, which is logical as there was a continuous decrease in the bird population during the sample period of the study.

Table 4.1 OLS and SEM Estimated Parameters (Pheasant Population)

Variables	OLS		SEM		
	Coef.	S.E.	Coef.	S.E.	% change
CornSoybeans	-0.071***	0.023	-0.117***	0.018	-0.574
Winer Wheat	0.891***	0.110	0.840***	0.099	0.390
Spring Wheat	0.263*	0.141	0.308***	0.112	0.161
Alfalfa	0.586**	0.295	0.769***	0.233	0.265
Other Hay	-0.151***	0.046	-0.074*	0.039	-0.076
CRP	0.783***	0.281	0.447*	0.230	0.220
Year	-0.316***	0.040	-0.322***	0.036	-
Constant	636.672***	80.800	649.730***	73.073	-
Observations	660		660		
R-squared	0.686				
Prob > F	<0.001				
Log likelihood			-7786.4248		
Likelihood ratio			3121.15		
Prob>Chi-squared			<0.001		

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; S.E. = standard error

Winter wheat acres is statistically significant at the 1% level (p<0.01) and positively associated with the pheasant population, which is consistent with previous findings that a rise of winter wheat acres benefits the bird habitat, reducing the mortality rate in winter weather and providing nesting cover (Pauly 2018). A rise in winter wheat acres by 10% would cause pheasant numbers to increase by 3.9% per mile. This variable seems to be of interest in increasing the pheasant population because the rate of increase of pheasant population (per mile of the survey routes) with increasing acres of winter wheat is highest among all crop-mix acres included in the study. The coefficients for spring wheat and alfalfa acres are statistically significant at the 1% level (p <0.01) in the mixed process and are positively associated with the bird population as expected. Regression results showed that a 10% increase in spring wheat acres added 1.61% to the pheasant population measure. Similarly, a 10% rise in alfalfa acres increased the pheasant population measure by 2.65%.

Regarding the CRP grasslands, it is found to be positive and statistically significant at the 1% level (p <0.01) in the OLS estimation and at the 10% level (p <0.1) in the joint estimation. The result appears to be consistent with the prior expectation. However, the CRP coefficient is marginally less supportive than winter wheat and alfalfa in enhancing the bird population. Pauly et al. (2018) found the nest success and nesting chronology was similar in both CRP and winter wheat. Based on their finding, it was expected to have relatively similar results with regard to pheasant population measures. It was not clear why CRP grassland acres seemed less effective compared to winter wheat and alfalfa, but this may be because of insufficient plant diversity, loss of habitat and increased mortality of chicks during the sample period. Overall, the impact of most of the variables studied on pheasant population were found to be as expected. In addition, the model was significant (Prob > F < 0.001, Prob>Chi-squared < 0.001), where the generalized least square method explained about 68% of variation of the model and log likelihood value and likelihood ratio in the conditional mixed process method were -7786.42 and 3121.15 respectively. The elasticity form (% change) employed for both models is converted by the ratio of the sample mean of the explanatory and response variables to the interaction of each variable coefficient for joint estimation.

4.2 Pheasant Harvest

It is known that the supply of pheasants may influence harvest volume because hunters are more satisfied when there is a sufficient number of birds, especially roosters, seen in the hunting area (Frey et al., 2003). Therefore, ample supply is a key element to a high satisfaction rate that is helpful for attracting hunters each year. Hunter satisfaction determines the economic benefit of pheasant hunting. The pheasant supply and hunters' success determine the harvest volume. In such cases, it was important to study both supply of and demand for pheasants jointly to understand the potential revenue generated from pheasant hunting.

Table 4.2 presents regression results associated with harvested bird counts. Although the OLS estimation for the demand equation is not coherent, considering the issues stated above, it is reasonable to observe the differences on marginal impacts with the other approach. Concerning an impact on the harvest volume, coefficients for total hunters and pheasant population are statistically significant at the 1% level ($p < 0.01$). The result shows, as expected, that each predictor has a strong positive association with harvested birds. It is relevant because a high bird density attracts more hunters and harvest volume goes up, which would then cause revenues to go up. The result shows that when all other variables were constant, an increase in each hunter adds about 11 birds harvested per season. In other words, a 10% increase in total hunters would have about a 13% increase in harvested birds per season in the overall counties included in the study area. The OLS estimation is considered an inconsistent and inefficient measurement in this analysis. However, the coefficient of total hunters (in number of birds) is not significantly different than in the joint estimation.

As stated above, a rise in the density of birds is of great importance to boost pheasant harvest. In addition, an increasing trend of pheasant numbers may lead to more hunting revenues. The regression result suggests that a rise by 10% in the number of pheasants per mile would boost about 2.45% birds harvested per year.

Table 4.2 OLS and SEM Estimated Parameters (Pheasant Harvest)

	OLS		SEM		
	Coef.	S.E.	Coef.	S.E.	% change
Total Hunters	12.020***	0.251	11.762***	0.236	1.324
Pheasant Population	802.809***	48.009	1,504.002***	133.481	0.245
Year	-158.006***	47.552	133.925*	72.940	-
Constant	309,702.208***	95,898.428	-278,836.862*	147,054.458	-
Observations	660		660		
R-squared	0.980				
Prob > F	<0.001				
Log likelihood			-7786.4248		
Likelihood ratio			3121.15		
Prob>Chi-squared			<0.001		

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; S.E. = standard error

Regarding the quantity of overall pheasants harvested over the sample period, the coefficient year was significant in both estimations. The OLS method produced a negative coefficient for year, which was expected. However, the year had a positive coefficient for the harvest equation in joint estimation, which was a surprising fact, and it is not clear what might have caused such a result. For the measurement of goodness of fit, the model was significant (Prob > F < 0.001) and R-squared value measured in generalized least square method explained about 98% of the variation, which is substantial in the analysis. As the simultaneous equation model was jointly estimated, the Prob>Chi-squared (< 0.001), log likelihood (-7786.4248) and likelihood ratio (3121.15) are determined by single value for both equations.

4.3 The Reduced Form

Based on (Stewart and Davis, 2005), empirical results achieved with equations (1) and (2) estimated simultaneously could be compared with a reduced form equation (3). Such a comparison is expected to provide an interesting observation in which total hunters, year and dummy variables are included back to the model by replacing the endogenous variable (pheasant population) with exogenous variables.

Regression results for the reduced form model are provided in Table 4.3. Utmost key variables (Total Hunters, Corn/Soybeans, Winer Wheat, Spring Wheat and Alfalfa) have similar directions on marginal effects. Corn/Soybeans, winter wheat and alfalfa are statistically significant at the 1% level ($p < 0.01$) and spring wheat is significant at the 5% level ($p <0.05$). The coefficients for corn/soybeans and other hay are found to be negative, while other variables have positive coefficients. When considering the elasticity, the third column in Table 4.3 shows that a 10% increase in corn and soybean acres would have a 1.69% decrease in bird harvested per season holding all other variables constant. Likewise, a 10% increase in winter wheat, spring wheat and alfalfa would increase by 0.88%, 0.38% and 0.75% harvested pheasants per season respectively. The winter wheat and alfalfa coefficients again have marginally higher impact in increasing the harvest quantity. It can be concluded that these crop acres are critical for determining the relative importance of how variations of these acres have affected the bird harvest. It is surprising to find that other hay and CRP are not statistically significant in the reduced form model. There may be various explanations for the disconnect between harvested birds and these acres. One of the reasons could be that those habitats were not opened for hunting purposes even though there may have been an adequate number of pheasants available. Therefore, changes in volume of pheasants in these habitats did not influence the quantity of harvested birds.

Table 4.3 OLS Estimated Parameters for Reduced Form (Pheasant Harvest)

	OLS		
VARIABLES	Coef.	S.E.	% Change
Total Hunters	12.305***	0.278	1.385
CornSoybeans	-211.731***	31.967	-0.169
Winter Wheat	1,164.327***	153.435	0.088
Spring Wheat	444.442**	196.735	0.038
Alfalfa	1,336.018***	405.371	0.075
Other Hay/ Non-Alfalfa	-41.635	64.114	-0.007
CRP	315.114	386.716	0.025
Year	-314.924***	59.244	-
Constant	627,422.535***	119,324.518	-
Observations	660		
R-squared	0.976		

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; S.E. = standard error

In general, a deficiency associated with estimating a reduced form model is that the approach provides no direct relationship between response and explanatory variables. In contrary, structural equations-based model clearly shows the relationship among them. Again, theoretically, the reduced model can be estimated consistently by OLS method. However, the joint estimation is considered to produce better estimation in the case of structural equations in the study. It is further justified with an example of how a relationship exists between crop-mix acres and harvested birds calculating a marginal effect manually where the coefficients are relative to joint estimation.

$$\frac{dPP}{dCS}\,\frac{dPH}{dPP} = \alpha_1 * \beta_2 \implies \quad 1{,}504.002 * (-0.117) = -175.97$$

$$\frac{dPH}{dCS}.\left(\frac{CS}{ph}\right)^{*} = -175.97 * \frac{18.76}{23469.96} = 0.141$$

where α_1 is marginal impact of corn and soybeans acres on pheasant population, β_2 is marginal impact of pheasant population on harvested birds, CS (corn/soybeans) and PH (pheasant harvest) are mean value of corn-soybeans acres and harvested pheasants for the sample data during the study period.

The coefficient differed slightly in reduced estimation (in the direct regression result of reduced form) because they were estimated using different approaches. However, as measured in terms of the elasticity, they appear relatively similar (0.169% and 0.141%) in influencing the harvested birds by increase in corn and soybeans acres.

4.4 County Variables

Efforts to create county specific dummy variables for pheasant population and harvest models were considered to produce more successful results controlling for potential influences of residuals. It also distinguished the number of available birds and harvest rate specific to each county. Differences appear to be related to the dominant birds available and harvest rate found across the state. In the following figures, the counties appear in four levels of color from darkest to lightest. The darkest color indicates “positively significant” and the lightest “negatively significant” counties. The figures below depict the regression result for each county with OLS and simultaneous estimation for supply and demand equations along with the reduced form version.

The regression results obtained with the OLS estimation, as presented in figure 4.1 and joint estimation in figure 4.2, show the density of pheasants in counties within the study area. The majority of counties along the James River valley seem to have substantial pheasant availability. The darkest colored counties include Aurora, Beadle, Bennett, Brule, Buffalo, Dewey, Douglas, Edmunds, Faulk, Miner, Potter and Sanborn, denoting a significant positive association with birds. These counties have a higher pheasant population than default county (Yankton). These counties with dense pheasant population are likely better positioned to generate additional revenue with the cumulative harvest volume.

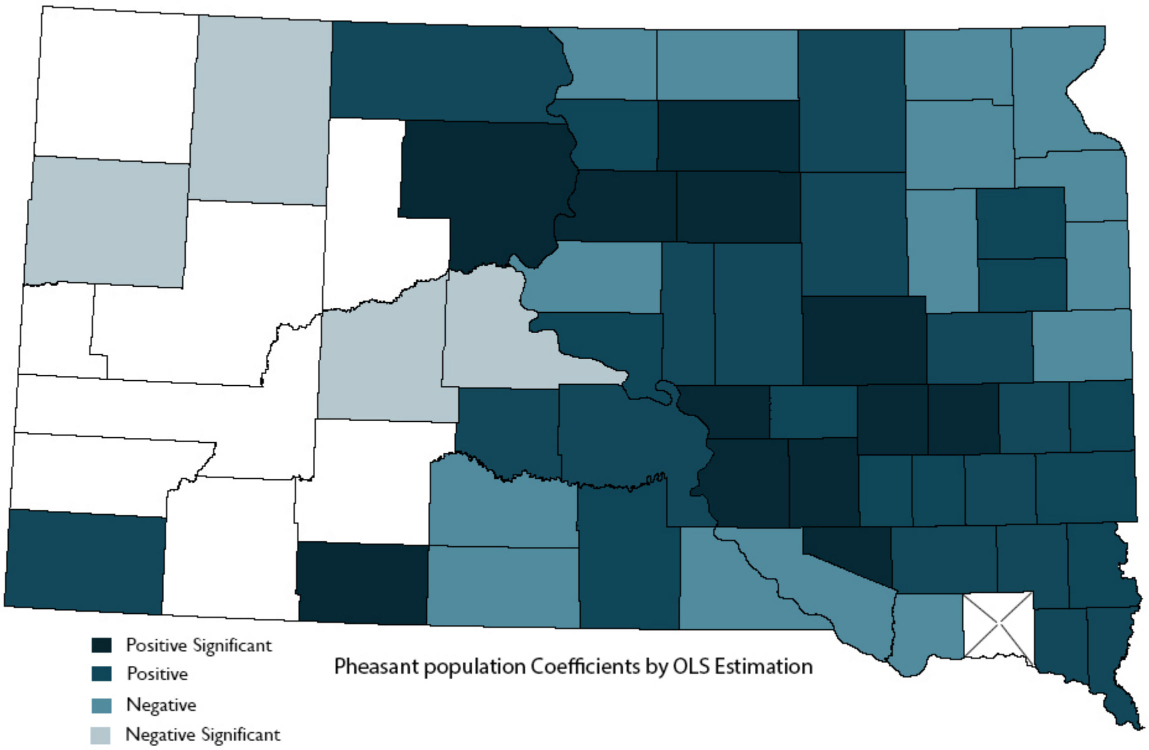

Figure 4.1 OLS estimated county parameters for pheasant population. The number of positively significant counties were 12, negatively significant counties were 4, positive insignificant counties were 23 and negative insignificant counties were 15 whereas Yankton county was defaulted.

Figure 4.2 showed that 9 counties (Brown, Hand, Hutchinson/Turner, Kingsbury, Lake, Lyman, McCook, Spink and Union/Clay) held strong positive significance which indicated that these counties tend to have the highest pheasant density across the state based on the default county. There can be several potential factors influencing the pheasant availability. A few drivers may be related to improved habitat quality and better weather along with less farming activities during nesting season over the study period. In addition, the increase in pheasant population in counties along the

James River corridor may be because birds were raised and released substantially in those counties.

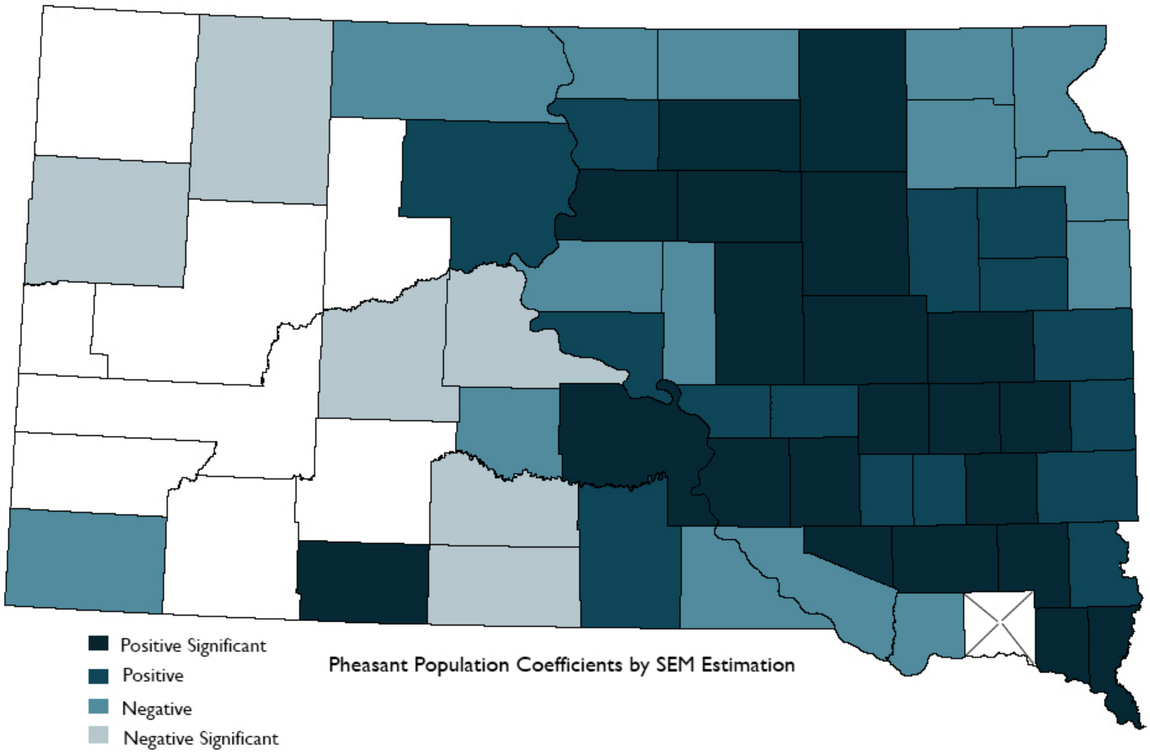

Figure 4.2 SEM estimated county parameters of pheasant population. The number of positively significant counties were 19, negatively significant counties were 6, positively insignificant counties were 14 and negatively insignificant counties were 15 where Yankton county was defaulted.

On the other hand, negatively significant coefficients represent that the counties with the bird density below that of the default county. The result showed that only a few counties along the western side of South Dakota, such as Butte, Haakon, Mellette, Perkins, Stanley and Todd, are negatively significant. Again, it was not clear what aspects in those counties were influencing negatively to the bird population during the study period. In addition, the western part of the state was not considered as having a significant pheasant abundance. The remaining counties apart from the darkest and lightest are not significant. These insignificant counties, whether positive or negative, basically indicates that they are not significantly different than the default county in terms of number of birds. However, it was challenging to interpret the findings for the insignificant counties. In general, possibly, something more was going on in determining the availability of pheasants throughout the state apart from the fluctuation of major variables used in the study.

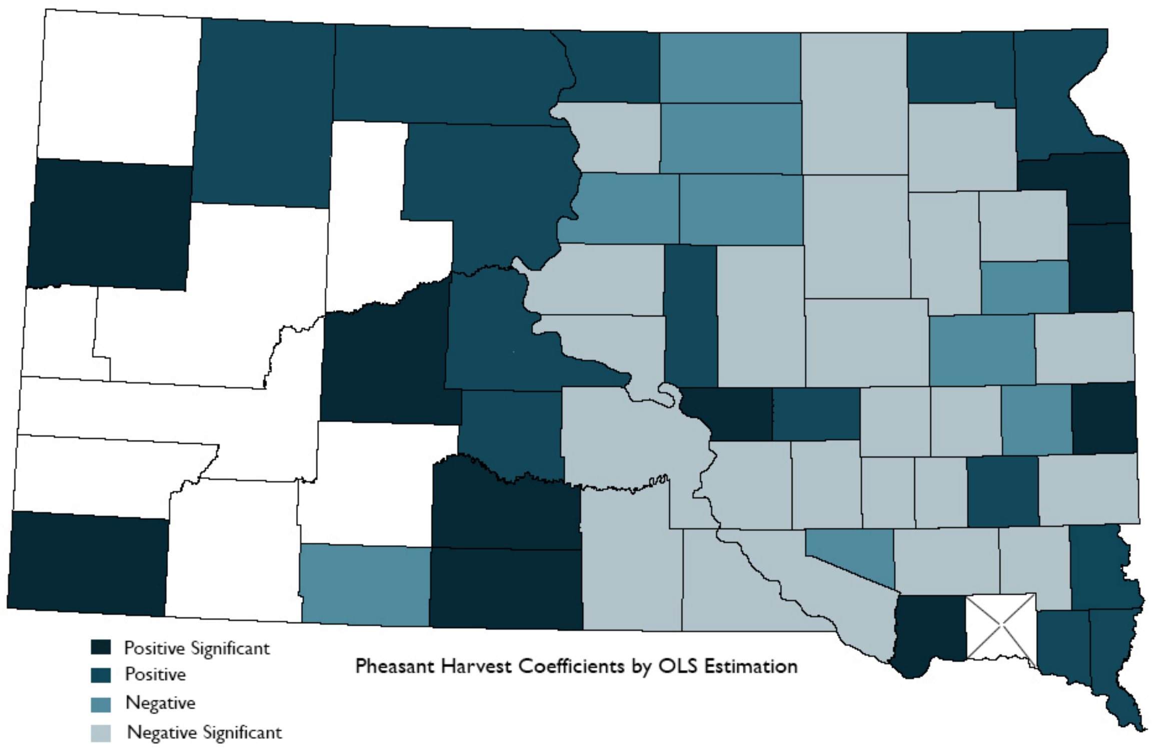

Figure 4.3 OLS estimated county parameters for pheasant harvest. The number of positively significant counties were 10, negatively significant counties were 22, positive insignificant counties were 13 and negative insignificant counties were 9 where Yankton county was defaulted.

Regarding the harvested number of pheasants, figures 4.3 and 4.4 show substantially more counties where pheasant population appears dense, having negatively significant coefficients representing number of harvested birds below than the default county in those areas. The few counties (in SEM estimation map) located towards the west and further east such as Bon Homme, Butte, Fall River, Grant, Haakon, Mellette, Moody and Todd, have positively significant coefficients indicating high percentage of harvested birds than the default county.

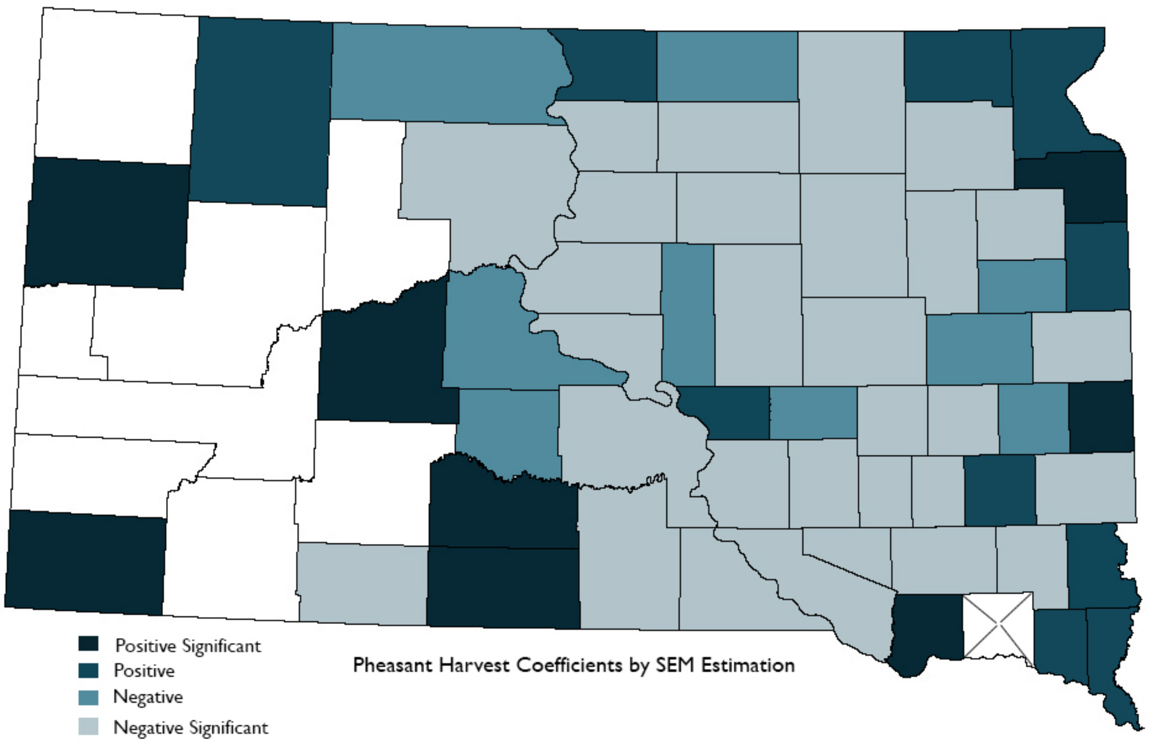

Figure 4.4 SEM estimated county parameters for pheasant harvest. The number of positively significant counties were 8, negatively significant counties were 28, positively insignificant counties were 9 and negatively insignificant counties were 9 where Yankton county was defaulted.

This relationship between pheasant density and harvest quantity over counties is not consistent with the prior beliefs. However, it may not be surprising to find this result as a larger bird population does not always have to mean a higher level of harvesting. Many other disturbances also influence the relative importance of why hunters may not have success in those counties where bird population were high. Furthermore, it is likely that some harvest numbers may not be representative of where birds were actually harvested, and also no data was available in terms of where birds were raised and released, thus artificially influencing the harvest levels regardless of the bird counts. The reduced model shown in figure 4.5 slightly changes the pattern, increasing the positive insignificant counties towards the east, but it again does not show significant difference in terms of increased harvest volume.

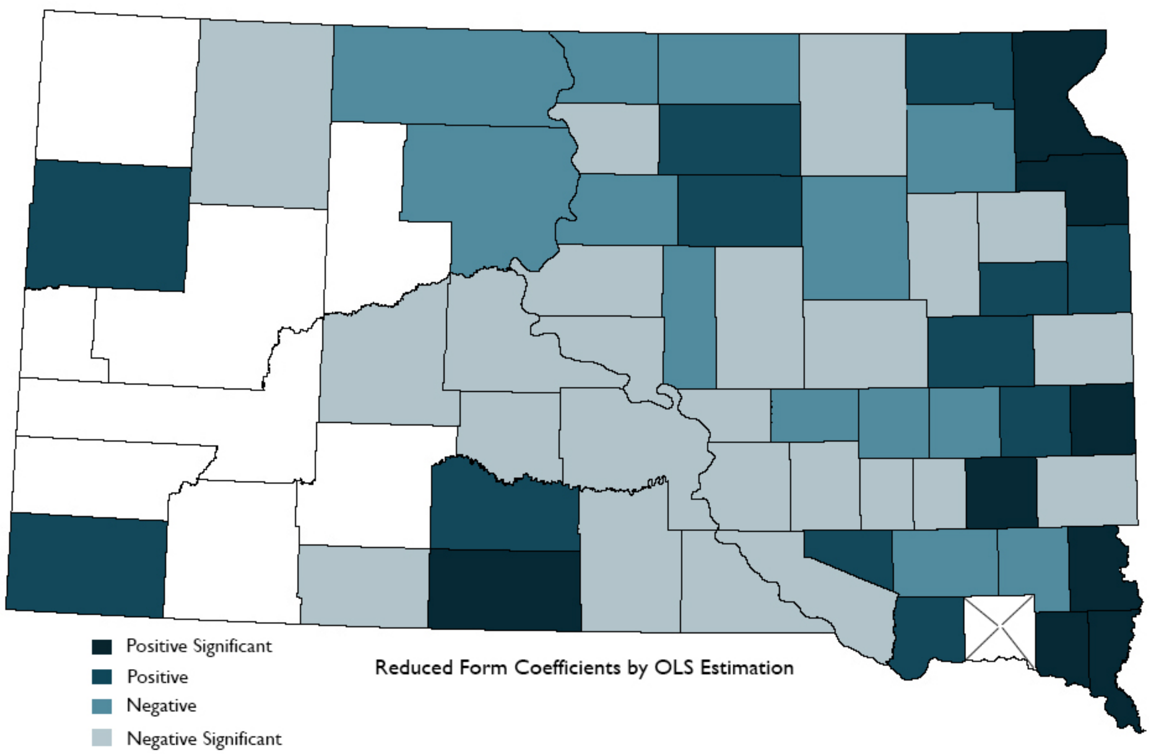

Figure 4.5 OLS estimated county parameters for reduced form model (pheasant harvest). The number of positively significant counties were 7, negatively significant counties were 23, positively insignificant counties were 12 and negatively insignificant counties were 12 where Yankton county was defaulted.

CHAPTER FIVE

5. Conclusion and Recommendations

As an upland game bird, pheasants are a major attraction for hunters. The hunting season plays an important role in the economy of south Dakota. In the past decade, a negative trend in the pheasant population has been observed, which is a growing concern for South Dakota and other states with hunting activities. The availability of grassland is an important driver in maintaining and even boosting the pheasant population. However, ground cover from protective grasses has been decreasing in recent years, which has translated into a declining bird population. There might be various reasons for the decreasing area of grass cover. However, substantial cropland expansion was one of the major reasons for widespread loss of grassland habitat particularly in the eastern portion of South Dakota (Wimberly et al., 2017). Maintaining or increasing undisturbed grassland, therefore, is a key aspect for habitat and a challenge for wildlife managers and policy makers. This study focused on understanding the impact on pheasant population based on crop mix acres together with harvested volume, which is lacking in the currently available literature. The results of this study could be useful for better management of land use and landcover practices for maintaining an optimal bird population.

Specifically, three different models were developed in this study. Pheasant population was analyzed based on some key crops and grassland acres, including CRP. The analysis also modeled the number of harvested birds based on bird population and number of hunters. Finally, a reduced model was developed where the number of harvested birds was estimated using crop mix acres and number of hunters. The data for pheasants and hunters came from surveys conducted by SDGFP and crop mix acreages were acquired from cropland data layer statistics provided by USDA. To address endogeneity and contemporaneous correlation between errors, the simultaneous equations model using conditional mixed process estimation was employed.

The study found that intensification of corn and soybean acres had significant negative responses with the pheasant population, which might be a reason why the pheasant population decreased between 2008- 2018. One of the reasons why corn and soybean acres increased could be the higher returns to farmers compared to small grains and forage crops or from enrollment of their land to CRP. Policy makers may have to provide additional support to farmers to reverse the trend.

Considering the potential nesting and brood rearing habitat, other hay acres was expected to be appealing and positively associated with pheasant numbers. This study, however, found that this variable was negatively related with the pheasant population. The reason behind this could be dryer weather during the study period. Other hay might be used for livestock feed production in dry conditions and hayfields would generally have less residual cover once grazed or harvested. Moreover, nests may be destroyed, and newly hatched chicks may not survive due to farm machinery used during harvest as the normal hay harvesting period in summer overlaps with the nesting and hatching period for pheasants. These findings can be compared to findings of other researchers studying the population density and harvested quantity of game birds.

In terms of CRP grassland acres, the result was consistent with pervious findings (Nielson et al., 2008, Warner et al., 1989, Pauly et al., 2018, Matthews et al., 2012), suggesting pheasants select habitat structure with diverse, dense, undisturbed and managed portion of CRP land, enhanced by inter-seeded grasslands, such as alfalfa and sweet clover fields for nesting and brood rearing. Therefore, this study concluded that increasing CRP land is associated with a higher pheasant population density. The study found that the number of pheasants increases with the increase of winter wheat, spring wheat and alfalfa acres. Winter wheat was the most influential factor in increasing the number of birds among all the variables included in the model. This result might be because of the fact that winter wheat is grown earlier in the season (Pauly et al., 2018), which can reduce mortality of birds during winter by providing good shelter for severe winter and helping birds to avoid predators.

Both alfalfa and spring wheat were found to be positively associated with the bird population. Alfalfa was slightly more significant than spring wheat with regard to increasing bird population. This is might be because alfalfa ground cover will regrow once it is harvested, and pheasants could reuse this habitat for brood rearing and food. The study found evidence that winter wheat and alfalfa were more supportive than CRP for increasing the pheasant population. This could potentially be because there was a slight decline in CRP acres and also because CRP might lack the vegetation structure favorable to pheasants during the study period (2008-2019) caused by insufficient plant diversity and poor stand maintenance (Rodgers, 1999). The CRP field age also has potential to reduce the pheasant density because habitat quality can decrease with field age (Eggebo et al., 2003). In addition, there was no evidence for a steep increase in alfalfa acres and there was a decline in wheat acres during the study period. Therefore, it is important that more emphasis be given to emergent CRP fields with diverse grass covers, which could potentially be achieved by increasing alfalfa and other grasses preferred by the pheasants.

Regarding the harvest model, the results demonstrated that bird harvest volume was strongly associated (positively) with bird population and number of hunters. This finding indicates that strong bird population and increased number of hunters increases the harvest volume, which is, to some extent, an expected result. The study also showed that crop mix acres, such as corn and soybeans, were negatively related with harvest volume whereas wheat and alfalfa acres were positively associated to the same. However, the study found no relationship between other hay and CRP acres and harvested birds. The loss may be because the access for these landscape acres were closed for pheasant hunting purposes during the sample period. It can be concluded that estimating parameters using the reduced model is logical, but this provides no direct relationship between response and explanatory variables.

In addition, there was a high potential for inconsistent and inefficient estimation of these parameters included in the model because of several other disturbances. Hence, county specific dummy variables were included for the models to produce more consistent and efficient results by controlling the potential influences of residuals. The results showed that counties such as Aurora, Beadle, Bennett, Brown, Brule, Douglas, Edmunds, Faulk, Hand, Hutchinson/Turner, Kingsbury, Lake, Lyman, McCook, Miner, Potter, Sanborn, Spink and Union/Clay were positively significant representing more pheasant population and highest preserved birds than the default county (Yankton). Further, Butte, Haakon, Mellette, Perkins, Stanley and Todd counties were negatively significant indicating a smaller bird population. The counties located towards the west and further east such as Bonhomme, Butte, Fall River, Grant, Haakon, Mellette, Moody and Todd were positively significant, representing higher harvest volume than default county. As opposed to the bird population, several counties along the James River valley were found to have negative relation, indicating a smaller number of birds harvested. The reduced model did not show significantly different pattern for harvested birds. This finding suggests that attributes connected with factors also play an important role in determining the bird population and harvest volume specific to each county. Hence, identifying such issues and implementing enhanced management practices would be beneficial.

Management Implications, Limitations and Recommendations for Future Research

As discussed before, diversity in land cover along with quantity and quality of CRP land is important for a healthy pheasant population. As an example, increased corn and soybeans acres have negatively impacted bird habitat and thus their population. There is a continuous increase of these crop acres, which may need to be reversed to optimize conservation practices, bird population and crop farming.

In South Dakota, the vast majority of the land (80%) is privately owned. Therefore, it is crucial that private landowners are continually encouraged, facilitated and supported to continue their role as stewards of bird habitat and its population (Runia et al., 2016). On the other hand, crop farming is an important component of the state's economy. It is, therefore, not practical to convert large acres of cropland to grassland. Also, crop farming is generally more profitable for famers, and therefore it is important to adjust the CRP rental rate when extending CRP contracts. Another way could be to consider a policy of providing subsidies to farmers to encourage them to produce more wheat, alfalfa and other types of forage crops suitable to pheasant habitat, which may then help increase habitat for pheasants. Another policy change seen in South Dakota is the Winter Coverage Endorsement option for insuring winter wheat. This policy is expected to benefit both pheasant habitat and agricultural producers (USDA RMA 2015, Pauly et al., 2018). Alternatively, adding these habitats into developing CRP fields may produce desirable solution for improving bird population.

This study was conducted covering most of the counties in South Dakota. There was comprehensive data available for different variables (e.g., brood survey data) considered in this study. However, it is noted that the data was incomplete for representing the range of pheasants throughout the state. For example, there were some counties omitted in this study due to unavailability of brood count survey routes. Further, this study used limited landcover acres and pheasant parameters that has a potentially highly fluctuating trend. In the future, the models developed in this work could be further improved using population and harvest data from additional counties. The reported study covered a duration from 2008 to 2019 when all types of land cover and other variables of interest were available. The models developed could be further expanded and enhanced using data for longer periods. Future studies could also consider including more variables that impact the pheasant population and harvest along with adding hunter satisfaction for the harvest model. In addition, it is noted that the methods presented in this thesis offered insights into the impact of major crop mix acres on pheasant population and impact of bird population and number of hunters on pheasant harvest volume across the state. The study could be expanded in the future for further evaluation of these parameters adding more covariates in other geographic regions and for other game birds.

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APPENDIX: AVERAGE VALUE AND COEFFICIENTS FOR COUNTIES

*Note: In the table, first and second column shows the average value of pheasant population per mile and pheasant harvest per season for each county over the period 2008-2019. The third and fourth column shows the coefficient obtained for pheasant population (PP) and pheasant harvest (PH) specific to each county. This study prefers simultaneous equations model for consistent and efficient results, hence, coefficients for pheasant population and harvest acquired by joint estimation approach have shown in the table. The fifth column shows the coefficients obtained by reduced form for pheasant harvest specific to each county. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.*

County Variables	Pheasant Per Mile	Pheasant Harvest Per Season	PP Coef.	PH Coef.	Reduced Coef.
Aurora	7.20	41749.08	4.964***	-13,233.063***	-7,603.194***
Beadle	4.12	58888.00	3.804***	-14,772.247***	-11,259.679***
Bennett	7.81	7552.25	2.315**	-6,553.310***	-3,449.070**
Bon Homme	0.66	5799.33	-1.241	3,385.653**	1,638.946
Brookings	1.93	18053.92	0.941	-7,653.503***	-6,090.246***
Brown	3.60	76814.83	4.232**	-24,289.959***	-18,652.801***
Brule	13.82	65350.08	10.290***	-29,005.451***	-16,828.834***
Buffalo	4.09	6423.92	1.627	1,689.849	3,950.333**
Butte	0.27	1176.42	-4.827***	7,676.746***	109.321
Campbell	2.70	17495.42	-1.139	1,376.998	-190.207
Charles Mix	4.07	35537.83	-0.897	-9,663.471***	-12,043.272***
Clark	2.47	29236.00	1.007	-5,802.578***	-4,347.328**
Codington	2.86	20266.58	0.509	-7,681.743***	-7,367.728***
Corson	4.86	5047.08	-1.586	-495.094	-3,458.537
Davison/Hanson	2.56	49845.00	0.932	-17,973.305***	-18,678.288***
Day	2.42	14147.00	-0.181	-4,416.451***	-3,322.913

Deuel	1.66	6575.42	-0.556	2,422.911	2,347.811
Dewey	6.87	13106.67	1.367	-3,605.064**	-2,399.955
Douglas	5.89	12978.33	3.814***	-4,987.774***	403.304
Edmunds	5.40	43298.58	4.535***	-3,099.207*	2,833.622
Fall River	1.33	1888.67	-1.102	4,742.847***	2,605.627
Faulk	5.32	40712.58	3.457***	-3,199.604*	706.415
Grant	0.58	4812.00	-1.299	4,631.439***	3,186.666**
Gregory	3.14	37194.92	-0.777	-5,364.979***	-8,608.587***
Haakon	0.86	6349.25	-10.156***	4,476.876***	-9,564.651***
Hamlin	2.28	11278.75	1.334	-1,571.915	662.704
Hand	5.86	42393.00	2.821**	-9,379.191***	-5,963.156***
Hughes	7.50	42797.00	0.268	-13,227.242***	-14,124.960***
Hutchinson/Turner	1.89	24904.33	2.446*	-7,562.789***	-3,207.755
Hyde	4.30	11845.67	-0.129	-323.089	-671.043
Jerauld	2.80	18389.17	0.526	-145.866	-152.853
Jones	4.90	13789.00	-0.629	-1,671.949	-3,100.628*
Kingsbury	2.04	18836.25	1.954*	-2,324.572	349.201
Lake	2.23	10703.50	2.159**	-2,353.727	1,002.288
Lincoln	0.92	5583.17	1.554	2,190.382	5,160.643***
Lyman	15.66	69793.17	4.605**	-24,020.771***	-17,697.209***
Marshall	1.86	8279.33	-0.259	1,684.767	2,663.212
McCook	1.92	14270.42	1.883*	557.683	3,454.092**
McPherson	1.90	23609.17	-0.643	-435.165	-2,129.348
Mellette	1.85	3024.83	-1.978*	4,744.552***	1,381.116
Miner	4.91	27521.50	3.397***	-4,888.479***	-415.774
Minnehaha	1.17	12251.33	1.219	-5,410.750***	-3,767.929**
Moody	1.13	6062.75	0.765	3,499.785**	5,274.814***
Perkins	1.15	11871.33	-7.203***	2,166.616	-9,311.642***

Potter	9.15	39428.42	2.937**	-6,893.151***	-3,037.875
Roberts	0.91	7823.00	-0.102	2,381.207	3,992.860*
Sanborn	6.28	21478.50	4.420***	-7,814.665***	-1,975.054
Spink	3.14	65813.75	3.678**	-5,888.252***	-1,155.654
Stanley	3.81	13152.17	-7.729***	-620.992	-11,084.477***
Sully	10.10	29948.92	-1.080	-8,299.417***	-9,505.569***
Todd	0.52	1376.58	-2.162*	7,519.575***	3,768.307**
Tripp	7.47	73843.25	0.291	-17,161.159***	-20,360.235***
Union/Clay	0.79	6988.25	1.992*	1,116.479	5,179.989***
Walworth	4.10	26557.33	0.606	-4,210.889***	-3,918.143**
Yankton	1.48	6935.00	Omitted	Omitted	Omitted