A study of the Martin farm in Dalton, Nebraska

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A study of the Martin farm in Dalton, Nebraska

by

Neil Martin

A creative component submitted to the graduate faculty in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE

Major: Agronomy

Program of Study Committee:

Major Professor: Mary H. Wiedenhoeft

Andrew W. Lenssen

Mark E. Westgate

Iowa State University

Ames, Iowa

2018

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INTRODUCTION

Farm operations should be conducted in such a manner as to maximize economic, agronomic, and environmental performance. When these goals are met, a farm can be considered a success.

When these goals are not met, farm viability is in jeopardy and the environment can be degraded. This state of affairs is likely due to several factors.

Many farm operations are managed by traditional farming methods. These methods, which are “tried and true”, are widely accepted. These methods developed long ago from observations and experiences. They have been proven, often over several generations and some are valid.

However, many of these methods are not always appropriate in today’s agricultural culture. An in-law once said to me, concerning advice from an extension agent, “I do things the way my daddy did and no d*** college boy can tell me different”. He and many others have missed out on many of the advances that modern agriculture has created. This argument is not intended to mean that all traditional methods are without merit, but is intended to convey that some of the old methods can be improved.

Not all farmers are aware of the scientific details of soil structure and soil health. They are not well informed about topics such as pest and disease management, crop nutrition, or environmental issues. Few farmers have the time, inclination, and technical background to become conversant on all of the issues involved in a complex operation. In spite of their best efforts, important details are sometimes overlooked because there is not enough time in a farmer’s day to attend to all the details.
A thorough examination of a portion or all of a farm operation’s aspects, when conducted by an impartial and competent individual or organization, can identify the operation’s strengths and weaknesses. A case study can point out what is working, and what could be working better. This study can bring to the attention of the farm manager potential solutions to noted problems, both operational and environmental.

This Creative Component project is structured as an actual agronomy based case study of an existing farm operation; other concerns, such as financial analysis are best left to others. The farm that will be featured in the case study is located a few miles west of Dalton, Nebraska and belongs to Neil and Linda Martin (Neil is the author of this case study).

OBJECTIVES AND GUIDELINES

Objective of case study

The objective of this case study is to examine the physical and operational details of the Martin farm with the intent of providing to the operators, a guide to improving the farm management.
Case study guidelines

The case study is constructed to fit the needs and goals of the farm’s operators and owners. The study will be mindful of the experience, resources, abilities, and goals of the owners and operators of the farm. It is structured in a manner that presents issues, explains their relevance, and suggests action plans where needed. When more than one suitable course of action is available, multiple actions are proposed. If no action is currently indicated, that also is noted. Both positive and negative aspects of the operation are noted in the study.

THE OWNERS AND THEIR GOALS

The owners

Several years ago, in anticipation of an upcoming mandatory retirement, the Martins purchased their farmland and arranged for it to be operated under a sharecrop agreement. This agreement has ended and the Martins are now the operators of the farm. The former tenant will continue to be employed on an “as-needed” basis. Linda received some prior exposure to farming during high school when her parents inherited and operated a family farm. Neil had no farm experience but has been gaining insights from helping the farm’s sharecrop tenant. Recently retired from a career flying heavy jets, he has become conversant with the operation and maintenance of farm equipment. In addition to being inexperienced as farmers, neither of them
has operated a business. Neil is nearing completion of a Master of Science degree in Agronomy from Iowa State University.

The owners’ goals

The Martins have established several goals for their farm operation. Their first priority is to learn enough about the farming business to enable them to operate the farm in an economically sustainable way – the farm needs to show a profit in order to survive. Next, the farm should be managed in an environmentally sustainable manner - at the end of the Martin’s tenure, they want the farm’s soil, infrastructure, and biota to be in as good or better condition than at present.

Desired soil improvements include:

- Increase soil organic matter.
- Increase soil organisms, such as earth worms.
- Increase soil water storage and plant available water.

Desired infrastructure improvements include:

- Remediation of a former oil production site.
- Improvements to the usability of field access points.
- Correction of roadside drainage deficiencies.
- Reduction of the land’s water erosion potential.

Desired biota improvements include:

- An increase of soil biota as measured by earthworm population.
• A decrease in the population of field damaging animal pests, such as burrowing squirrels and badgers.

Lastly, the Martins would like to operate the farm in a manner that provides the time to pursue other interests such as family events and travel.

LOCATION OF THE FARM

The Martin Farm is located in southwestern Nebraska in Cheyenne County. The farm consists of 470 acres divided between three quarter sections. Two of the quarter sections touch at a corner and the third is not contiguous. The most distant field is one mile from the others. An equipment barn and a newly constructed house are located on the farm’s westernmost parcel. These three parcels lie a few miles west of Dalton, Nebraska on Cheyenne County road 58 (Figs 1-5).
Figure 1. General location of the Martin farm in the Nebraska Panhandle, (Google Maps, 2018).
Figure 2. The Martin farm consists of three quarter sections along Cheyenne County Road 58 (Google Earth, 2017).
Figure 3. The 161 acre west field hosts an equipment barn and an under-construction home (NRCS Web Soil Survey, 2017).
Figure 4. The 154 acre center field (NRCS Web Soil Survey, 2017).
Figure 5. The 156 acre east field (NRCS Web Soil Survey, 2017).
The Martin farm is situated in the high plains region of the Great Plains. At the farm’s 4300 foot elevation, the winters are cold and the summers are warm. The winter average high and low are 39°F and 17°F, respectively, while the average summer high is 83°F and the average summer low is 55°F (Table 1). A monthly presentation of temperature averages gives a better idea of normal temperatures and precipitation timing (Figure 6, Table 2).

Table 1. Seasonal climate averages in Dalton, Nebraska, which is 2 miles east of the Martin farm (NCDC/NOAA, 2017).

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<tr>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Inches</td>
<td>°F</td>
<td>°F</td>
</tr>
<tr>
<td>Winter</td>
<td>1.52</td>
<td>16.8</td>
<td>39.4</td>
</tr>
<tr>
<td>Spring</td>
<td>6.43</td>
<td>33.0</td>
<td>58.9</td>
</tr>
<tr>
<td>Summer</td>
<td>8.05</td>
<td>55.4</td>
<td>83.0</td>
</tr>
<tr>
<td>Fall</td>
<td>3.77</td>
<td>35.1</td>
<td>61.1</td>
</tr>
<tr>
<td>Annual</td>
<td>19.77</td>
<td>35.2</td>
<td>60.7</td>
</tr>
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Figure 6. Average monthly high, average, and low temperatures (°F) in Dalton, NE, which is 3 miles east of the Martin farm. (NCDC/NOAA, 2017).

![Average monthly temperatures](image)

Table 2. Monthly precipitation in Dalton, NE (NCDC/NOAA, 2017).

<table>
<thead>
<tr>
<th>Month</th>
<th>Precipitation in inches</th>
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<tbody>
<tr>
<td>January</td>
<td>0.35</td>
</tr>
<tr>
<td>February</td>
<td>0.55</td>
</tr>
<tr>
<td>March</td>
<td>1.26</td>
</tr>
<tr>
<td>April</td>
<td>2.06</td>
</tr>
<tr>
<td>May</td>
<td>3.11</td>
</tr>
<tr>
<td>June</td>
<td>3.29</td>
</tr>
<tr>
<td>July</td>
<td>2.78</td>
</tr>
<tr>
<td>August</td>
<td>1.98</td>
</tr>
<tr>
<td>September</td>
<td>1.63</td>
</tr>
<tr>
<td>October</td>
<td>1.43</td>
</tr>
<tr>
<td>November</td>
<td>0.71</td>
</tr>
<tr>
<td>December</td>
<td>0.62</td>
</tr>
<tr>
<td>Total</td>
<td>19.77</td>
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The coldest and driest months of the year are November, December, January, and February (Figure 7). The soil is normally undisturbed by tillage, frozen, and has a low infiltration rate (Pikul et al., 1996). A total of 2.2 inches of water falls as snow, which blows around until most of it sublimates into the atmosphere. Only a portion of the water enters the soil (Figures 6 and 7).

The spring months of March, April, and May are characterized by thawed soil, an increase of precipitation to 6.4 inches, and increasing temperatures (Figures 6 and 7). Winter wheat resumes growth in March and early spring crops are planted in late March or in April. March and April receive less moisture than May, resulting in a better fieldwork environment than compared to the environment in May.

The warm months of June, July, and August receive 8.1 inches of rain, mostly from convective storms (Figures 6 and Table 2). Convective precipitation presents the possibility of hail and damaging winds. July’s 2.8 inches of rain (2.8 inches) can interfere with the harvest of early season crops such as winter wheat and field peas.

During the autumnal months of September, October, and November the climate cools and dries (Figures 6 and 7). During these months crops such as corn and millet can be harvested. Dry soil conditions in the fall allow applications of herbicide for weed control.

**TOPOGRAPHY**

The United States Geological Survey (USGS) topography maps show flat to gently sloped (3 to 6 percent) fields with minor areas of steeper terrain of 6 to 9 percent grade (United States
Geological Survey, 2016). The following topographic map of the farm’s area was modified from an online USGS map of Cheyenne County (Figure 8). With the exception of a normally dry swale across two of the three quarter sections, the land has no water features. GPS systems indicate that elevations on the farm range from 4300 ft. MSL (mean sea level) to 4330 ft. MSL. Although the USGS map shows that none of the fields has an elevation variance greater than 35 feet, several small areas have of up to 9 percent. These areas present a water erosion potential that will be discussed in the erosion section of this report.

Figure 8. USGS topography map of the Martin farm (USGS US Topo Download (V1.0), 2017).
WATER

Irrigation

The Martin farm is a dryland farm, without irrigation. If the fields were irrigated, the land would be more productive (Wajid et al., 2002). The amount of productivity increase with irrigation is variable and depends on factors such as the amount and timing of natural precipitation, plant population, and the amount of irrigation water that is available. The NRCS Web Soil Survey rates all of the farm’s soils as prime if irrigated. The NRCS Web Soil Survey soil descriptions can be viewed in the Soils Appendix.

No distribution system exists in Cheyenne County to store or distribute surface water for irrigation. However, the farm’s terrain can accommodate pivot irrigation; suitable electric power for well pumping is available; and the Ogallala Aquifer lies a few hundred feet beneath the surface. However, an irrigation well permit will likely never become available.

The Ogallala aquifer is recharged by surface infiltration, and a balance between aquifer recharge and withdrawal is maintained to prevent depletion of the aquifer. In Cheyenne County, the Nebraska Department of Natural Resources and the affiliated South Platte Water Resources District issue irrigation well permits. The District currently rates all Cheyenne County groundwater as fully appropriated or over appropriated because groundwater withdrawals meet or exceed groundwater recharge. Consequently, at present a moratorium on the issuance of new irrigation well permits exists. Annual irrigation well withdrawals are restricted to 14 inches of water and this rate may be increased or decreased in order to balance groundwater withdrawals and recharge (South Platte Natural Resources District, 2017; Nebraska Department of Natural
Resources, 2009). Domestic water wells are not affected by the moratorium or by limitations and the Martin farm has a plentiful supply of water for domestic use but not for crops.

**Water for crops**

All of the farm’s crop water arrives as precipitation. The area averages 19.8 inches of precipitation (Table 1), (NCDC/NOAA, 2017). Approximately 3 inches of this precipitation occurs during the coldest months, when the soil is frozen. This precipitation generally consists of snow, which accumulates, melts and refreezes, or just blows around until it sublimes into the atmosphere. The remaining 17 inches of precipitation occurs when the soil is thawed, resulting in infiltration.

According to the NRCS soil reports, the farm’s soils typically have good infiltration and water storage properties. Lab tests of the top 10 inches of soil indicate that the soils have an organic matter contents that range from 1.4% to 2.8% with an average of 2%. An increase of soil organic matter would likely be beneficial to crops. An increase of organic matter would increase the water holding capacity and infiltration rate of water into the soil, and subsequent movement of water into the root zone of crops. In addition, increased organic matter would improve the CEC of the soil. An increased CEC would reduce the leaching of the cation nutrients that currently may be lost due to leaching (Brady and Weil, 2008).

Minimum-tillage and, to a greater extant, no-till preserves a surface layer of crop residue that shades and cools soil, thus slowing evaporative water loss. Soil water storage efficiency becomes significantly greater as tillage is reduced (Tanaka and Anderson, 1997).

A long-term experiment performed at the High Plains Agricultural Laboratory compared infiltration rates with long term no-till soil with long-term no-till that had been converted to
moldboard tillage in 1969 (Kettler et al., 2000). The laboratory is located 15 miles south of the Martin farm and its soils are similar to the silt loams that are found on the farm. The experiment found no difference in infiltration rates for the first 2.5 cm of applied water and found that subsequent water applications infiltrated into the moldboard tilled soil at approximately two thirds the rate of the no-tilled soil. Subsequent water applications infiltrated the no-till soil at a rate of 163 mm hr\(^{-1}\) and infiltrated the plowed soil at a rate of 110 mm hr\(^{-1}\). The study notes that the average infiltration rate for moldboard-plowed soil was 5.1 cm of water in 31 minutes, indicating that the moldboard-plowed soil could absorb a 50-year precipitation event without runoff (Kettler et al., 2000).

**Action plan for water**

In order to improve or maintain the high infiltration and high water storage properties of the farm’s soils, tillage should be minimized. The current practice of no till should be maintained as much as possible. Consideration should be given to altering the crop rotation sequence and the crops themselves in order to improve the efficiency of water use.


**SOILS**

**Soil maps**

The soils on the Martin Farm are all loams and most are silt loams. The upper profile of the soils contains an average of 50% silt (NRCS Web Soil Survey, 2017). Figures 9, 10 and 11 are NRCS Web Soil Survey soil map screenshots. The major soil series that are present in the farm are Alliance, Duroc, Keith, and Kuma.

Alliance silt-loam (Fine-silty, mixed, superactive, mesic, Aridic Argiustolls) has loam in the A horizon, underlain by silt loam and silty clay loam and weathered bedrock at 60 inches. The parent material of Alliance soil is loamy loess over sandstone or limestone. Alliance soil is well drained and has moderately high to high water conductivity. The water table in Alliance loam is more than 80 inches and the soil profile can store about 11.7 inches of water.

Duroc loam (Fine-silty, mixed, superactive, mesic, Pachic Hapustolls) has either loam or silt loam in all of its horizons. It is well drained, has a moderately high to high water conductivity and its available water capacity is 15.7 inches. The parent material of Duroc soil is alluvium.

Kuma silt loam (Fine-silty, mixed, superactive, mesic, Pachic Hapustolls) is well drained with no hydraulic restrictions to at least 80 inches of depth. The cited soil profile (0 inches to 80 inches) is able to store 11.7 inches of water. The soil’s parent material is loess and all of the horizons in this soil are loams.

Keith silt loam (Fine-silty, mixed, superactive, mesic, Aridic Argiustolls) is a loam underlain by silt loam and very fine sandy loam. Its parent material is loess. Keith soil is well drained and has a moderately high to high water conductivity. The soil profile’s available water
capacity is about 19.8 inches (NRCS Web Soil Survey, 2017). Full descriptions of these soils are available in Appendix 1.
Figure 9. The east field soil map indicates mostly loam soil with a 0-3% slope. (NRCS Web Soil Survey, 2017).
Figure 10. The center field soil map indicates mostly loam soil with a 0-3% slope and a minor amount of 3-6% slope. (NRCS Web Soil Survey, 2017).
Figure 11. The west field soil map indicates mostly loam soil with a 0-3% slope, 31 acres of 3-6% slope and a minor amount of 3-9% slope (NRCS Web Soil Survey, 2017).
The west field is traversed by a normally dry wash, which is fed by a watershed that is comprised of thousands of acres of farmland. Extended periods of wet weather and periods of very heavy precipitation result in runoff flow and storage in this swale. The wash is vegetated with native and introduced grasses and several cottonwood trees and is well protected from water erosion. The wash grasses are mostly little bluestem (*Schizachyrium scoparium* (Michx.) Nash), redtop bent (*Agrostis stolonifera* L.), smooth brome (*Bromus inermis* Leyss), and Johnsongrass (*Sorghum halepense* (L.) Pers.). Only during and after periods of heavy precipitation, the wash flows eastward and crosses the southern end of the Center field. The southern portion of the west field exhibits several light colored areas that are limestone outcroppings. A darkened, two acre rectangle near the east end of the center field southern portion is covered by native vegetation (bigroot prickly pear (*Opuntia macrohiza* Englm.), blue gramma grass (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths], buffalo grass (*Bouteloua dactyloides* (Nutt.) J.T. Columbus], and yucca (*Yucca glauca* Nutt.) that grow over a shallow shelf of sandstone and limestone (pers. obsv).

The Center field hosts a continuation of the same normally dry wash as the west field. This drainage path is nearly level and receives deposits of soil that was eroded from upstream fields. Two limestone outcrops are visible in the southwest quadrant of this field. The northeast quadrant of the field has a light colored area adjacent to Road 58. This area is a former oil production site and will be detailed in the section titled “Low fertility land and its remediation“.

The east field is gently sloped rolling terrain. No drainages exit the property. Rare periods of extended precipitation can lead to short duration ponding and long term mud in the center of the northeast quadrant. The partitioned southeast corner of the east field is an abandoned homestead that is not part of the Martin farm.
**Soil nutrients**

Soil samples were collected on 8 October 2017. Each field was divided into four quadrants equal to roughly 40 acres per sample area. Ten individual cores at a 10-inch depth were obtained from within a ten-foot radius of the center of the sampling area. The ten individual cores were composited prior to submission to Ward Laboratories, located in Kearney, Nebraska. The soil test analyses for each field are presented in Appendix 1.

In general, the test results indicate deficiencies of phosphorus and sulfur in all fields, zinc in both the west field and east field, and manganese in parts of west field and Center field. The iron chlorosis warning in west field sample 1, (Figure 12), is most likely due to a small subsurface limestone outcrop (high pH) and is not indicative of a field wide need for iron. The need for nitrogen will be dependent on planned crop, previous crop, residual nitrates and planned yields.

A discussion with Brian Reimers, a Panhandle Coop region manager, resulted in a plan to apply MAP, urea, ammonium sulfate, and Micromerge (S, Zn, Mn, and B) in a dry blend. The plan rates for the east half of the east field are 38 lb a⁻¹ of MAP, 47 lb a⁻¹ of urea, 18 lb of ammonium sulfate, and 10 lb a⁻¹ of Micromerge. The per-acre cost will be $37.34. The mixture and cost can varies according to the needs of specific fields and crops.

**Action plan soil nutrients**

The soil test results indicate some need for improved soil fertility, thus a nutrient management plan should be developed and implemented. This plan should consider the crop to be planted, previous crops, currently available nutrients, expected yields, and account for nutrient
variations within the fields. Expected yields for crops can initially be based on county average yield data from the FSA.

In the future, the number of soil sampling locations should be expanded in order to reduce the sampling area and variability within the sampling area. Detailed records of applications should be maintained for comparison to future soil test results and possible correlation to crop performance.

**SOIL ORGANIC MATTER**

Soil organic matter (SOM) is the fraction of soil that is composed of plant and animal material. The portion that most affects farming is the soil organic matter that is easily decomposed in the soil. This portion is found in the upper part of a soil profile and normally consists of less than 20% of total SOM. A soil’s agricultural quality increases as its SOM fraction increases (Brady and Weil, 2008).

Several physical properties of soil are influenced by SOM, contributing to soil particle aggregation and also increasing water infiltration and water storage properties. On the soil surface, organic matter (residue) moderates soil temperatures, lessens the impact of raindrops, reduces water and wind erosion, and inhibits the growth of weeds. (Brady and Weil, 2008).

Within a soil, the humus fraction of SOM constitutes a large portion of the cation exchange capacity (CEC) and also buffers soil pH (Brady and Weil, 2008). On the surface and within a soil, organic matter serves as the base of a food source for soil biota and mineralizes nutrients as it is decomposed (Brady and Weil, 2008).
The amount of SOM in a soil is variable and dependent on many factors such as climate, tillage, soil type, and moisture content. Factors that can be managed include tillage, crop type and rotation, and fallow periods. No level of SOM is considered to be ideal for cropping but, in general, more is better. The original soil of the Martin farm, prior to any cultivation, approached 3.5% SOM (Brady and Weil, 2008), which is substantially above the average analyzed level of 2.1% on the Martin farm (Figures 12, 13, and 14) and is not likely to occur on farmed land in semi-arid regions (Sainju et al., 2007).

Management of SOM

Any disturbance of a soil leads to a diminished SOM content partially due to aggregate destruction. Of the tillage methods, no-till is the least destructive to aggregates and SOM (Six et al., 1998). A reduction of tillage intensity to no-till can slowly increase SOM levels (Gale, 2000).

A common practice in the SW Nebraska region is the rotation of winter wheat with summer fallow. In this rotation, the ground is left fallow for 14 months after wheat harvest, until the next winter wheat crop is planted. This rotation is used to bank water from the fallow period for use during the crop year. During the fallow year the fields are either clean tilled for weed control or left covered with stubble and sprayed with herbicides to control weeds. During this fallow period little organic matter is added to a soil and decomposition of existing SOM continues, leading to a net decrease in SOM (Lickacz and Penny, 2001).
**Action plan for soil organic matter**

In the past, farmers in the semi-arid high plains region included fallow years in their crop rotation in order to “save up” water in fallow years for use during crop years. Most common is a wheat – fallow rotation in which half of a farm’s land is farmed each year (pers. obs.). This practice is still in use on many Cheyenne County farms. The use of summer fallow has been shown to be detrimental to SOM and should not be utilized (Brady and Weil, 2008).

The crop rotation established by the former sharecropper was corn – fallow - winter wheat – peas, which resulted in a long fallow period (11 months) between corn and winter wheat. This fallow period occupied a spring and summer, during which SOM decomposed without replenishment of crop residue or roots. A rotation change to corn – peas – winter wheat shortens the longest fallow period and places most of the non-growing time in cold months when SOM decomposition is minimized.

In order to conserve and perhaps build SOM, tillage should be minimized to the greatest extent possible. Annual soil tests, sampled at the same times and locations, should document an increase in SOM over a period of several years.

**LOW FERTILITY LAND AND ITS REMEDIATION**

**Location of low fertility land**

Within the center field, an area of apparent low fertility exists; crop plants are stunted or absent. The area consists of a semi-circle adjacent to Road 58 and an adjoining extension to the
west. The amount of land within this area is approximately 1.4 acres out of 154 acres in the field (Figures 12 and 13).

Figure 12. Center field area of low fertility (Google Earth, 2018).
Within this area of low fertility both crops and weeds struggle to survive. Even though the area of low fertility land is small (1.4 acres), it causes a reduction in the center field’s yield and profit potential. At corn’s current value of $3.50 per bushel and a yield of 80 bushels per acre, the revenue loss for the field would be $280 per year. An economical remediation of low fertility would increase revenues in a few years.
Oil and gas exploration

A search of Cheyenne County records showed a history of oil exploration and production in the region. Mr. William Sydow, Director of the Nebraska Oil and Gas Conservation Commission, was consulted about the oil history of this land.

In 1985, an oil production well was drilled in the center field. Along with the well, pipelines, storage tanks, and a reserve pit were later constructed. The purpose of the reserve pit was to dispose of drilling waste. Soon after the well was constructed, oil storage tanks and a pipeline were added to the facility (Figure 14).

In 1998, the well was plugged and abandoned; the tanks were removed a short time later. Sydow indicated a high possibility that buried, abandoned equipment exists on the site today.

Figure 14. The center field oil storage tanks and a transfer pipeline in 1998 (Google Earth, 2018).
Because the field’s low fertility land coincides with the land that was affected by production, it is reasonable to conclude that oil production activities caused the low fertility. Sydow stated that the possibility of soil contamination by an oil spill was low and further stated that bacteria should have degraded any hydrocarbons in the soil by now. He did feel that salt contamination was a possibility on the site. During drilling operations, several layers of saline bentonite clay were penetrated. Bentonite is a 2:1 clay with a high CEC affinity for sodium from NaCl. If this saline material had been disposed of on the site (a common practice) it would certainly contaminate the area. Many crops, including maize and peas are sensitive to sodium in the soil solution (Brady and Weil, 2008).

Mr. Sydow suggested that another contributor to low fertility could be soil compaction. The tank farm on this site hosted a lot of heavy weight wheeled traffic. The crude oil was stored in the tanks and transferred to tanker trucks for off-site transport. In order to support the weight of this traffic and the weight of the tanks themselves, soil was normally fortified with the addition of gravel and road base fill material, such as a mixture of gravel, sand, and clay. This material was initially compacted during construction and further compacted by wheeled traffic during normal traffic use.

**Oil site soil tests**

Three soil samples from this site were submitted to Ward Laboratories, Inc. of Kearny, Nebraska. Sample 1 was from 0-10 inches, sample 2 at 30 inches, and sample 3 at 12 inches. Samples 1 and 2 were taken in the tank farm turnout, and sample 3 was taken over the reserve pit (Figure 15). The soil test results are located in Appendix 2.
Soils that have a Na base saturation level above 15% are considered to be sodic and crops may encounter growth problems at sodium levels that are lower than 15% (Espinoza et al., 2011). The soil tests indicated high levels of sodium. The sodium level in sample 3 was 2601 ppm and Na base saturation was 35%. A previous sample taken approximately 150 feet southwest of the oil site showed the sodium level was 253 ppm and Na base saturation was 1%.

The excavation for samples 1 and 2 encountered a highly compacted layer of soil, sand, and gravel that extended from the surface to 24 inches deep. Below this level the soil appeared to be
native noncompacted silt loam (pers. obs.). This confirms Sydow’s thoughts about soil modification to bear heavy wheeled traffic.

**Effects of compaction**

The physical effects of soil compaction include decreased water infiltration and hydraulic conductivity, decreased soil porosity and aeration, and increased soil strength which inhibits root growth and penetration. Plants affected by compaction exhibit symptoms such as mineral deficiencies, a stunted growth habit, poor yields, and early death (Plaster, 2009). The following images compare healthy pea plants from soil adjacent to the compacted soil with affected pea plants in the compacted area (Figures 16 and 17).

Figure 16. Healthy pea plants in fertile soil near oil site (N. Martin, 2017).
Remediation of sodium contamination

Sodium levels in the oil site were substantially higher than in the field surrounding the site. Two ways to reduce the sodium levels in the soils were offered by Mr. Sydow.

First, Sydow indicated that the incorporation of gypsum (CaSO$_4$) has proven to be an effective remediation for sodium contamination. Calcium’s +2 oxidation state can replace sodium +1 on bentonite’s cation exchange sites. The sodium in solution then binds with sulfate and leaches into deeper soil levels (2Na$^+$ + SO$_4^{2-}$ • 2H$_2$O). At present, a local source of gypsum has not been located; agricultural gypsum in the region is not in demand and is not available.

The second method is a deep ripping operation to a depth of approximately 2.5 feet could break up the compacted imported fill, which may initiate infiltration and leaching to reduce sodium levels. Construction equipment is available for this purpose and would require a 35 mile
delivery charge in addition to rental fees. However, Mr. Sydow indicated a high possibility of encountering buried, abandoned oil equipment and plumbing. The potential of damage to equipment makes this approach undesirable.

**Remediation of soil compaction**

The exploratory holes that were excavated for chemical analysis were also used to determine the physical nature of the low fertility soil. The soil in the tank farm area was loose soil and gravel for the top one inch of the profile. A mixture of highly compacted pea gravel, sand, and clay exist to a depth of 24 inches. Between 24 inches of depth to 30 inches the soil transitioned to a native, noncompacted soil of silt loam. The compaction impairs the soil matric potential, aeration, and root penetration (Brady and Weil, 2008).

The soil over the reserve pit was of a different nature. It was not compacted and contained little stone or gravel material. Instead it was a rather sticky mass of clay and sand that is very unlike the native silt loam soil. Three ways exist to reduce the site’s soil compaction.

First, an expensive way to remedy this compaction is to remove and replace the non-native soils. This would involve the excavation and removal of approximately 2,300 cubic yards of soil. At a conservative removal cost estimate of $5 per cubic yard, the removal cost would be $11,500. A similar cost would be incurred for installation of replacement soil collected from the center field.

A second method would be to deep rip the compacted area in order to lessen compaction levels. Ripping a small area such as the site’s compaction zone is not a large undertaking, financially or technically. However, Sydow indicated a high probability of buried, abandoned oil equipment. A risk of equipment damage in the event of entanglements with buried debris makes
this method inadvisable. For example, as the Martin’s equipment barn was being erected on the west field, an abandoned, uncharted, buried oil pipeline was discovered. No easement or location existed for this pipeline.

A final method utilizes cover crops that have a potential of reducing the site’s soil compaction. Multiple cover crop varieties may be needed to meet the requirements of low water use, high salt tolerance, rapid growth, aggressive tap roots to penetrate soil, and aggressive branching roots to build SOM.

A perfect remediation crop may not exist. However, a mixture of the following plants may result in a gradual soil improvement in the oil site area over many years. The degree of contamination and compaction is likely not uniform and each of these plants may find an environmental niche in which it survives or even prospers. As the soil’s state of compaction is lessened, increased infiltration and leaching may lessen the degree of sodium contamination. The following plants could provide remediation:

- Tillage radish, \textit{(Raphanus sativus L.)}, is known for rapid growth and a tap root that can penetrate hard soil to at least thirty inches (Chen and Weil, 2009). However, it does not have a high salt tolerance and is a high water user. This author has tested tillage radishes in the east field and found them to be a successful cover crop.

- Barley, \textit{(Hordeum vulgare L.)}, has a good salt tolerance, is a low water user, and has a fibrous root system which adds to soil organic matter. Barley is a good scavenger of soil nitrogen.

- Canola, \textit{(Brassica napus L.)}, is a cool season broadleaf that has a tap root system with fine exploratory extension roots that extend to 50 cm in soils (McNeill and Kolesik, 2004). Canola is a medium water user and has a good salinity tolerance.
• Berseem clover, \(Trifolium alexandrinum\) L., is an annual legume of fair salinity tolerance and low water use. It has a short taproot that may be useful in relieving surface compaction.

• Sunflower, \(Helianthus annuus\) L., is deep rooted annual that has a fair salinity tolerance. It is a high water user and is noted for effective mining of nutrients that are deep within the soil profile.

All of the above plants are included in a USDA – ARS cover crop compilation (USDA-ARS, 2012). A casual perusal of small seed quantities on Amazon has shown that a mixture of all of the above plants can be seeded for less than $150 per year for the entire site.

It should be noted that all of the suggested cover crops are annuals. At present, annual weeds populate the oil site. Control of the weeds and depletion of their seed bank will probably require multiple chemical applications over a period of several years. Survival of a perennial such as alfalfa is unlikely under this circumstance.

**Action plan for the center field soil remediation**

All of the recommendations except the use of cover crops for soil compaction remediation, have high costs or risks that render them impractical. The success of planting of cover crops to remediate soil compaction, and possibly initiate a decline in soil sodium levels, is not guaranteed. If cover crops are utilized, soil parameters should be periodically sampled in order to determine if progress is occurring. Annual soil tests that include compaction and sodium analysis should be performed at approximately the same locations and dates.

If a mixture of the above plants is to be seeded, the recommended seeding rates will need to be adjusted to lower rates. For example, if 5 types of plants are sown, each plant variety should
be seeded at a rate that is 1/5 the recommended rate. Normal, unadjusted planting rates are as follows:

- Barley – 60 lb ac\(^{-1}\)
- Berseem clover – 10 lb ac\(^{-1}\)
- Canola – 5 lb ac\(^{-1}\)
- Tillage radish – 10 lb ac\(^{-1}\)
- Sunflower – 5 lb ac\(^{-1}\)


While remediation is in progress, soil nutrition could be addressed. In order to keep the operation simple, include the site in the nutrition program that is used on the rest of the center field. If the remediation is successful and the site is returned to agricultural production, test its soil and adjust the nutrient application to suit its needs.

**EROSION**

When the Martin’s farmland was purchased, the NRCS and FSA maps of it showed a HEL (highly erodible land) designation for the west field and the center field. The HEL designation is indicated whenever a 1/3 of a field’s area or 50 acres meet the HEL criteria. Whenever a field’s USLE (universal soil loss equation) or WEQ (wind erosion equation) factor exceeds 8 times the field’s T value (soil loss tolerance), the field is designated as HEL (NRCS, 2013). This designation requires compliance with approved erosion mitigation plans in order to be eligible for any USDA monetary programs.
A request by the Martins; to the NRCS for redetermination of the HEL designation resulted in a reclassification of the land’s status and removal of the HEL designation. Even though the HEL designation was in error and was removed, the center field and west field are sloped and vulnerable to water erosion.

Both the center field and west field, have slopes of up to 6% in a few spots. One small area of 9% slope in the west field is depicted in the NRCS Web Soil Survey, but a site inspection does not confirm its existence (pers. obs.). The sloped ground in the west field and center field present an opportunity for water erosion, but the practice of no-till cultivation has, thus far, prevented any significant erosion (pers. obs.).

**Water Erosion**

**Center field erosion**

When the farm was acquired the center field contained a newly forming gully (Figure 18). The gully dimensions were approximately 300 feet long, 5 to 10 feet wide, and 1 to 3 feet deep. The gully had not eroded to the point of having vertical walls. The gully showed signs of having been filled by cultivation; the tenant farmer filled and compacted the gully with cultivation equipment. The gully and its 20 acre (est.) watershed have since been maintained in a no till system and no sign of erosion has appeared, even after periods of intense precipitation (pers. obs.).
West field erosion

The west field exhibits two areas of water erosion. The first of these is adjacent to road 105 on the east boundary of the field (Figure 19). Sheet runoff from portions of the west field, from the eastern neighboring field, and runoff from road 105 contribute to a flow along the west side of Road 105. This flow has eroded a gully that is approximately 300 feet long, 5 to 10 feet wide, and up to 3 feet deep. No-till cultivation has greatly reduced runoff from the west field but the road itself and the clean tilled field to the east have maintained their contribution to the flow in the gully.
The forming gully has the potential to expand, in width, into both the west field and into Road 105 (Figure 20). Construction of the new residence has excavated a large amount of concrete rubble from the old homestead. The excavated rubble and waste concrete from new construction was broken into appropriate size pieces and used to line the developing gully with riprap. This riprap lining slows the velocity of water flow and has, so far, stopped the erosion. The riprap will be expanded with the future addition of rocks that are collected from the fields. The riprap lining should be monitored in order to identify and correct any shortcomings in its performance.
Figure 20. Concrete riprap was placed in forming gulley along Road 105 (N. Martin, 2017).
Grassy wash

Running across the west field and Center field is a grassy wash that carries runoff from several thousand acres of upstream watershed (Figure 21). The wash rarely flows and when it does, the flow is slow and non-erosive (pers. obs.). A mix of grass species and a few trees populate the wash and serve as wildlife habitat (Figure 22). In fall, the grass is usually cut and baled as feed for a horse rescue operation. As long as the wash remains in its current state, no additional management will be needed to prevent erosion.

Figure 21. The west field grassy wash rarely flows (NRCS Web Soil Survey, 2017).
Figure 22. The west field grassy wash that runs across the west and center fields, is normally dry throughout the year (N. Martin, 2017).

Potential west field water erosion

A third potential erosion spot exists in the southern portion of the west field. Drainage from approximately fifteen acres converges into a single flow that empties northward into the grassy wash (Figure 23). In the past, this flow has created a depression of approximately 8 feet deep, 200 feet long, and 50 feet wide. This depression is still accessible to farm equipment, but further erosion will adversely impact its accessibility.
A field inspection and consultation with Troy Isenbart from the Sidney, Nebraska NRCS office has resulted in a plan to install two terraces to sequester runoff that would otherwise flow directly into the depression. The terraces will each be 750 feet long and will be constructed from on-site material (Figure 24). The total estimated cost of the terrace project is $3,520. Under a cost share program with Nebraska’s South Platte Natural Resources District; the South Platte Natural Resources District will pay approximately half of the project’s cost. The Martins or their successors will be obligated to maintain the terraces for a period of ten years.

**Action plan - water erosion**

Terraces should be constructed to prevent further water erosion in the west field. The terrace project will require several days for a contractor to construct. The field where the terraces will be located will be planted in peas with an anticipated late July harvest. The Martin’s plan is to schedule construction to occur immediately after the pea harvest is complete. That will allow
time after terrace construction to conduct weed control activities and prepare for the planting of winter wheat in early September.

Wind erosion

The Martin’s farm currently utilizes no-till cultivation on all of its farmed area. Except for the areas that have been disturbed for the purpose of house and barn construction, no signs of wind erosion, such as blowing dust, have been observed. Other no-till fields in the area do not display any visible evidence of wind erosion. In contrast, nearby fields that are disc-cultivated do generate blowing dust during windy conditions (pers. obs.). It is reasonable to conclude that the Martins no-till system is adequately managing wind erosion.

Action plan for wind erosion

No-till cultivation should be continued all fields and all crop residue should remain in the fields. Fields and improvements should be monitored for developing wind erosion problems.
CROPS

The semiarid climate of the farm’s region and the lack of irrigation water restrict the choice of crops to water efficient crops. Small grains such as hard red winter wheat (*Triticum aestivum*, L.), Proso millet (*Panicum miliaceum* L.), oats (*Avena sativa*, L.), barley (*Hordeum vulgare* L.), and milo [*Sorghum bicolor* (L.) Moench], are all viable candidates. Corn (*Zea mays* L.) and field peas (*Pisum sativum* L.) that are planted at an appropriate population are also good candidates. Rotations of these crops can be continuously planted on the farm without any need for water saving fallow years.

To be successful, a crop must not only grow well; it must have a market. The three closest elevators are between 3 1/2 and 25 miles from the farm. They are all owned by the same cooperative and, between them, accept hard red winter wheat (*Triticum aestivum*, L.), corn (*Zea mays* L.), milo [*Sorghum bicolor* (L.) Moench], Proso millet (*Panicum miliaceum* L.), soybeans [*Glycine max* (L.) Merr.], and sunflower (*Helianthus annuus* L.) grains. An additional elevator, 30 miles away accepts dry beans, dry field peas, and lentils. A few other markets exist, but they prefer to work with larger operations than the Martin farm.

The most common dryland crop in the farm’s vicinity is wheat, followed by low population corn that is planted at a rate of 16,000 seeds per acre (pers. obs.). Both of these crops are accepted at the nearest coop elevator and are grow well in the farm’s soil and climate. A third crop, dry field peas, is new to the region and, so far, has been exempt from insect and disease pressure (Panhandle Research and Extension Center, 2017). Field peas are relatively easy to plant and handle. The only drawback to field peas is that the nearest market facility for them is twenty five miles away from the fields.
The Martins own a John Deere 7200R tractor, a FAST three point mounted sprayer with a 90-ft boom span, and a 26-ft Great Plains no-till grain drill. That equipment will handle planting for wheat and peas, and weed control for all crops. Equipment for planting corn can be borrowed, traded, or rented; harvest operations for all crops can be hired.

**Action plan for crops**

A three-year rotation of corn, peas, fallow and wheat in that order is recommended. The crops have a local market and are a good agronomic combination. The rotation distributes labor by staggering planting and harvesting dates. Peas are planted in April and harvested in late July; wheat is planted in early September and harvested in early July; corn is planted in May and harvested in October. Future crop and climate developments may allow additions or deletions to the crop choices.

**COVER CROPS**

**Benefits of cover crops**

Cover crops are un-marketed crops that are grown in fields that would otherwise be unplanted. Some of their benefits are:

- Anchor soil and protect it from water and wind erosion (Snapp et al., 2004).
- Shade the soil to slow evaporation losses (Snapp et al., 2004).
• Immobilize nutrients, which slows their loss to leaching. These nutrients will be
mobilized later for use by subsequent crops (Snapp et al., 2004).

• Deep-rooted cover crops can scavenge nutrients that have descended below the root depth
of many commodity crops (Weil and Kremen, 2006).

• Compete with weeds (Snapp et al., 2004).

• Build soil organic matter (Sainju et al., 2012; Weil and Kremen, 2006).

• If cover crops are dissimilar to preceding and subsequent crops, they can disrupt disease
and pest cycles (Snapp et al., 2004).

• Deep-rooted cover crops may reduce soil compaction (Williams and Weil, 2003; Chen
and Weil, 2009).

Drawbacks of cover crops

• Planting and establishing a cover crop can be as expensive as planting a commodity crop
(Weil and Kremen, 2006).

• Cover crops consume soil water. In a dryland operation in Cheyenne County, a cover
crop may deplete the soil of water that is needed for a subsequent cash crop (Weil and
Kremen, 2006).

• If not terminated in a timely fashion, a cover crop can interfere with emergence of the next
crop (Benech-Arnold et al., 2000)

• Cover crops that are not terminated before bearing seeds, become weeds (Ingels C et al.,
1994).

• Cover crops have a potential to harbor pests and diseases that will affect the subsequent
commodity crop (Ingels C et al., 1994)
Nitrogen and other nutrients that are sequestered in a terminated cover crop may not be immobilized at a time that is useful to the next crop (Snapp et al., 2004).

**Action plan for cover crops**

The use of cover crops has many potential benefits and detriments. Much anecdotal evidence exists that supports the use of cover crops and much of that may be advertising exaggeration. Research at many universities shows that a cover crop may be beneficial or it may be detrimental to a succeeding crop. The many variables that control the success of a cover crop make it difficult to decide on a course of action.

If the right cover crop(s) can be included in a crop rotation on the Martin’s farm, it may provide benefits to the enterprise and to the soil. Because the establishment of a cover crop is expensive, it should be approached with caution. A good implementation would be to initially plant a cover crop(s) in a small portion of each field. Keep the project going for several years and monitor the results with soil tests, yield monitoring, disease and pest records, nutrient applications, and visual observations. Both cover cropped sub-fields and non-cover cropped fields should be monitored for comparison.

Selection of which plants to use as cover crops initially seems to be complex, but can be simplified by establishing spatial and temporal niches that a viable cover crop must fit into. The Martin’s farm is located on the high plains in USDA zone 5. This zone occasionally endures winter temperature lows of -20F. The most common temporal niche for cover crops is between a July harvest of crops, such as wheat and peas, and cold temperatures in late October. Another temporal niche extends from spring thaw to mid-August, when the cover crop will be terminated prior to the planting of winter wheat in September. A good way to begin a cover crop investigation would
be to select a crop for the fall time niche between the wheat and corn crops. A good candidate cover crop is the tillage radish (*Rahpanus sativus* L.). If planted in early August and, if precipitation is timely, the tillage radish taproot can reach depths of three feet by November. The upper twelve inches of the radish taproot will grow to one to two inches in diameter and the above ground vegetation will form a complete canopy closure (Gruver et al., 2016). The taproot can easily penetrate hard soils and leaves bio-pores through compacted soil layers (Jacobs, 2012). The tillage radish is a good scavenger of nitrates and other nutrients and its early spring decay ensures that the nutrients will be mineralized in time for a spring planted crop, such as corn (Jacobs, 2012). The tillage radish’s weed suppression properties are due to competitive fall growth and allelopathic activity (Jacobs, 2012); however, recent research indicates an absence of any allelopathic activity (Lawley et al., 2012). The radish will winter kill in the Martin’s climate and requires no attention prior to spring planting.

Tillage radishes should be drilled at a rate of 5 to 10 pounds per acre, lower rates are associated with larger taproots (Jacobs, 2012). A recent purchase of a small amount of tillage radish seed by the author indicates that seeds should be available for $5 per pound, amounting to a direct planting cost of $25 per acre. At this cost, it may be wise to limit the initial test cover crop to 20 to 40 acres. A program of frequent scouting and detailed records of this cover crop performance test will aid in evaluation of crop. Yields of the crops that are grown after the test cover crop should be documented for comparison with the control crop’s yield.
WEED MANAGEMENT

Weeds are plants that grow where they are not wanted (Figure 25). Weeds compete with crops for resources such as water, sunlight, and nutrients; they can diminish crop yields by up to 100 percent. Weeds are propagated by seeds, rhizomes, and cuttings. Weed seeds arrive in a field via wind, water, equipment and animal traffic, and from preexisting weeds already in the field. Seeds that do not germinate when deposited on soil may become part of the soil seed bank and may germinate when the right temporal and environmental niche is present.

Figure 25. Common sunflower (*Helianthus annuus*) grows by the roadside (N. Martin, 2017).
The Martin farm is host to many weed species. When the farm was purchased the fields were very weedy. After purchase the farm was tended by a tenant under a sharecrop agreement and the weeds were somewhat controlled. During the last season of the sharecrop agreement the weeds prospered. This was mostly due to anticipated low cash prices for crops. In order to avoid an economic loss, the tenant was forced to reduce weed control efforts. The Martins were preoccupied with home construction and failed to act to keep the weed population in check. The farm has recently changed operators from the tenant to the Martins themselves and weed management now has a high priority.

Although many weed species exist in the fields, not all of them are a threat to the crops. This is due to factors such as life cycle timing that differs from that of the crop, or an inability to successfully compete with the crop. The weeds specifically addressed in this section are the ones that constitute the greatest threat to crop yields. A brief description of these weeds and available control methods is provided below.

**Management of Predominant Weeds**

**Canada thistle** *[Cirsium arvense (L.) Scop.]*

Canada thistle is a member of the sunflower family and has a large presence in the Martin’s area (Figure 26). It aggressively colonizes pasture, waste, and crop lands. In dense patches, Canada thistle can reduce crop yields by 60% to 90% (Wilson, 2002). Canada thistle, a dioecious plant, reproduces by seeds and rhizomes. Its rhizomes can grow 9 – 18 feet in a year, leading to
large, expanding patches of the plant (Stubbendieck et al., 2003). Due to its aggressive nature, the perennial Canada thistle has been placed on the Nebraska noxious weed list.

Canada thistle blooms in June. Female plants may produce a few thousand seeds, which are distributed by wind. Both male and female plants reproduce from rhizomes. The thistle’s rhizomes survive frozen soils during winter months (Stubbendieck et al., 2003).

Figure 26. Canada thistle growing in Hyde Park, London (N. Martin, 2013).

Management of Canada thistle

The best management of Canada thistle is to prevent its import. Farm equipment that has not been cleaned prior to field entry can distribute seeds and rhizome segments of Canada thistle. The use of contaminated crop seed can distribute and plant unwanted Canada thistles. Canada
thistle can also be carried to a field by wind. The thistle’s seeds form occasional, single plants, which do not, at first, appear to be a problem. After a couple of years, these single plants can become dense patches, which expand to become a problem. When left unmanaged, Canada thistle patches will continuously expand.

**Mechanical control of Canada thistle**

Canada thistle may be managed by mechanical means. In order to kill Canada thistle the roots must be destroyed. Infrequent cultivation of the thistle is counterproductive because many of the rhizome fragments that cultivation creates will form new plants. However, if Canada thistle’s rhizomes are severed every 10 days for a period of up to two years, the thistle rhizomes will eventually deplete their resources and die (Wilson, 2002). This method is not practical on farmland that is planted every year and is not compatible with the farm’s no-till operation. Canada thistle seed production can be curtailed by mowing prior to early bloom. In the case of thistle patches that have bloomed, these areas should be avoided by harvest equipment to prevent seed spread.

**Biological control of Canada thistle**

Some promising biologic controls to manage Canada thistle have been identified. Thistle stem gall flies (*Urophora cardui*) and thistle stem weevils (*Hydroplontus*) damage but do not kill the thistle. An intentional infection of white mold, caused by the fungus *Sclerotinia sclerotiorum*, reduced thistle shoot density by 80% (Wilson, 2002). The introduction of white mold is unlikely to be well received by nearby soybean or pea growers.
**Chemical control of Canada thistle**

The most effective Canada thistle controls are herbicides. According to Panhandle Coop agronomist Darin Borges, fall applied Showdown® (glyphosate group 9) or WideMatch® (fluroxypyr and clopyralid, both group 4) is very effective against Canada thistle. WideMatch® is labeled for use in winter wheat crops. Both of these products are most effective when applied in the fall after the first frost. Other herbicides with various modes of action are available for use on Canada thistle (D. Borges, pers. comm., 2017).

**Action plan for Canada thistle**

Control of Canada thistle and intermixed musk thistle is required, not only to satisfy the county weed inspector, but to help ensure a successful farm operation. Before a course of herbicide treatment is commenced, the advice of an agronomist or other qualified specialist should be solicited. This advice will help the operators avoid needless expenses and ineffective treatments. Control of Canada thistle will require several years of treatment (Wilson, 2002). Because of the long duration of treatment, herbicides should be rotated by modes of action in order to delay the development of resistances.

**Musk thistle** (*Carduus nutans* L.)

Musk thistle is a member of the sunflower family and is an introduced European weed that is on the Nebraska noxious weed list (Figure 27). Musk thistle can infest any ground that is not cultivated or treated with herbicides (Stubbendieck et al., 2003).

Musk thistle normally grows as a biennial plant, but it can also be an annual weed. Its prolific seeds can germinate and emerge anytime during the growing season. As a biennial plant,
musk thistle seedlings form overwintering rosettes, which bolt in the spring. The bolted thistles begin blooming in early June and continue for several weeks. The seeds are naturally scattered by gravity, wind, and animals. Most of these seeds will germinate shortly after dissemination, but some may survive years of dormancy (Roeth et al., 2003). Thistle seeds can also be scattered and transported by farm equipment.

Figure 27. Musk thistle blooms in Boulder County, Colorado open space (N. Martin, 2015).

Management of musk thistle

The best management of musk thistle is to prevent its establishment. Farm equipment that has not been cleaned prior to field entry can distribute seeds and root segments of musk thistle. The use of contaminated crop seed can distribute and plant thistles. Musk thistle can also be
carried to a field by wind. These seeds form occasional, single plants, which do not, at first, appear to be a problem. After a couple of years, especially in no-till fields, single plants become dense patches. As soon as scouting identifies a musk thistle presence, plans should be made to aggressively manage the thistle. Small, infrequent areas of musk thistle can be controlled by chemical spot treatments but denser thistle infestations may require treatment of large portions of a field or of an entire field (Roeth et al., 2003).

**Cultural control of musk thistle**

Cultural control of musk thistle is possible by the use of competitive plants. Species that maintain a thick continuous presence in fields are most effective. Established perennial pastures provide good control of musk thistle (Roeth et al., 2003), but are not consistent with the Martins’ farming plans.

**Mechanical control of musk thistle**

Because musk thistle reproduces only from seeds, mechanical control can be gained by mowing it during the early bloom stage. The timing of mowing operations is important. If mowing occurs too soon, musk thistle will respond with one or more new stalks and blooms. If it occurs too late, seeds may mature and disseminate from severed blooms (Roeth et al., 2003). This method is not generally practical in the farm’s planned crops because it would also destroy growing crops. However mowing may be justified to control dense patches of thistle.

Musk thistle does not reproduce from its roots. Occasional cultivation that severs the roots below the root crown (2 – 3 in. below the soil surface) kills the thistle plants (Roeth et al., 2003). This control method is inconsistent with the Martin’s no-till operation.
It is unlikely that mowing or spot cultivation will lead to complete control of musk thistle. Small areas of thistle, or individual thistles, are difficult to detect, when they are surrounded by a growing crop (pers. obs.) These unseen thistles will distribute seeds and maintain the infestation.

**Biological control of musk thistle**

In the Martin farm’s region, biological control agents for musk thistle consist of the musk thistle head weevil (*Rhinocyllus conicus*) and rust fungus (*Puccinia carduorum*). The weevil was introduced from Europe in 1969. Musk thistle head weevils gather on bolting musk thistles to feed on flower buds and to reproduce by laying eggs in the flower buds. The weevil’s larvae feed on the thistle flower and interfere with seed production (Roeth et al., 2003). Musk thistle rust becomes active as the musk thistles begin the bolt in the spring. The rust forms small pustules, which produce spores in a couple weeks. Infected thistle leaves turn yellow and die shortly after (Roeth et al., 2003). Both of these musk thistle biological controls only suppress the thistle; they require the use of additional methods to eliminate musk thistles from a field.

**Chemical control of musk thistle**

Chemical control of musk thistle can be very effective, especially when herbicides are applied in the fall. The increased downward translocation that occurs as fall temperatures drop, increases the kill rate of systemic herbicides. Spring herbicide treatments are effective when applied prior to bolting. Herbicides such as, Banvel®, can be effective against musk thistle. Both of these herbicides can be tank mixed with glyphosate or 2,4-D ester for increased effectiveness (Roeth et al., 2003). Before an herbicide is selected, a local herbicide specialist should be
consulted. A coop advisor can provide good information on herbicides, their restrictions and limitations, and application details.

**Action plan for musk thistle**

The farm’s musk thistle population should be aggressively managed. If left to grow unhindered, musk thistle will increase its population density in all three fields and will increasingly impact the crop yields. In general, controls that are applied to Canada thistle will also control musk thistle.

Additionally, a minor, non-overturning cultivation can control musk thistle by severing roots from plants. A cultivation tool, such as a sweep, can accomplish this without greatly disturbing the placement of crop residue on the soil surface. Even though this cultivation is not strictly no-till, it may be a reasonable deviation from no-till.

**Downy brome (Bromus tectorum L.)**

Downy brome, a grass, is common throughout Nebraska (Figure 28). It is a European, introduced winter annual grass that aggressively colonizes roadsides, cropped and fallow fields, disturbed areas, and waste areas. Locally known as cheatgrass, it is misnamed. True cheatgrass *Bromus secalinus* is a close relative. Downy brome seeds are commonly found in uncleaned, binned seed, which is intended for use as crop seed (Stubbendieck, 2003).

Downey brome normally sprouts in the fall and overwinters in dormancy. It can also germinate in the spring, but only vernalized plants produce seeds. With many tillers, downy brome grows to a height of 6 to 24 in., depending on environmental conditions. Downy brome
has an extensive fibrous root system and is very water competitive with wheat. Moderate to heavy infestations can reduce wheat yield by 30% to 80% (Klein et al., 2008).

As its name implies, young downy brome has a very soft feeling texture. As it matures it turns into a dry scratchy mass containing numerous seeds with stiff awns (pers. obs.). Downy brome is a prolific seed producer, releasing as many as 80 million seeds per acre. These seeds are viable for 2 years or more (Klein et al., 2008).

Figure 28. Downy brome dominating a wheat field near Dalton, Nebraska (N. Martin, 2016).

Management of downy brome

On the Martin farm downy brome is widespread. It is present as patches in the crop fields, in the field margins, and in and around the windbreak. Because of downy brome’s heavy yield penalty, allowing it to grow is a costly policy. Considering its large seed production, downy
brome should be prevented from forming seeds. If seed production can be prevented for a period of 2 to 3 years, downy brome should cease to be a large concern.

**Cultural control of downy brome**

Good equipment sanitation reduces the import of weed seeds and control of field perimeters and waste areas slows the spread of downy brome. Over a multi-year period, establishment of a competitive, perennial grass such as crested wheat can suppress the growth of downy brome in field margins (Beck, 2009). This method has worked well in the areas that were disturbed by barn construction in the west field home site.

**Mechanical control of downy brome**

Mowing can reduce downy brome seed production but, because the weed’s lower tillers are close to the ground, many seeds will not be affected by mowing. Mowing may be useful on small areas but it will have to be followed by a follow-up treatment of another type (pers. obsv).

Cultivation can efficiently uproot or bury the weeds on fallow ground and between crop rows (Klein et al., 2008). Within cropped fields cultivation between crop rows will miss the brome that is situated close to the crop row. Additionally, cultivation is inconsistent with the Martin’s no-till practice.

**Biological control of downy brome**

No biological control agents are available for downy brome (Beck, 2009).
**Chemical control of downy brome**

In the Nebraska Panhandle downy brome has not yet exhibited resistance to herbicides and many suitable herbicides are available. On bare fields downy brome may be controlled economically with glyphosate. Because glyphosate does not have residual activity, crop planting can occur without delay (Klein et al., 2008). Downey brome is commonly found within emerged winter wheat fields. According to Panhandle Coop chemical advisor Darin Borges, herbicides such as Maverick®, Olympus®, and PowerFlex® are all registered for selective downy brome control in winter wheat. These, and similar herbicides may require lengthy replant delays (D. Borges, pers. comm., 2017). Rotation plans should be considered prior to selecting herbicides from this group. The advice of an agronomist or herbicide specialist could be helpful in making an herbicide choice.

Herbicide applications to control downy brome can be effective in the fall or in the spring. Fall applications provide a higher level of control than do spring applications. For spring applications use the higher of label rates if a range is given (Beck, 2009).

**Action plan for downy brome**

The downy brome population needs to be controlled to prevent its expansion and to reduce its pressure on crop yield. Waste areas and roadsides should be cleared of downy brome by mechanical and chemical means and then planted with a competitive grass such as crested wheatgrass.

A fall herbicide application should be conducted to kill newly emerged downy brome. If the field to be sprayed has an emerged winter wheat crop, apply a selective herbicide and observe the wheat growth stage restrictions in the chemical’s label. This application should be
completed while the downy brome is still in a growing phase (prior to mid-October). A spring 
an application on unplanted fields can be made when the downy brome is actively growing. Non-
selective herbicides may be used and replant restrictions should be compatible with planned 
crops. In fields of winter wheat, one of the selective herbicides may be applied prior to jointing. 
These herbicides generally have replant restrictions.

Kochia [*Bassia scoparia* (L.) A.J. Scott]

Kochia, a member of the goosefoot family, is an introduced, highly invasive Eurasian 
annual (Figure 29). It thrives in pastures, cropped fields, and disturbed areas (Stubbendieck et al., 
2003). From over-wintered seeds, kochia germinates in the early spring when the soil 
temperature reaches 39F (UNL Cropwatch, 23 Feb, 2017). Most (70% to 95%) kochia seeds 
germinate in the first spring after they are distributed. The remaining seeds are viable for only a 
few years, which limits the duration of kochia seeds in a seed bank (Jhala et al., 2014).

Kochia matures into a pyramidal form up to four feet tall and is a large contributor to a late 
hay fever season (Stubbendieck et al., 2003). After maturity kochia breaks free from its taproot 
and tumbles with the wind, scattering its abundant seeds (Jhala et al., 2014; Stubbendieck et al., 
2003). Season-long kochia infestations have caused high (up to 60%) yield penalties in wheat 
crops, (Kumar and Jha, 2015).
**Bassia scoparia**, also known as *Kochia scoparia*, is included in the noxious weed lists of many states, but not in Nebraska. However, many Nebraska counties encourage vigorous efforts to control the weed.

**Management of kochia**

As with most annual invasive weeds, a good way to lessen kochia outbreaks is to minimize the import of seeds. Seeds can arrive on uncleaned equipment, especially on combines. Unwanted seeds can also arrive in contaminated crop seeds. In the Martin’s area, many wheat operations plant binned seed from the previous harvest. The use of certified or cleaned seed would lessen the incidence of unintentionally planted kochia. Good sanitation will not prevent all
kochia seed imports; personal observations have shown that no field is safe from the neighbor’s tumbleweeds (pers. obs.). Management of this weed will be a continual process.

**Cultural control of kochia**

Early spring cultivation, prior to crop planting, efficiently kills kochia seedlings and buries seed that has not germinated (Bokan et al., 2012). A second cultivation, after the harvest of summer crops can prevent the maturation of any remaining kochia plants. Neither of these cultivations are compatible with the farm’s no-till culture.

**Mechanical control of kochia**

In non-crop areas and in post-harvest fields, kochia seeding may be prevented by a thorough mowing operation. In order to be effective, the mowing must occur before kochia plants flower and may have to be repeated to control regrowth (Bokan et al., 2012). Low growth that escapes mower blades is capable of producing seeds. It may not be practical to mow 450 acres to control kochia, but it is practical to mow dense patches of kochia in fields and waste areas.

**Biological control of kochia**

No biological controls are available for kochia (Jha et al., 2013).

**Chemical control of kochia**

In the Nebraska Panhandle, kochia has demonstrated resistance to triazine (group 5), sulfonureas (group 2) and glyphosate (group 9). Elsewhere in Nebraska, resistance to dicamba
and fluroxypr (group 4) has developed. In addition to singular resistances, kochia has demonstrated multiple resistances. Even though Kochia has developed resistance to several herbicide families, it remains vulnerable to other herbicide groups (Jhala et al., 2014; Lawrence, 2016). Additionally, the kochia that is resistant to a particular chemical family in a particular location, may not be present in another location. The best source of information about local kochia resistances and which herbicides work in a specific location, is the county extension office or a local agronomist.

In order to increase the likelihood of an effective kill, herbicides that affect multiple sites of action should be utilized. These can be premixed proprietary blends or tank mixed blends. The best time to control kochia is in the spring prior to planting. Banvel has been effective in the farm’s area but, has encountered resistance elsewhere (D. Borges, pers. comm.). Kochia within growing winter wheat fields may be sprayed with a selective product such as Dow WideMatch® when the kochia is at least 1 inch tall (WideMatch® label).

**Action plan for kochia**

Kochia should be aggressively managed to prevent an infestation. Cultivation is the most popular kochia control in the Martin’s area; it is an effective control but it is inconsistent with no-till farming.

An ongoing kochia herbicide program should concentrate on the prevention of kochia seed production. A spring post emergence herbicide application should be applied prior to crop planting. The herbicide’s replant interval should be compatible with planned spring crops. If corn is to be planted, a product with residual activity should be included in the application. This application should prevent most of the kochia competition with crop plants.
After harvest of the early crops (field peas and wheat) another herbicide application may be needed to kill the kochia that was hidden in the crop. This application may be delayed to allow time for the germination and sprouting of other weeds, but should be accomplished before the kochia is 4 inches in height.

Because most kochia seeds germinate in the spring, the success of seed control efforts will not be evident until spring. Control will not be total but the amount of emerging kochia should be decreased from the prior year. Some new kochia will probably emerge from seedbank carryover and from seeds that were dispersed from passing tumbleweeds.

**Red root pigweed (Amaranthus retroflexus L.)**

Redroot pigweed, a member of the large pigweed family and a native to North America, is an adaptable and widespread plant (Figure 30). Once used by Native Americans as food, it is an invasive, yield-reducing weed. It thrives in cultivated and fallow fields, waste areas, and roadsides (Stubbendieck, 2003). Redroot pigweed grows to 3 to 6 feet tall and its form is pyramidal. It has a shallow red taproot, a characteristic shared by smooth pigweed (Amaranthus hybridus L.) and Powell amaranth (Amaranthus powellii S. Watson). Redroot pigweed is monoecious and normally bears up to 30,000 seeds on a single plant. (Weaver, 2001).

Redroot pigweed is phenotypically plastic and will adapt to a wide range of environmental and cultural conditions. Hybrids between redroot and smooth pigweed and Powell amaranth are not uncommon and the resulting seeds are not viable (Schonbeck, 2015; Weaver, 2001). Buried in soil, redroot pigweed seeds may be viable for twenty years but normally become die after only a few years. Germination occurs at high temperatures (86F – 104F) which prevents early season
control of pigweeds. Pigweed’s C-4 photosynthesis pathway ensures robust growth of seedlings. A large redroot pigweed population in a rowcrop, such as soybeans, has been observed to reduce yield by 34% (Sellers et al., 2003) (Figure 31).

Figure 30. Redroot pigweed grows in a waste area (N. Martin, 2017).
Management of redroot pigweed

Redroot pigweed infestations are more robust in no-till and conservation-till systems than they are in conventional tillage systems. Redroot pigweed density can be an order of magnitude larger in no-till plots than in conventional-till plots under the same conditions. No-till and conservation-till systems concentrate weed seeds on or close to the soil surface where they have a good chance of germination. This is because conventional tillage buries some or all of the surface weed seeds. Some of the seeds germinate, some become or remain dormant, and some become non-viable (Sellers et al., 2003). Due to the Martins’ preference for a no-till system, a management system that does not rely on tillage will be implemented in order to keep pigweed in check.
Cultural control of redroot pigweed

Redroot pigweed that is in a vegetative stage can be suppressed by livestock grazing. However, if pigweed is grazed while it is in a reproductive stage, the seeds are not digested and they are deposited back in the field of origin. In a growing crop all growth stages of pigweed can be present at once; grazing after harvest will probably not be effective. However, grazing may be of value during an extended fallow period when a continuous livestock presence can be maintained and plants can be consumed prior to producing seeds (Rajcan and Swanton, 2000).

Redroot pigweed responds to partial shading by growing taller. Redroot pigweed that emerges in complete shade experiences a reduction in growth rate; the same is true for many other weeds. Because redroot pigweed does not emerge until soil temperatures exceed 86F, an early season crop, such as winter wheat or field peas should completely shade the soil by the time the pigweed emerges (Rajcan and Swanton, 2000). After harvest the pigweeds may be managed by chemical or mechanical means. Planting crops in narrow rows and high populations, whenever possible, can help shade emerging weeds, helping cash crops to out-compete weeds (Curran, 2017).

A weak spot in the Martin farm’s crop rotation is the growth of redroot pigweed in the corn crop. Due to the farm’s dryland status, short varieties of corn are planted and populations are limited to about 16,000 plants per acre. This combination does not completely shade the ground. When pigweed and other weeds emerge within the cornfield, they do not prosper but are certainly viable. Because corn is harvested in October, the pigweeds have time to complete their reproductive stage before harvest.
Mechanical control of redroot pigweed

Redroot pigweed infestations are more robust in no-till and conservation-till systems than it is in conventional tillage systems. No-till and conservation-till systems concentrate weed seeds on or close to the soil surface where they have a good chance of germination. Conventional tillage buries some or all of the surface weed seeds (Sellers et al., 2003). The most effective cultivation method is the use of an inversion plow, which inverts the plow layer and deeply buries most seeds. Some of the buried seeds germinate, some become or remain dormant, and some become non-viable. Inversion plowing is also the method that is most destructive to soil structure (Brady and Weil, 2008). Cultivation would certainly be an effective control of redroot pigweed, but it is not consistent with the farm’s no-till system.

Wherever mowing can be accomplished without disturbing crops it can be utilized to prevent the formation of seeds. Mowing should be conducted at the first indication of flower formation. Because redroot pigweed flowers can be generated at axillary buds at the stem nodes, mowing should be low in order to destroy as much of the plant as possible. Multiple mowing operations may be necessary.

Biological control of redroot pigweed

No biological control agents are currently available in the Martin farm’s region.

Chemical control of redroot pigweed

In the Nebraska Panhandle region, redroot pigweed has demonstrated a resistance to the triazine family of photosystem II inhibitors. Aatrex, Caparol, and Princep are three of the affected herbicides. In eastern Nebraska, other members of the pigweed family have developed
additional resistances. Palmer amaranth (*Amaranthus palmeri* S. Watson) has resistance to ALS inhibitors, HPPD inhibitors, and photosystem II inhibitors; common waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer) has showed resistance to triazine (group 5 photosystem II inhibitor), HPPD inhibitors, ALS inhibitors, and growth inhibitors (Jhala et al., 2014; Lawrence, 2016). It is a reasonable assumption that panhandle area redroot pigweed will develop additional resistances in the future. Any chemical controls that are applied to redroot pigweed should include multiple sites of action and chemical families should be rotated between years (Jhala et al., 2014).

**Action plan for redroot pigweed**

The Martin’s present crop rotation of corn – field peas – wheat provides a rotation between spring and fall seeded crops which provides a cultural control for redroot pigweed. The remainder of redroot pigweed control will best be provided by chemical means. An herbicide treatment that includes action at multiple sites should be formulated with the assistance of a local agronomist or coop advisor. The herbicides should be altered from year to year with respect to sites of action.

After summer harvests, residual pigweeds will grow aggressively, if water is sufficient, and will need to be controlled by herbicides or mowing prior to flowering. A delay in this treatment, if possible will allow additional pigweed seeds to germinate prior to applying controls.

Mowing pigweeds in roadside and waste areas should prevent the production of seeds in these areas. Mowing should occur prior to flowering and multiple mowing operations will be required in order to deal with the mixture of pigweed life stages. If low-growing pigweeds remain after being mowed, they will require chemical control.
INSECT PESTS

The Martin farm is located in the semi-arid southwest Panhandle region of Nebraska. Because of its location and climate, most of the insect problems that are present in moister climates to the east are not a problem in the Martin’s area. The following sections cover existing and potential threats to the Martin’s current crop rotation. Information was gathered from Panhandle Cooperative specialist Darin Borges and from the University of Nebraska Extension Service.

Wheat Insect Pests

Hessian fly (*Mayetiola destructor*)

Hessian flies, one of the most damaging wheat pests in the country, may have traveled to North America within the livestock supplies that accompanied Hessian soldiers during the revolutionary war (Figure 32). The fly prefers wheat hosts, but can also survive in rye, triticale, and barley crops, as well as in various grasses. It is most prevalent in the eastern portion of Nebraska (Foster and Hein, 2009).

Hessian flies overwinter in the flaxseed stage on hosts, including volunteer wheat, until spring when the larvae pupate and adults emerge. Adult Hessian flies do not feed, and they complete their reproductive cycle by laying eggs and dying within a few days. Two or more
Hessian fly generations occur each year, ending with overwintering larvae in the fall (Pedigo and Rice, 2009).

Figure 3. Adult Hessian fly on wheat leaf. (Scott Bauer, USDA Agricultural Research Service, Bugwood.org, 2011) licensed under a Creative Commons Attribution 3.0 License.

When asked about Hessian flies, most local farmers are unfamiliar with the insect (pers. obs.). No Hessian fly winter wheat planting date is established for Cheyenne County for two reasons: the flies do not damage local crops and because winter comes early in the high plains. Wheat planting must occur early than the fly-safe dates in order to allow crop establishment prior to cold weather (Foster and Hein, 2009). Darin Borges of Panhandle Cooperative has confirmed that regional farmers do not currently take precautions against Hessian flies (Borges, pers. comm., 2017).
Hessian fly management

At this time, no management actions are needed against the Hessian fly. However, an awareness of the fly and its current range should be maintained. Changes in the short or long term regional climate or adaptations of the fly may expand its range into the Nebraska panhandle region.

Wheat stem sawfly (*Cephus cinctus*)

The western stem sawfly is the most destructive insect pest of wheat in the Martin farm’s Panhandle region (Figure 33). A 2016 survey of western Nebraska counties listed Cheyenne County near the top of the list of infested counties (Bradshaw and Peterson, 2016).

Figure 33. The wheat stem sawfly is a threat to Cheyenne county wheat (Frank Peairs, Colorado State University, Bugwood.org, 2008).
Wheat stem sawfly adults emerge from wheat stubble over a three to five week period in the spring. They do not feed, and survive for about a week, while they mate and lay eggs. The eggs are oviposited into growing wheat stems close to the base. Taller plants and plants in field margins are preferred for egg deposition (Michaud, 2013).

Five instars of the wheat sawfly larvae feed within wheat stems, then descend to the base of the stems, where they cut or girdle the stem. Pupation occurs within the wheat stems and adult sawflies emerge in the spring (Michaud, 2013).

Wheat stem sawflies damage crop yields by diverting nutrients from their destinations within the plant. They also compromise shoot integrity by girdling the stem from within, which results in lodging of the affected stems. Yield losses from serious infestations can amount to 30% to 50% (Thomas and Bradshaw, 2015).

**Cultural control**

Deep tillage can decrease the viability of sawfly larvae by burying their larvae in the soil. Shallow post-harvest disc tillage lifts the wheat stubble crown, exposing the sawfly’s in-stem location. This can increase the sawfly larvae’s exposure to dryness and to winter cold which should decrease their viability by a small percentage (Irell and Peairas, 2014). Tests in Saskatchewan indicated that sawfly larvae do not survive temperatures below -22C (-8F) (Saskatchewan Agriculture Knowledge Centre, 2017). This temperature is often seen during Cheyenne County winters. Unfortunately, this use of tillage is counter to the goals of the farm’s no-till practice. Because sawfly infestations tend to concentrate in the margins of wheat fields, larger fields that reduce the ratio of border to area may reduce overall sawfly damage (Irell and Peairas, 2014).
Sawflies also oviposit into the stems of oat, and rye plants, but their larvae will not mature. The use of these crops as trap crops may reduce sawfly populations in subsequent years (Irell and Peairas, 2014). Crop rotation may also lessen sawfly pressure during the first year of wheat in a rotation (Knodel et al., 2016).

The majority of wheat stem sawfly damage to wheat yields is due to lodging of stems, which makes the wheat difficult to harvest. The best wheat stem sawfly resistance tool is to plant solid stem varieties of wheat. Sawfly larvae will still feed within solid stem varieties, but stronger stems are less likely to lodge than are the stems of hollow stem varieties. Early solid stem wheat varieties carried a large yield penalty, but some newer varieties have reduced that penalty (Michaud, 2013).

Chemical control

No cost-effective chemicals exist for the wheat stem sawfly. Chemicals that are effective are those that target adult sawflies. Because adult sawflies emerge during a three to six week period and because female sawflies lay eggs soon after emergence, frequent applications of pesticide are required to disrupt the sawfly reproductive cycle. The low value of wheat does not justify the expense of multiple pesticide applications (Michaud, 2013).

Biological control

The most effective biological enemy of wheat stem sawflies is a parasitic wasp (*Bracon cephi*). This parasitoid population has followed sawfly infestations into Colorado and Nebraska (Michaud, 2013). The female wasp is able to detect sawfly larvae within a wheat stem and lays her eggs within the stem near the sawfly larvae. After hatching, the wasp larvae feed on the
sawfly larvae, killing them before they can cut the host plant stem. This prevents lodging of the wheat stem and substantially reduces yield loss (Knodel et al., 2016; Michaud, 2013). *Bracon cephi* overwinters as cocoons in the upper half of wheat stems. In order to preserve these cocoons, wheat stems should be left standing after harvest and should not be buried (Knodel et al., 2016). The use of stripper heads for harvest preserves much of the wheat stalks.

**Action plan for wheat stem sawflies**

The threat from wheat stem sawflies should be estimated prior to planting winter wheat. If the flies were present prior to harvest, consideration should be given to planting a solid stem wheat variety that has a good yield potential, such as Warhorse or Bearpaw. After evaluating all known threats to wheat, if a suitable solid stem variety cannot be found to satisfy all trait concerns, select a variety that has a high stem strength. When wheat is harvested, preserve the wheat stem as stubble. The parasitic wasp, *Bracon cephi*, overwinters in the stem and should be preserved as an effective control of sawfly larvae.

Because field borders can be more severely infested by sawflies than the field interior, wheat should be planted in large blocks in order to reduce the ratio of border to area. Planting in squares such as quarter sections is ideal. If possible, avoid planting wheat adjacent to neighboring wheat fields. If wheat fields are to be adjoining, consider planting a trap crop at their intersection. Barley, oat, and rye are suitable trap crops for the wheat stem sawfly.
European corn borer (*Ostrinia nubilalis*)

After its early 20th century import to North America, the European corn borer (ECB) has become established throughout the most of the east-of-the Rockies United States and Canada farmland (Figure 34). Its territory includes the Nebraska Panhandle region, where it exists as a two generation per year pest (Borges, pers. comm., 2017). Overwintering in stalks and residue, ECB larvae pupate in the spring and emerge as moths. The ECB moths quickly mate and, after three days, the females oviposit their eggs on the underside of host (usually corn) leaves (Pedigo and Rice 2009).

Figure 34. European corn borer on a cornstalk (Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org, 2011).
After hatching, the first generation ECB larvae progresses through five instars and their feeding locations progress from leaves to stalks. Mating and egg laying end the first generation of the ECB. The second-generation larvae instars feed on pollen, leaf axils, sheaths, and collars and then bore into stalks and ears, where they overwinter (Hodgson and Rice 2017; Pedigo and Rice, 2009).

Crop damage due to an ECB infestation can be substantial and is caused by leaf damage, ear drop, and stalk and shank damage. Ear tip feeding does not cause much harm to field corn, but it does enable fungal damage by creating an entry point to the ear (Hodgson and Rice 2017).

**Cultural controls of ECB**

An early harvest of corn can avoid a portion of ECB yield damage by reducing ear drop and stalk lodging (Hodgson and Rice, 2017). However, there are no grain drying facilities in the Martin farm’s vicinity and harvest must wait until a desired grain moisture level naturally occurs.

The most effective tillage practice for ECB control is to leave harvest residue exposed on the soil surface during winter, then bury the residue by disk ing in the spring. However, because the ECB is mobile and can lay eggs outside of a field, this method may not provide complete control. Moths that emerge outside of a given field may return to the field (Hodgson and Rice, 2017).

**Chemical controls of ECB**

Many insecticides are labeled for control of ECB. Timing of a chemical application is important because it must be accomplished before ECB larvae enter the shelter of stalks and ears. A single insecticide application, applied 14 days after egg laying should suffice for a particular
ECB generation (Hodgson and Rice, 2017). Diligent scouting is required in order to determine the necessity and timing of insecticidal applications.

**Biological controls of ECB**

European corn borer eggs and larvae are vulnerable to predation by such agents as ladybug beetles, lacewings, spiders and mites. This predation can kill an average of 7.5% of ECB larvae. Applications of foliar insecticides may harm the ECB predators (Hodgson and Rice, 2017).

**Bt management of ECB**

The use of plant-incorporated protectants in corn has greatly reduced losses due to the European corn borer. A protein (Cry1Ab) derived from the *Bacillus thuringiensis* has been inserted into corn genome and is toxic to caterpillar pests such as the ECB. Other than selecting and planting a suitable Bt hybrid, no further action is required to protect a crop from the ECB. A portion of each field’s corn must be an ECB susceptible variety and is known as the refuge crop. The purpose of the refuge crop is to slow the development of Bt resistance in the ECB population. The simplest refuge crop method is to use “refuge in a bag” seed, in which the proper amount of refuge seed is premixed with the Bt seed.

**Action plan for European corn borer**

When selecting corn seed, choose a Bt variety that is premixed with a refuge crop seed. Advice on seed selection can be obtained from crop advisors, supplier literature, and extension publications.
Western bean cutworm (Striacosta albicosta)

The western bean cutworm (WBC) has a single generation each year that begins with moth emergence in mid-July (Figure 35). The moths are able fliers and can travel for miles after emergence. After mating, female WBCs oviposit on all types of corn or other hosts. Egg masses are laid on the upper leaf surfaces in the top third of corn plants and consist of 5 to 200 eggs, which usually hatch in 5 to 7 days. WCB larvae develop through five instar stages then drop to the soil surface and burrow to a depth of 3 to 6 inches, where they construct a cell in which to overwinter (Seymore et al., 2010; Peairs, 2014).

Figure 35. The western bean cutworm feeding on corn ear. (Frank Peairs, Colorado State University, Bugwood.org, 2008).
WBC larvae feeding sites vary with the development stage of its host. If corn has not tasseled, larvae feed on pollen within the flag leaf. If tasseling has occurred, WBC larvae will feed on silks within the ears and, if kernels are formed, the larvae will feed on developing kernels. Yield losses due to ear infestation by several WBCs per ear can reduce grain yield by 40 percent (Peairs, 2014).

**Cultural controls of WBC**

Soil disturbance by cultivation is suspected to compromise the integrity of WBC overwintering cells, however no data exists to verify this in the farm’s region (Seymore et al., 2010). This tillage would be counter to the farm’s no-till goal.

**Biological controls of WBC**

Several predator insects (adult ladybird beetles, spiders, and nabids) feed on early WBC larvae up to the third instar. Also, blackbirds feed on WBC larvae that are within ear tips. Naturally occurring predation on the WBC has a beneficial effect but it is unlikely that sufficient control of the WBC will be maintained solely by biological controls (Seymore et al., 2010).

**Chemical controls of WBC**

Before control by insecticide is initiated, it should be timed to occur after 95% of the corn tassels have emerged and before larvae have taken shelter in the silks. Additionally, a typical economic threshold for treatment of WBC is reached when either egg masses or small larvae are present on 5% to 8% of a field’s plants (Seymore et al., 2010; Peairs, 2014). Particular chemical recommendations can be obtained from the county extension office or chemical suppliers.
**Bt control of WBC**

Several Bt corn hybrid traits are effective against the western bean cutworm. Varieties that express the Cry1F toxin have demonstrated an 80% control level when used for WBC prevention. Varieties that express multiple toxins such as Cry1Ab and Cry1F, such as Herculex I®, are effective against both the WBC and the ECB (Peterson et al., 2017). In parts of southwestern Nebraska, the effectiveness of Cry1F has been decreasing and it has become advisable to scout for WCB in fields that are planted with that trait. Varieties that express the VIP3A protein, such as Agrisure®, and Viptera®, are effective against the WBC (Peterson, 2016).

**Action plan for western bean cutworm**

The most practical management method for the western bean cutworm is to plant a variety that expresses the Cry1F protein. However, seeds that carry genetic modifications sell at a premium to non-traited seeds. Before making a seed selection, consideration should be given to the costs and benefits of planting GM seeds. If traited corn is not planted, frequent scouting should be initiated to determine the need for chemical treatments.

Compare the costs and likelihood of chemical treatments with the increased cost of GM seed. Discuss chemical options and costs with suppliers and obtain agronomic data from seed dealers. This analysis will need to be completed well ahead of planting in order to ensure seed availability.
**Western corn rootworm** (*Diabrotica virgifera virgifera*)

The western corn rootworm (WCR) overwinters as eggs within the soil, preferably near corn plants (Figure 36). The eggs hatch in early June and the rootworm larvae begin feeding on root hairs and on the small roots of corn plants. As they grow, the WCR larvae move to larger roots, tunneling into them and into the plant’s crown. After the initial feeding stage, the larvae pupate and transform into adult beetles, which emerge from the soil in mid to late July. WCR beetles feed on corn silks, mate, and lay eggs until their food source is depleted (Peairs and Pilcher, 2013; Calvin, 2003).

Figure 36. Adult western corn rootworms (Whitney Cranshaw, Colorado State University, Bugwood.org, 2011).
Although WCR larvae can inflict significant damage to a plant’s root mass, a large plant can recover from much of the damage, as long as lodging does not occur. Small plants (four leaves or less) cannot produce new roots fast enough to overcome severe root pruning by WCR larvae. WCR beetles feed on silks where the silks emerge from ears, potentially interfering with pollination. Silks that grow out of the ears at a fast rate may maintain enough exposure for pollination to be successful. However, severe silk clipping will result in unfilled corn kernels (Calvin, 2003).

**Cultural controls of western corn rootworm**

Early planting allows corn root masses to reach a larger size prior to being subjected to feeding by WCR larvae. It also allows silk pollination to begin before emergence of and feeding by adult WCR beetles (Calvin, 2003). However, the farm’s average last frost date of 4 June (USA Gardener, 2010) restricts early planting dates to mid to late May.

The most economical way to manage the WCR is crop rotation. Because the rootworm prefers to feed on corn and to lay eggs in corn, a change in crops can disrupt the rootworm’s lifecycle. Any WCR larvae that hatches in a non-corn environment is likely to starve from the lack of corn roots to feed on. Extended diapause WCR, which can overwinter twice in the absence of corn hosts, have not been reported in the farm’s region (Peairs and Pilcher, 2013). The Martins are using a three-year crop rotation, which should provide protection from extended diapause WCR, should they enter the area.
Chemical control of western corn rootworm

Insecticides are available for control of the larval WCR. Seed can be treated prior to planting and treatments can be applied by in-furrow application. Treatments also can be applied to control adult beetles, which prevents them from laying eggs (Peairs and Pilcher, 2013). Pesticide specialists and extension staff have current information about which pesticides are currently best for the Panhandle region.

Action plan for western corn rootworm

A scouting program should be used to detect any WCR infestation. Examinations of corn plant root masses up to six leaves will reveal any root feeding damage from WCR larvae and an examination of silks throughout pollination will show clipping damage from WCR beetles. Continuous corn crops should be avoided in order to deprive the WCR of a continuous host. Advice about pesticides and the need for them should be sought from coop advisors and extension staff.

Field Pea Insect Pests

Field peas are a new crop in the Nebraska panhandle region and a very new crop to Cheyenne County. Because peas are a new crop, insect pressures do not yet exist. According to the University of Nebraska Panhandle Research and Extension Center, no insects or diseases have been observed in their test plots. Insects (and diseases) have not yet caught up to the crop (Panhandle Research and Extension Center, 2017). Field peas have long been cultivated in North
Dakota (ND) as a cash crop and as a cover crop. The climate conditions in ND are similar, but colder, than in the Nebraska panhandle region. It is a reasonable expectation that the insect pests of the peas in ND may eventually be a threat to the same crop at the Martin farm.

Pea aphids infest ND pea crops and can inflict considerable damage to yields and can also serve as a vector of pea seed-borne mosaic virus. Lygus bugs can also be a problem in ND pea fields. Lygus bugs feed on pea seeds and pods. A toxin that Lygus bugs inject during feeding inflicts additional damage to developing seeds. (Endres et al., 2016). These insects are not currently affecting Nebraska panhandle pea crops, but may have a presence in the future.

**Action plan for field peas**

It is an expectation that insect pressure on Cheyenne County pea crops will exist in the future. An informal insect scouting program should be maintained and extension resources should be monitored to warn of future infestations.

**Future field pea insect pest precautions**

In the future, both long and short-term climate fluctuations may occur, which could change the suitability of the Nebraska panhandle region to various insect and disease pests. New pests may arise due to introduction or adaptations. It would be wise to maintain a scouting program for unknown threats. Extension services at both University of Nebraska and at Colorado State University both publish information about field peas that is specific to the high plains region of southwest Nebraska.
CROP DISEASES

Wheat Diseases

According to Panhandle Coop advisor Darin Borges, the most common wheat diseases in Cheyenne County are rust and wheat streak mosaic (D. Borges, pers. comm., 2018).

Leaf rust

Wheat leaf rust is caused by the fungus *Puccinia triticina* and occurs occasionally in western Nebraska (Figure 37). The rust infections begin when urediniospores are transported into Nebraska by spring winds blowing from southern states and Mexico. The urediniospores are deposited on plant surfaces and on the ground where water splash can relocate them to plant surfaces. Ideal infection conditions are wet surfaces and temperatures between 59F and 68F. Ideal development conditions are wet weather and temperatures between 68F and 77F. Uredinia form in 7 to 10 days and new urediniospores are soon released to begin new infections (Wegulo and Byamukama, 2012).

Crop damage from leaf rust is heaviest when flag leaves or other upper leaves are infected, which reduces grain fill. Yield losses from a severe infection of leaf rust can exceed 50% (Wegulo and Byamukama, 2012).
Wheat stem rust

Wheat stem rust is caused by the fungus *Puccinia graminis* and is present on the Great Plains at a low level (Figure 38). Most Great Plains winter wheat cultivars are resistant to wheat stem rust. Like *Puccinia triticina*, *Puccinia graminis* overwinters in the southern states and Mexico, and is transported north by spring winds. Ideal infection conditions are wet plant surfaces and a temperature between 58F and 84F. Wet weather and a temperature range of 79F to 84F are best for development (Wegulo and Byamukama, 2012). Stem rust weakens stems, which
causes lodging and shriveled grain. This rust is capable of widespread destruction in a short time period (Wegulo and Byamukama, 2012).

Figure 38. Wheat stem rust on wheat stems (Mary Burrows, Montana State University, Bugwood.org, 2010).
Wheat stripe rust

Wheat stripe rust is caused by the fungus, *Puccinia striiformis* f. sp. *tritici* (Figure 39). It overwinters in southern states and Mexico and is transported north by spring winds. Ideal infection conditions are wet plant surfaces and a temperature between 45°F and 54°F; growth is best in wet conditions and temperatures between 50°F and 59°F. Stripe rust damages wheat tissues by forming necrotic spots or stripes. It also desiccates infected plants by consuming water and nutrients (De Wolf, 2010; Wegulo and Byamukama, 2012).

Wheat cultivars that are susceptible to stripe rust can experience a losses up to totality if they are severely infected with stripe rust (De Wolf, 2010; Wegulo and Byamukama, 2012).

Figure 39. Wheat stripe rust on wheat leaves (Howard F. Schwartz, Colorado State University, Bugwood.org, 2008).
Cultural control of wheat rusts

The best control of wheat rusts comes from the utilization of resistant cultivars. Wheat varieties have been tested for resistance to various diseases and the results of these tests are readily available from seed companies, dealers, and extension services. Because wheat rust fungi can develop new races that may defeat a cultivar’s resistance to it, one should keep informed on the efficacy of varietal resistances (Wegulo and Byamukama, 2012).

The Barberry (*Berberis* sp.) plant can serve as an alternate host to stem rust and stripe rust. This plant has been mostly eradicated in wheat growing areas, but may be included in landscaping by unaware gardeners (Wegulo and Byamukama, 2012).

Chemical control of wheat rusts

Many fungicides are available for use on wheat fungus diseases. If a fungicide is to be applied prior to an infection, a product belonging to the strobilurin class, such as Quadris®, is appropriate. For a post infection application, a triazole class product is indicated. Attention must be paid to pre-harvest and growth stage restrictions (Wegulo and Byamukama, 2012; De Wolf, 2010). The advice of a local applicator or coop specialist will be helpful in making a product decision.

Action plan for wheat rust

In order to anticipate the arrival of fungal disease, monitor the disease status of regions that are typically upwind from the Nebraska panhandle region. These diseases normally begin in Texas and spread north through Oklahoma, Kansas, and Colorado before reaching the farm’s area. If an infection seems likely, a preventive treatment may be advisable. Frequent scouting for
fungal diseases should be conducted. Consider planting wheat varieties that have demonstrated a resistance to fungal diseases.

**Wheat streak mosaic**

Wheat streak mosaic is a viral disease that is vectored by the wheat curl mite (*Aceria tosichella*) (Figure 40). It is also transmissible through wounds on wheat plants. In the Nebraska panhandle region hail often causes these susceptible wounds. The wheat curl mite also vectors the Triticum Mosaic Virus and High Plains virus. Both of these viruses can simultaneously infect wheat plants, which compounds the severity of the mosaic infection (Wegulo et al., 2008).

The wheat curl mite grows from egg to adult in 8 to 10 days and can spread rapidly through a field. The mite requires a living host to survive. The presence of volunteer wheat in fields at harvest time gives the mite a “green bridge” on which to live on until emergence of newly planted wheat in the fall. It moves to the newly emerged winter wheat and overwinters there. Many other grasses can host the wheat curl mite, as long as they are actively growing (Wegulo et al., 2008; Wegulo, 2017).

Yield damage by the wheat streak mosaic virus is greatest after fall infections. Lost yield can range from slight to total (Murray et al., 2005).
Cultural control of wheat streak mosaic

Because the largest factor in after-harvest survival of the wheat curl mite is the presence of a “green bridge” host that can feed the mite until a new crop of winter wheat is emerged, elimination of that bridge is important to controlling the mite. In continuous wheat crops, the most likely bridge host is volunteer wheat that emerges prior to harvest. Often, pre-harvest hail will knock wheat kernels to the ground where they can germinate and grow. Other grassy weeds can also serve as bridge hosts for the mite. A timely termination of the bridge hosts by either cultivation or herbicide should occur about a month prior to planting the next wheat crop (Wegulo et al., 2008). Resistance is an effective defense against wheat streak mosaic disease.
Ratings for wheat streak mosaic are available from seed suppliers and dealers (Wegulo et al., 2008).

**Chemical control of wheat streak mosaic**

Because a virus causes wheat streak mosaic, no chemical controls exist for wheat streak mosaic.

**Action plan for wheat streak mosaic**

If wheat streak mosaic is present or anticipated in the area, seed selection criteria should include resistance to the disease. If a field is severely infected, consider terminating the wheat crop and eliminate all possible hosts for the wheat curl mite. Use crop rotation to lessen the amount of carryover hosts for the wheat curl mites.

**Corn Diseases**

According to Darrin Borges, a chemical advisor at Panhandle Coop, the Martin farm is unlikely to experience significant corn disease. The farm’s area hosts both irrigated and non-irrigated cornfields that are widely spaced and seldom share borders with other cornfields, thus limiting direct pathways for diseases to spread between fields. Additionally, the Martin farm is currently using a three-year crop rotation, which creates a temporal disruption in the life cycle of some corn diseases. The farm’s dry climate and low humidity hinder the establishment of fungal
disease, especially in non-irrigated fields. Based on his experience, Mr. Borges predicted that the most likely corn diseases on the Martin farm will be common smut and, during wet years, common rust (D. Borges, pers. comm., 2018).

**Common smut**

Common smut disease is caused by the fungus *Ustilago maydis* and develops on leaves, stalks, and ears of corn plants (Figure 41). The fungus overwinters as teliospores in soil and in crop residues. Infections take place in wounds caused by insect feeding and mechanical damage, including hail damage. After infection, galls form and are filled with black teliospores. Except for galls that form on ears and displace kernels, the galls usually do not harm the corn plant (Jackson, 2018). In field corn crops, smut infections inflict minor damage to yields (Pataki and S netselaar, 2006).
Figure 41. Common smut on cornstalk (William M. Brown Jr., Bugwood.org, 2008)

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Management of common smut

Fungicides are not effective in the control of common smut and other management methods, such as crop rotation, field sanitation, and seed treatments are not effective. The only practical method of common smut management is the utilization of resistant corn varieties. However, no variety is completely resistant to *U. maydis* (Pataki and Snetselaar, 2006).

Action plan for corn smut

If common smut of corn is a concern, try to plant a variety that is resistant to infection by *U. maydis*. However, it may be a difficult task to locate a suitable commercial hybrid that carries the resistance (Jackson, 2018).

Common rust

Common rust of corn is caused by the fungus *Puccinia sorghi* which, as an obligate parasite, requires a living host for survival (Figure 42). This pathogen overwinters in the temperate southern states and travels north as wind-borne urediospores. In wet conditions and a temperature range of 61F to 77F, *P. sorghi* infections can occur on both upper and lower surfaces of corn leaves. The author has been unable to locate an estimate of yield damage due to common rust other than the yield loss is less than that of southern rust (*Puccinia polysora*). A severe infection of southern rust is estimated to reduce yield by up to 45% (Jackson-Ziems, 2014).
Cultural control of common rust

Rust resistant corn varieties are sometimes planted in the southern states but not many resistant corn varieties are marketed for use in Nebraska. In Nebraska, common rust is not a significant annual threat to corn and, in 2014, only about 40% of seed suppliers have rated their hybrids for common rust resistance (Jackson-Ziems, 2014).
Chemical control of common rust

Many fungicides are effective for control of common rust. These fungicides are most effective when applied at an early stage of infection. A pesticide specialist or extension agent will be able to recommend suitable products for use against common rust. These products are often expensive to apply so a cost-benefit analysis should be made prior to application (Jackson-Ziems, 2014).

Action plan for common rust

Monitor the disease status of regions that are typically upwind from the Nebraska panhandle region. These diseases normally begin in Texas and spread north through Oklahoma, Kansas, and Colorado before getting to the farm’s area. As the disease approaches, scout the corn fields frequently to enable early detection of common rust. If it is determined that common rust will be a problem, and the cost-benefit ratio of a fungicide application is favorable, make the application when the disease is in an early stage.

Pea Diseases

Pea fields are not common in Cheyenne County and according to Darin Borges, a Panhandle Coop chemical advisor, have not yet developed any disease pressures (D. Borges, pers. comm., 2017).
In the 2017 field pea test plots at the Panhandle Research and Extension Center in Scottsbluff, Nebraska, no insect pests or diseases have been observed in the Nebraska Panhandle region (Panhandle Research and Extension Center, 2017). Insect and disease pressures will eventually occur in the field pea crop but for now there are no problems.

**WILDLIFE MANAGEMENT**

The Martin farm is located in a rural area and is frequented by many species of wildlife. An inventory of observed species, both permanent and migratory, is presented. This inventory is not comprehensive; it includes only animals that have been personally observed on the farm and only those animals that may materially affect the farm. Some of the animals are beneficial to the farm, some are detrimental, and many are both. The following paragraphs discuss these animals, their nature, and what actions, if any, should be taken to manage them.

**Birds**

**American Robins** (*Turdus migratorius*)

American robins are migratory insectivores and are present during all seasons except winter (Figure 43). The robins’ diet consists mostly of insects, arthropods, earthworms, spiders, and snails, when they are present. Their diet is not selective; it includes whatever insect species
are available. During cold weather, the robin’s diet consists mainly of fruit (Grunberg and Sells, 2004).

Figure 43. Robins in April snow in Niwot, Colorado (N. Martin, 2014).
Action plan for robins

American robins have not been observed on the farm in large numbers and their presence is concentrated mostly around the house and barn. They are currently not in need of management actions.

House Sparrows (*Passer domesticus*)

House sparrows are present on the Martin farm, occasionally in large numbers (Figure 44). House sparrows are granivorous and can inflict noticeable damage to grain crops. If the house sparrows gain access to stored grain, damage will occur due to consumption and fecal contamination. House sparrows prefer to nest as large groups in close quarters. They will often nest within a structure such as a barn or under the eaves of a structure, creating an unsanitary mess. This author has found evidence of house sparrows on the engine of his truck. The house sparrow harbors and transmits many human diseases and is a host for many insect pests such as ticks, bedbugs, and lice (Fitzwater, 1994).
Management of house sparrows

Because the house sparrow is an introduced species, it is afforded no legal protections. It may be managed by methods such as the use of repellants and toxicants, predation by cats, trapping, and shooting. House sparrows should be chased out of any inappropriate nesting areas. This can be accomplished at any time of their nesting cycle (Fitzwater, 1994).
**Action plan for house sparrows**

Although they may be intermittently present in large numbers, house sparrows are not currently nesting on or in any of the farm’s structures and present no particular nuisance. The situation should be monitored and if an adverse change occurs, management actions should be taken.

**Ungulates**

Only two ungulates species have been observed on the Martin farm, white-tailed deer and pronghorn. They are both common visitors and arrive throughout the year as individuals, pairs and in herds (pers. obs.).

**White tailed deer** (*Odocoileus virginianuu*)

The white-tailed deer is a medium sized deer and is found throughout most of the United States, Mexico, and southern Canada (Figure 45). Mature white-tailed males weigh 150 lb to 310 lb and females weigh about 30% less than the males. White-tailed deer gather in large groups (yards) of as many as 150 members and also in smaller sub-herds (Whitaker, 1996; Craven and Hygnstrom, 1994).

The diet of white-tailed deer varies regionally and consists of a mixture of forbs, fruit, nuts, and grasses. Agricultural crops such as corn, alfalfa, small grains, vegetables, and fruit trees are consumed when they are available. Average daily dry matter consumption is 2% to 4% of the white tailed deer’s weight. A mature white-tailed buck can consume as much as 12 pounds of dry
matter daily. When a large herd of white-tailed deer passes through fields during crop season, noticeable damage to crops is incurred. Crops are lost to the herd’s consumption and also to trampling and bedding (Craven and Hygnstrom, 1994; Whitaker, 1996).

Figure 45. White-tailed deer in a dandelion patch near Potter, Nebraska (N. Martin, 2017).

Herds tend to move about an area rather than remain in a fixed location. This behavior limits the damage that is inflicted on any particular field. However, due to a long term reduction in the number of deer predators, deer populations have been increasing, sometimes surpassing an area’s carrying capacity. When this happens, deer herds can inflict severe damage to agricultural crops (Craven and Hygnstrom, 1994).
**Pronghorn Antelope** (*Antilocapra americana*)

The American antelope is not a true antelope and is the only member of the family *Antilocapra* (Figure 46). It is smaller than the white-tailed deer at three feet high and 110 pounds of weight. Their white rumps are conspicuous when they are alarmed. Pronghorn are most likely to be found in a herd (up to 100 members) and may also be observed in small groups and as individuals. Like antelopes, Pronghorn are known for their speed. Pronghorn can sustain speeds of 70 mph for several minutes before slowing to a sustainable 30 mph.

The diet of pronghorn mostly consists of forbs and new grasses and they eat a lot of sagebrush. They appear to favor field peas in their diet (pers. obs.). Like the white-tailed deer, pronghorn can damage a crop through foraging, trampling, and bedding behaviors. (Schemnitz, 2005).

Figure 46. Pronghorn in post-harvest pea field Dalton, Nebraska (N. Martin, 2017)
Management of ungulates

A six-foot high, seven wire perimeter fence will effectively exclude deer and pronghorns from farmland. (Schemnitz, 2005). The Martin farm’s land is located in three separate quarter section parcels and the total perimeter distance is six miles. Using cost data from Kencove farm fence supplies (http://www.kencove.com/fence/T+Posts_product.php), and a standard deer fence design, the materials-only cost of fencing all three parcels is $17,795. The inclusion of wide machinery gates will substantially raise the fencing cost. If hired labor is employed to build the fence, the cost will be considerably higher. Other management methods such as repellants and noise generators are available, but are intended to protect small areas only. None of these are suitable for use on a large scale (Schemnitz, 2005).

Perhaps the best and most affordable deer control is hunting season. Hunters, both acquaintances and strangers, frequently request permission to hunt on farms. When permission is granted to responsible hunters, the ungulate population is reduced and a reduction in future damage may be realized. Many farmers require hunters to sign a liability release prior to granting permission to hunt. There are several deer hunting seasons in Nebraska occurring between September 01 and January 10. Antelope (pronghorn) seasons occur between August 20 and January 31. The dates for specific seasons depend on the type of weapon that will be used for the hunt. Specific information can be found at: http://outdoornebraska.gov/huntingseasons/. Before any attempt at deer control is undertaken, a cost – benefit analysis should be conducted. Personal observation has shown that large, persistent deer or pronghorns herds are not common in the Martin’s area.
Action plan for ungulates

The Martin farm currently grows low value crops, such as wheat and corn. The complete destruction of an acre of 45 bushel, four dollar wheat would amount to a loss of only 180 USD. This loss is not a compelling reason to build an $18,000 deer fence. The Martin farm does not currently grow any high value crops such as vegetables or tree fruits. If these valuable crops were to be grown in the future, a cost benefit analysis may show justification for protective fencing. However, the most likely future location for a deer fence would be surrounding a family vegetable and fruit garden near the house. In this case a cost-benefit analysis is not required because emotion, rather than logic, makes the decision to build a fence.

Rodents and Lagomorpha

Several members of the rodent family are present on the Martin farm - gophers, mice, and ground squirrels. Prairie dogs, although not currently present, could become a problem at any time. Rabbits and hares, which are Lagomorpha, are present on the farm.

Jackrabbits (*Lepus californicus*)

Blacktail jackrabbits reside on and around the Martin’s farm. Taxonomically, the jackrabbit is not a rabbit, but is a hare. Adult jackrabbits are up to 22 inches in length and weigh 5 to 10 pounds. The habitat preference of the blacktail jackrabbit includes prairies, meadows, and cultivated fields. Although it is not observed in large numbers on the farm, jackrabbit populations can swell when conditions are right (Whitaker, 1996).
The blacktail jackrabbit can have up to 4 litters each year with up to 8 births in each litter (Whitaker, 1996). An adult blacktail jackrabbit weighs 3 to 7 pounds and consumes up to a pound of green vegetation each day. In large populations, this hare can damage a crop and can also strip the bark from any trees that may be present (Knight, 1994).

**Cottontail rabbits (Syvilagus floridanus)**

Cottontail rabbits, like jackrabbits, are prolific breeders (Figure 47). If no deaths occur, a single mated pair could expand to a population of 350,000 in five years.

Figure 47. Cottontail rabbit on garden lawn in Niwot, Colorado (N. Martin, 2014).
Fortunately, few cottontails live past their first year. Cottontail habitats are a mixture of brush cover mixed with open areas. This type of habitat is provided by the yards around typical farm and suburban houses (Vantassel et al., 2010).

During periods of green plant growth, the feeding of cottontails is mostly harmless, but when this preferred diet is unavailable, the cottontail turns to twigs and tree bark, thus damaging woody plants (Whitaker, 1996). Although cottontails have not been numerous enough to cause substantial crop damage, their population around a homestead can be a damaging nuisance to landscaping, vegetable gardens and equipment. Rabbits can indirectly transmit disease to humans. Rabbit-borne ectoparasites, such as fleas and ticks, can transmit the diseases of Lyme and tularemia to humans (Vantassel et al., 2010).

Cottontail rabbits are responsible for causing extensive damage to the wiring of automobiles and other machinery that are parked in their vicinity. Three times the author has had a Honda CRV completely disabled by gnawing damage to its wiring. The wiring insulation is made from a soy-based insulation material (http://www.nbcnews.com/business/autos/honda-soy-based-wiring-covers-irresistible-rodents-lawsuit-n504746) and is attractive to rabbits and rodents.

Management of Lagomorpha

Management of cottontail rabbits and jackrabbits may be achieved by several means. They may be excluded from high value crops, such as vegetable gardens by fencing. Trap and release methods may offer relief from cottontail damage, as may the use of repellants. Finally, shooting cottontails and jackrabbits is an effective population reduction method (Vantassel et al., 2010). A small-game hunting permit is required in Nebraska and seasonal rules apply.
Out of season permission to shoot cottontails may be obtained in order to protect property (Vantassel et al., 2010).

**Action plan for lagomorphs**

The populations of rabbits and jackrabbits should be monitored. These populations increase rapidly under favorable conditions and can quickly become damaging. Currently, the population of rabbits is regulated by predators and requires no management intervention.

**Rodents**

**House mice** (*Mus musculus*)

House mice are common pests in and around most structures on farms (Figure 48). Introduced from Asia, their range now includes all of the United States and southern Canada (Timm, 1994).

The habitat of house mice is in or near structures such as houses and barns and also in open and cultivated fields. In the fields mice consume many weed seeds. When temperatures are moderate, house mice may locate away from humanity but, when the weather turns cold, they will seek the shelter and warmth of structures. Their jumping, gnawing, and climbing abilities help them gain access to many shelters. Additionally, mice can squeeze through entries that are less than a half inch wide. In protected spots, house mice build nests and produce 5 to 10 litters
of 5 or 6 young each year. These mice are mostly nocturnal and generally limit their daily travels to 30 feet from home (Timm, 1994; Whitaker, 1996).

Figure 48. A house mouse is a common farm pest (Zorba the Geek - geograph.org.uk, 2016).

The habitat of house mice is in or near structures such as houses and barns and also in open and cultivated fields. In the fields mice consume many weed seeds. When temperatures are moderate, house mice may locate away from humanity but, when the weather turns cold, they will seek the shelter and warmth of structures. Their jumping, gnawing, and climbing abilities help them gain access to many shelters. Additionally, mice can squeeze through entries that are less than a half inch wide. House mice are mostly nocturnal and generally limit their daily travels to 30 feet from home (Timm, 1994; Whitaker, 1996).
In an agricultural field, the dietary choices of house mice may be beneficial to farmers. Their diet consists of weed seeds and insects. However, in a structure the diet of house mice can be very destructive. House mice will eat or sample just about any food they come across and can quickly consume or contaminate just about any food in the building. Like most rodents, mice have a need to gnaw. Clothing, wood, electric wiring, and wallboard are all subject to gnawing damage. House mice can also carry and transmit to humans, many diseases such as salmonellosis and ringworm (Timm, 1994; Whitaker, 1996).

**Management of house mice**

Given the unpleasantness caused by the presence of mice in a human environment, it is wise to take action at the first sign of them, rather than waiting until the mouse population is large. House mice are afforded no legal protections and may be managed by any means desired.

The easiest way to reduce house mice numbers is with toxicants. This may be a practical course in an uninhabited structure such as a storage barn. However, before administering poisons in or around a dwelling, consideration should be given to where the poisoned mice will die and decay. If there is any chance that this death will occur inside the dwelling, use a different control method. A poisoned mouse may die and decay in inaccessible locations. Additionally, poison should not be used if another, non-target animal, will consume the poison or poisoned mice (Timm, 1994; Orkin, 2018).

Trapping methods such as glue boards, snap traps, and multiple capture traps can be effectively used to reduce the mouse population, if timeliness is not important. Mouse predation by “barn cats” can help control a mouse population, especially if multiple cats are employed (Timm, 1994; Orkin, 2018).
Exclusion of mice from a structure is a somewhat permanent method of population control. All possible access points that are larger than .25 inch should be sealed with concrete, sheet metal, or small mesh hardware cloth. A detailed inspection of the structure should be conducted to discover all possible entry points (Timm, 1994).

**Action plan for house mice**

House mice are well adapted to human habitations and other structures and are able to reproduce prolifically. At the first sign of their presence, measures to manage their population should be taken. Toxicants are effective, but should not be deployed within a house. Inside of a house, snap traps and multiple capture traps are appropriate. Introduction of predators, such as cats can be a very effective mouse control. Use of several control methods will be more effective than the use of just one.

**Prairie Dogs (Cynomys ludovicianus)**

The black–tailed prairie dog is a common burrowing rodent in the Martin farm’s region (Figure 49). An adult black-tailed prairie dog weighs about 2 to 3 pounds. A family consists of a male, several females and their annual offspring. The family lives in a multi-chambered burrow, which may extend as deep as 14 feet. A mound of excavated earth surrounds the openings. To create a defensive zone, vegetation is clipped short for several feet around the mound (Hygnstrom and Virchow, 1994).
Prairie dogs are gregarious animals, living in dense colonies of up to 35 residents per acre. Prairie dogs prefer to establish colonies in shortgrass prairie land. In areas of taller grass, prairie dogs can become established after livestock have grazed the grass, reducing the grass height. When unconstrained, prairie dog towns can cover more than 1,000 acres. In any prairie dog town lookouts constantly scan the surrounding ground and sky for predators. A normal adult black-tailed prairie dog diet is mostly green grasses supplemented by forbs. Seasonal flowers, seeds, and insects are also consumed (Hygnstrom and Virchow, 1994).

Prairie dogs cause losses to agricultural producers. Their expansive colonies take land out of production and their appetite takes crops from surrounding fields. Prairie dog burrows can
serve as “trip hazards” to livestock and can initiate water erosion initiators in fields, banks, and roads. Prairie dogs host fleas and ticks and can transmit several diseases to humans, including black plague (Hygnstrom and Virchow, 1994).

**Management of prairie dog**

The Martin farm does not currently host prairie dogs, but it is vulnerable to colonization at any time. At present, the black-tailed prairie dog is not under protection and several population management tools are available. Cultivation of prairie dog town areas, followed by 1 to 2 years of fallow may cause prairie dogs to move to more hospitable ground, as may frequent leveling of burrow mounds. Several toxicants consisting of toxic bait or fumigants are labeled for use on prairie dogs. If these are to be utilized, services of a certified pesticide applicator are recommended and may be required. Prairie dogs may also be trapped and released, but it may prove difficult to find a willing recipient for the released animals. Additionally, the trapping of individuals will be a slow process (Hygnstrom and Virchow, 1994).

Prairie dog populations may also be managed by shooting individual members. High velocity ammunition of .22 caliber or larger is recommended. After prolonged exposure to the noise of shooting, prairie dogs may seek shelter when gunshots are heard. In order to increase the effectiveness of shooting, some landowners have hosted competitive shooting events. Whatever prairie dog control is utilized, it will be more successful if it is deployed before the population becomes large (Hygnstrom and Virchow, 1994; Whitaker, 1996).
Action plan for prairie dogs

Prairie dogs form communities that may start with only a few members. However, a population can quickly swell to damaging proportions. Fields should be scouted for prairie dogs and the farm operators should be prepared to take quick action should prairie dogs move into the area. Toxicants, administered by a registered pesticide applicator, are the most effective action against prairie dogs.

Thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*)

The thirteen-lined ground squirrels are small rodents that visually resembles chipmunks (Figure 50). An adult weighs 8 ounces and, including the tail, is 10 inches long. The thirteen-lined ground squirrel was originally habituated to grasslands and has adapted to cleared land, such as farmland.

This ground squirrel’s diet is that of an omnivore. The thirteen-lined ground squirrel consumes all manner of animals including grasshoppers, worms, beetles, and mice. They also dine on each other. The diet includes plant material such as seeds, shoots, fruits, and cereals. When a normal diet is unavailable, the thirteen-lined ground squirrel turns to cached seeds and cereal grains (Cleary and Craven, 2005).

The thirteen-lined ground squirrel lives in 2-inch diameter burrows that descend into intricate networks of tunnels, entrances, and galleries. It is here that hibernation occurs and here that annual litters of 3 to 14 young are born. In suitable habitats individual ground squirrel burrows may be aggregated into a large mass of burrows (Whitaker, 1996).

When the thirteen-lined ground squirrel is present in large numbers, quite a bit of damage can occur to field and crop. Their excavations can ruin the smoothness of fields and their
consumption of seeds, shoots, and crop grains can have an effect on the farm’s economics (Cleary and Craven, 2005).

Figure 50. A thirteen lined ground squirrel gathering seeds (Steven Katovich, USDA Forest Service, Bugwood.org, 2013).

Management of thirteen-lined ground squirrels

Because the thirteen-lined ground squirrel is a good climber and jumper, exclusion by fencing is a costly control method. Wire fencing combined with sheet metal panels must be constructed both above and below ground to be effective. Additionally, special gates are required to prevent ingress by the squirrels. Although it has not been calculated, the cost of fencing out the thirteen-lined ground squirrels is sure to be unsupportable (Cleary and Craven, 2005).
Deep cultivation may cause ground squirrel populations to relocate. The use of toxicants and fumigants by certified pesticide applicators may also decrease ground squirrel populations. The thirteen-lined ground squirrel is offered no legal protections and may be taken without restriction (Cleary and Craven, 2005).

**Action plan for thirteen-lined ground squirrel**

On the Martin farm, predation by badgers, foxes, coyotes, snakes, and raptors keeps the ground squirrel population in check; this predation occurs at no cost to the farm. Of these predators, badgers appear to be the most active and aggressive. As long as the thirteen-lined ground squirrel population remains stable and small, there is no need to interfere with the natural control of the ground squirrels.

**Raptors – Airborne Predators**

**Red-tailed hawk (*Buteo jamaicensis*)**

The most common raptor observed above the Martin farm is the red-tailed hawk (Figure 51). Many red-tailed hawks have been observed in flight, but often are seen sitting on a post, power pole, or tree branch. The red-tailed hawk is an opportunistic feeder, and its diet includes small mammals, birds, and snakes. Within the small mammal category is a preference for familiar farm pests such as rats, rabbits, voles, ground squirrels, and prairie dogs. Red-tailed hawks also eat carrion (Cornell Lab of Ornithology staff, 2015).
Figure 5.1. A red-tailed hawk on fencepost (Terry Spivey, USDA Forest Service, Bugwood.org, 2010).
Owls (Athene cunicularia)

Owls are present and most have only been heard, but not seen near the farm. Only one species has been visually observed at the farm; the burrowing owl (Figure 52).

Figure 52. A burrowing owl on mound (By Lip Kee from Singapore, Republic of Singapore (burrowing owl IB.jpg, 2006)

Burrowing owls are common in the region, possibly due to the large number abandoned badger burrows that can be found in and around the fields. Burrowing owls often take up
residence in abandoned badger holes. The owl’s diet consists mainly of small rodents, such as mice, rats, and gophers (Cornell Lab of Ornithology staff, 2015).

Bald eagle (*Haliaeetus leucocephalus*)

Although not as numerous as the red-tailed hawk, bald eagles are occasional raptors in the Martin farm region (Figure 53).

Figure 53. A bald eagle at Barr Lake, Colorado (N. Martin, 2014).

Bald eagles are large, up to 3 feet tall and they can span 6 ½ feet. They build large aeries in trees, mate for life, and produce annual clutches of 2 to 3 young. No eagle nests have been
observed on the farm, but the farm serves as an occasional hunting ground for bald eagles. There is little open water near the farm, which alters the bald eagle’s normally aquatic diet. The bald eagle’s non-aquatic diet is composed of mammals, including rabbits. Like other raptors, bald eagles also consume carrion. Bald eagles are highly protected; it is illegal to possess any part of the bird or its nest, even a feather (Cornell Lab of Ornithology staff, 2015).

Management of air-borne raptors

All of these observed raptors feed on animals that are considered to be agricultural pests, and should remain welcome on farm properties. Care should be taken to avoid harming the raptors by unintentional poisoning. Farms often manage rodent populations with the use of toxicants. After consuming a toxicant, these rodents normally die, sometimes in an open area. This carrion, if subsequently consumed by a raptor, can cause great harm to that raptor.

Action plan for raptors

Because all of the observed raptors are beneficial to the Martin’s farm, no actions should be taken.
Ground Dwelling Predators

Several ground-dwelling predators have been observed on the Martin farm. These predators have kept the rodent and lagomorph populations in check.

Badgers (*Taxidea taxus*)

The badger is a powerful mammal characterized by strong, short legs, long claws, and shaggy gray to brown hair (Figure 54). Adult male badgers weigh up to 30 pounds and females are about 10 pounds less. Badger habitat covers most of the country west of the Mississippi river. Preferred terrain is open prairie, farmland, and the edge of treed areas. The home territory of a badger may be as much as 2.5 square miles, although higher population densities have been reported. Badgers suffer predation by other, larger predators, such as lions and bears, but these are rare animals in the farm’s area. Young badgers can fall prey to coyotes and large raptors (Whitaker, 1996).
Badger diets consist of small animals such as birds and their eggs, reptiles, insects and rodents. Badgers require the equivalent of about two ground squirrels each day. Badgers are able excavators and they use this ability to pursue burrowing animals such as ground squirrels and pocket gophers into their network of holes (Whitaker, 1996). In the process of pursuing their prey into burrows, badgers greatly enlarge the burrows. This action can turn a minor annoyance of small burrows and mounds into a major disturbance in a field’s smoothness, especially after the burrows collapse (Figure 55). These enlarged burrows can become lodging for badgers, but are not normally occupied for more than a day. The enlarged burrows are also used as dens by
foxes and maternity dens by coyotes (Lindzey, 1994; Whitaker, 1996). When smoothing badger burrow mounds, it is not unusual to flush a burrowing owl out of the hole.

Figure 55. A badger hole in field near Dalton, Nebraska (N. Martin, 2017)

The Martin’s farm has many badger burrows scattered around the fields. These burrows are approximately 10 inches in diameter and may extend from several feet to as much as 30 feet in length. These large holes and accompanying tailings piles make a mess of the smooth surface of a field and present a threat to machinery and foot traffic. The hazard is persistent in no till fields and individual burrows and mounds can last for years.

**Management of badgers**

Several methods can be utilized to reduce damage from badgers. Fencing is a viable option but costs are prohibitive on a large scale (Lindzey, 1994). Habitat modifications may send the badgers elsewhere. Also, an informal visual assessment suggests that frequent cultivation causes
badgers to relocate. Badger burrows are rare in the area’s conventionally tilled fields and are common in no till fields. Whether this is due to a direct effect on badgers or due to an effect on their prey has not been determined (Lindzey, 1994). As a non-protected species in Nebraska, badgers may be hunted between 1 November and 28 February (http://outdoornebraska.gov/huntingseasons/). Because badgers are mostly nocturnal, badger control by hunting may be difficult (Whitaker, 1996).

Action plans for badgers

Because badgers have a large appetite for rodents, it is best to leave them alone. The field damage that badgers produce can be repaired with a loader or grader blade on a utility tractor. If the field is not a no-till field, cultivation can repair the badger’s burrowing damage. Most farms in the area, including the Martin’s farm, have the required equipment. When fields are covered with growing crops, badger damage, if it can be found, will have to be repaired with manual labor or left unrepaired until after harvest.

Red fox (Vulpes vulpe)

Occasional red foxes have been spotted on the Martin farm (Figure 56). Their habitat of choice is open range with some brush or tree cover. Foxes excavate their dens in rises that have a good approach view. They also utilize slopes, stream banks, badger burrows, and hollowed out trees. Unlike badgers, red foxes may maintain a group of dens for an entire season or for generations (Phillips and Schmidt, 1994).
The red fox diet consists of rabbits, rodents, and seasonal fruits. They are able to reduce the population of rodents, especially during the winter when fruits are not available. Foxes are opportunistic feeders; they will prey upon poultry, ground nesting birds, pets, and small or young livestock. Red foxes bear litters of 4 to 9 pups in the spring and raise them until autumn, when the young disperse (Phillips and Schmidt, 1994; Whitaker, 1996).

**Management of red foxes**

If it is desired to manage the red fox population, the same methods and hunting dates that apply to badgers also apply to red foxes except separate seasons exist for harvesting and running foxes in Nebraska (http://outdoornebraska.gov/huntingseasons/).
Action plan for red foxes

The presence of foxes is beneficial to the Martin farm. There are no pets or livestock to be preyed upon by foxes and the foxes’ diet is mostly restricted to rodents and rabbits. The west field presents good denning opportunities in a grassy wash that is not farmable; currently, fox dens are not harming farm operations and should be left alone.

Coyote (Canis latrans)

Coyotes live throughout the United States, Mexico, and western Canada (Figure 57). They resemble a medium sized dog and adult males weigh 25 pounds to 45 pounds. Their habitat has expanded from open prairie to most areas in North America, including very populous urban areas (Whitaker, 1996). Coyote presence on the Martin farm is intermittent. Most often, their proximity is not established visually, but audibly, from their nocturnal howling.
Coyotes do not normally utilize dens, except when hiding from predators, during bad weather, and when caring for their young. Their dens can most often be found on slopes, rocky areas, and in both vegetated and open areas. These burrowed dens have openings of 1 to 2 feet in diameter and can be as long as 30 feet. They may be adapted from the dens of other animals.
Coyote liters of 5 to 7 pups are born in April and May. By autumn, the pups leave the family. Coyotes cause little physical damage to a farm’s arable land.

Coyotes have an opportunistic diet. They prefer rabbits, but also kill and consume animals ranging in size from mice to deer. Insects, carrion and fruit are all acceptable to a coyote. Coyotes also kill and consume livestock and pets when the opportunity to do so exists. When preying on livestock, coyotes will take the most convenient animal, not just the sick and elderly and they may kill more prey than they can eat. Because coyotes eat carrion, they are often credited for a kill they did not commit (Green, 1994; Whitaker, 1996).

Coyotes host several parasites including fleas, ticks, and mites. Distemper, and hepatitis, and mange are common diseases and coyotes may transmit rabies and tularemia to humans (Green, 1994; Whitaker, 1996).

**Management of coyotes**

Several methods of control are available to manage coyotes. In Nebraska, coyotes are a non-protected, non-game animal. This allows the taking of coyotes year round without permit by Nebraska residents (http://outdoornebraska.gov/furbearerspecies/). Toxicants are registered for use on coyotes and both require the services of a certified pesticide applicator (Green, 1994). The use of toxicants may damage off-target animals. Traps can be used to control coyotes. Care must be taken to minimize the destruction of off-target animals. Shooting coyotes is allowed without restriction in locations where firearms may be discharged. Nebraska residents may shoot coyotes without permits or limitations (https://www.coyotehunting101.com/coyote-hunting-nebraska/).
Action plan for coyotes

The Martin farm does not currently have livestock or pets and coyotes do not present a threat to the farm or its occupants. The coyote diet of rabbits and rodents is performing a service to the farm and should not be discouraged. If the farm acquires animals in the future, coyote management may be required to protect those animals from predation.

SUMMARY

The Martin farm has some strengths that should enable it to be a success. It is located close to farm suppliers and crop markets. The farm’s climate is semi-arid, but provides enough precipitation to successfully grow non-irrigated crops. The farm’s 440 arable acres should be enough to support the Martins, but not enough to require employees. When necessary, tasks such as combining can be easily contracted.

The farm’s soils are almost entirely loams and silt loams. The soils have good infiltration and hydraulic conductivity and their NRCS web soil survey profiles indicate that available water storage capacity is generally above 11 inches. The soils have been analyzed and found to be deficient in some nutrients and micronutrients. A nutrient plan has been developed and has been implemented.

Several water erosion problems have been noted in the farm’s fields. One erosion spot, a gully that was along the west field eastern boundary, has been addressed with the installation of riprap. Another area, in the west field, would benefit from installation of terraces to sequester
Terraces will be constructed in the summer of 2018, after harvest has cleared the field. All other potential water erosion areas appear to have been managed with the initiation of no-till cultivation. All of the farm’s areas will be monitored for erosion during and after intense precipitation events.

At the time of purchase and at present, the farm’s weed populations are large enough to cause a reduction in crop yields. The weeds of greatest concern are Canada thistle (*Cardus arvensis*), musk thistle (*Cardus nutans*), downy brome (*Bromus tectorum*), kochia (*Kochia scoparia*), and redroot pigweed (*Amaranthus retroflexus*). All of these can be managed by multiple tactics, including crop rotation, mowing, and herbicide application. When herbicides are selected, the advice of persons with local expertise should be sought. Consideration should be given to the acquisition of personal-use credentials for the application of restricted chemicals.

With a few exceptions, insect threats to crops can be managed by cultural means such as crop rotation and field sanitation. Diligent scouting for insect pests should uncover most insect threats prior to significant crop damage. Corn insect pests, such as the European corn borer and the western bean cutworm can be managed with the use of Bt crops. Local crop advisors are available to help with the selection of Bt corn varieties.

Crops varieties should be selected for resistance to anticipated diseases. Wheat is susceptible to stem rust, leaf rust, and stripe rust. Wheat varieties that are resistant to these rusts should be selected for planting. During and after wet weather, wheat should be scouted for signs of rust. Corn is susceptible to common rust, which is visually detectable and is treatable by fungicides. At present, insect and disease threats to field peas do not exist on the Martin farm.

Many animals are present on the Martin farm, but only two present a current threat. House mice should be managed by a combination of techniques. They should be excluded from
structures by elimination of ingress routes. Entrapments, toxicants, and predation by cats should also be employed to manage mice. Thirteen lined ground squirrels also require management actions. The excavations by ground squirrels are only a nuisance, but the squirrels attract badgers, which create large burrows and mounds in their pursuit of ground squirrels. Fumigants are the most practical method of removing thirteen-lined ground squirrels from the farm.

References


Kumar, V., and P. Jha. 2015. Effective preemergence and postemergence herbicide programs for Kochia control. Weed Technology 29:24-34.


APPENDIX 1

Soil Descriptions

1618—Keith loam, 1 to 3 percent slopes

Map Unit Setting

National map unit symbol: 2tv5x
Elevation: 3,100 to 4,300 feet

Mean annual precipitation: 15 to 23 inches
Mean annual air temperature: 46 to 52 degrees F
Frost-free period: 130 to 160 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Keith and similar soils: 96 percent
Minor components: 4 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Keith

Setting

Landform: Rises
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loess

Typical profile
- Ap - 0 to 6 inches: loam
- A - 6 to 9 inches: loam
- Bt1 - 9 to 13 inches: silty clay loam
- Bt2 - 13 to 30 inches: silt loam
- Bk - 30 to 47 inches: silt loam
- C - 47 to 79 inches: very fine sandy loam

Properties and qualities
- Slope: 1 to 3 percent
- Depth to restrictive feature: More than 80 inches
- Natural drainage class: Well drained
- Runoff class: Low
- Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum in profile: 15 percent
- Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
- Available water storage in profile: High (about 11.4 inches)

Interpretive groups
- Land capability classification (irrigated): 2e
- Land capability classification (nonirrigated): 2e
- Hydrologic Soil Group: C
- Ecological site: Loamy Upland (North) (PE 16-20) (R072XA015KS), Loamy
- Upland (North) (PE 16-20) (R072XA015KS)
- Other vegetative classification: Loam (G072XA100KS), Silty - Veg. zone 2
Hydric soil rating: No

Minor Components

**Duroc**

*Percent of map unit: 3 percent*

*Landform: Draws*

*Landform position (two-dimensional): Toeslope*

*Landform position (three-dimensional): Base slope*

*Down-slope shape: Linear*

*Across-slope shape: Concave*

*Ecological site: Loamy Upland (North) (PE 16-20)*

(R072XA015KS) **Hydric soil rating: No**

**Lodgepole**

*Percent of map unit: 1 percent*

*Landform: Playas*

*Landform position (two-dimensional): Toeslope*

*Landform position (three-dimensional): Base slope*

*Down-slope shape: Concave*

*Across-slope shape: Concave*

*Ecological site: Closed Upland Depression (North) Draft (April 2010)*

(PE 16-20) (R072XA011KS)

**Hydric soil rating: Yes**

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1650—Kuma loam, 0 to 1 percent slopes

**Map Unit Setting**

*National map unit symbol: 2wz83*

*Elevation: 3,170 to 4,800 feet*

*Mean annual precipitation: 15 to 23 inches*

*Mean annual air temperature: 46 to 52 degrees F*

*Frost-free period: 130 to 160 days*

*Farmland classification: Prime farmland if irrigated*
Map Unit Composition

Kuma and similar soils: 99 percent
Minor components: 1 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Kuma

Setting

Landform: Plains
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loess

Typical profile

Ap - 0 to 7 inches: loam
Bt - 7 to 20 inches: loam
Btb - 20 to 30 inches: loam
Btkb - 30 to 47 inches: silt
loam Cb - 47 to 79 inches:
loam

Properties and qualities

Slope: 0 to 1 percent

Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)

Available water storage in profile: High (about 11.7 inches)

Interpretive groups

Land capability classification (irrigated): 1
Land capability classification (nonirrigated): 2c
Hydrologic Soil Group: B
Ecological site: Loamy Tableland (R072XY100KS)

Other vegetative classification: Loam (G072XA100KS), Silty - Veg.

zone 2

(072XY036NE_2)

Hydric soil rating: No

Minor Components

Lodgepole, frequently ponded
Percent of map unit: 1 percent
Landform: Playas
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Base slope
Down-slope shape: Concave
Across-slope shape: Concave

5101—Alliance loam, 1 to 3 percent slopes

Map Unit Setting
National map unit symbol: 1v0l6
Elevation: 3,000 to 5,000 feet

Mean annual precipitation: 16 to 20 inches
Mean annual air temperature: 46 to 54 degrees F
Frost-free period: 130 to 150 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition
Alliance and similar soils: 99 percent
Minor components: 1 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Alliance

Setting

Landform: Plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loess over sandstone

Typical profile

Ap - 0 to 9 inches: loam
Bt - 9 to 21 inches: silty clay loam, silt loam

Bt - 9 to 21 inches: silt loam C
- 21 to 52 inches: weathered bedrock
Cr - 52 to 60 inches:

Properties and qualities

Slope: 1 to 3 percent

Depth to restrictive feature: 40 to 60 inches to paralithic bedrock

Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 10 percent
Available water storage in profile: High (about 11.6 inches)

Interpretive groups

Land capability classification (irrigated): 2e
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: B
Ecological site: Loamy Upland (North) (PE 16-20) (R072XA015KS)

Other vegetative classification: Loam (G072XA100KS), Silty - Veg. zone 1
Hydric soil rating: No

Minor Components

Lodgepole, frequently ponded
- Percent of map unit: 1 percent
- Landform: Playas
- Landform position (three-dimensional): Dip
- Down-slope shape: Concave
- Across-slope shape: Concave
- Other vegetative classification: Clayey Overflow - Veg. zone 2

Hydric soil rating: Yes

5102—Alliance loam, 3 to 6 percent slopes

Map Unit Setting
- National map unit symbol: 1v017
- Elevation: 3,000 to 5,000 feet
- Mean annual precipitation: 16 to 18 inches
- Mean annual air temperature: 46 to 50 degrees F
- Frost-free period: 130 to 150 days
- Farmland classification: Prime farmland if irrigated

Map Unit Composition
- Alliance and similar soils: 100 percent
  - Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Alliance

Setting
- Landform: Hillslopes
- Down-slope shape: Convex, concave
- Across-slope shape: Linear
- Parent material: Loess over sandstone

Typical profile
Ap - 0 to 7 inches: loam
Bt - 7 to 26 inches: silty clay loam, silt loam

Bt - 7 to 26 inches: very fine sandy loam
C - 26 to 43 inches: weathered bedrock
Cr - 43 to 60 inches:

Properties and qualities
Slope: 3 to 6 percent

Depth to restrictive feature: 40 to 60 inches to paralithic bedrock

Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 10 percent
Available water storage in profile: High (about 11.7 inches)

Interpretive groups
Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: B
Ecological site: Loamy Upland (North) (PE 16-20) (R072XA015KS)

Other vegetative classification: Loam (G072XA100KS), Silty - Veg. zone 1

(072XY015NE_1)

Hydric soil rating: No

5942—Duroc loam, 0 to 1 percent slopes

Map Unit Setting
National map unit symbol: 2tv63
Elevation: 3,100 to 5,190 feet
Mean annual precipitation: 15 to 23 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 110 to 160 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition
  Duroc and similar soils: 93 percent
  Minor components: 7 percent
  Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Duroc

Setting
  Landform: Swales
  Landform position (two-dimensional): Footslope
  Landform position (three-dimensional): Base slope
  Down-slope shape: Linear
  Across-slope shape: Concave
  Parent material: Slope alluvium

Typical profile
  Ap - 0 to 6 inches: loam
  A - 6 to 21 inches: loam
  Bw - 21 to 32 inches: loam
  Bk - 32 to 55 inches: loam
  C - 55 to 79 inches: loam

Properties and qualities
  Slope: 0 to 1 percent
  Depth to restrictive feature: More than 80 inches
  Natural drainage class: Well drained
  Runoff class: Negligible
  Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
  Depth to water table: More than 80 inches
  Frequency of flooding: None
  Frequency of ponding: None
  Calcium carbonate, maximum in profile: 12 percent
  Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Very high (about 12.4 inches)

**Interpretive groups**
- Land capability classification (irrigated): 1
- Land capability classification (nonirrigated): 2c
- Hydrologic Soil Group: B
- Ecological site: Loamy Tableland
  (R072XY100KS) Hydric soil rating: No

**Minor Components**

**Keith**
- Percent of map unit: 5 percent
- Landform: Plains
- Landform position (two-dimensional): Summit
- Landform position (three-dimensional): Interfluve
- Down-slope shape: Linear
- Across-slope shape: Linear
- Ecological site: Loamy Tableland
  (R072XY100KS) Hydric soil rating: No

**Lodgepole**
- Percent of map unit: 2 percent
- Landform: Playas
- Landform position (two-dimensional): Toeslope
- Landform position (three-dimensional): Base slope
- Down-slope shape: Concave
- Across-slope shape: Concave
## Soil analyses

### West field soil analysis

### Soil Analysis Report

**Location:** WESTFIELD

| Sample ID | Soil pH | Modified WDRF Eppi | Soluble Salts 1:1 mmnho/cm | Excess Lime Rating | Organic Matter LOI% | FIA Nitrate ppm N | Depth | Phosphorus ppm P | Method | Ca-P | Sulfate ppm S | K ppm | Ca ppm | Mg ppm | Na ppm | Zn ppm | Fe ppm | Mn ppm | Cu ppm | H | K | Ca | Mg | Na |
|-----------|---------|---------------------|---------------------------|-------------------|---------------------|-------------------|-------|------------------|--------|------|----------------|-------|--------|--------|--------|--------|-------|-------|--------|-------|---|---|---|---|---|
| 1         | 8.3     | 0.16                | LOW                       | 1.8               | 2.9                 | 9                 | 5     | 0.29             | 2.4    | 1.4  | 0.28         | 334   | 4572   | 129    | 9      | 4.0    | 3     | 92    | 4     | 0     |
| 2         | 6.6     | 0.19                | NONE                      | 2.3               | 19.6                | 59                | 17    | 483              | 1877   | 231  | 3.6          | 0.41  | 17.6   | 12.2   | 0.49   | 12.6   | 0     | 10    | 75    | 15    | 0 |
| 3         | 7.0     | 0.07                | NONE                      | 1.5               | 0.7                 | 2                 | 8     | 433              | 1872   | 226  | 3.2          | 0.13  | 9.2    | 5.7    | 0.39   | 12.4   | 0     | 9     | 76    | 15    | 0 |

### Fertilizer Recommendations: In Actual Pounds of Plant Nutrients per Acre

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Center field soil analysis

| Sample ID | Soil pH | Modified WDRF Blot | Soluble Salts 1:1 | Excess Lime Rating | Organic Matter LOI% | FIA Nitrate ppm N | Depth Nitrate Lbs N/A | Method Phosphorus ppm P | Ammonium Acetate ppm K | Ca ppm | Mg ppm | Na ppm | Ca-P Sulfate ppm S | Zn ppm | Fe ppm | Mn ppm | Cu ppm | Ca(NO₃)₂ Chloride ppm B | Hot Water Boron ppm B | Sum of Cations meq/100g | % Base Saturation |
|-----------|---------|--------------------|-------------------|-------------------|---------------------|-------------------|---------------------|-------------------------|-------------------------|------------------|-------|-------|-------|-------------------|------|-------|-------|-------|----------------|------------------|-----------------|-----------------|
| 1         | 8.0     | 0.13               | NONE              | 1.4               | 5.6                | 17                | 12                  | 392                     | 2165                    | 153              | 10    | 5.1   | 3.66  | 7.5              | 2.4  | 0.41  | 13.3  | 0     | 8                | 82               | 10              | 0               |
|           |         | 0 - 10 in          | M-P3              |                   |                     |                   |                     |                         |                         |                  |       |       |       |                   |      |       |       |       |                  |                  |                 |                 |
| 2         | 7.1     | 0.13               | NONE              | 1.6               | 10.5               | 32                | 8                   | 444                     | 2137                    | 256              | 10    | 5.2   | 0.17  | 6.1              | 3.6  | 0.43  | 14.0  | 0     | 8                | 76               | 15              | 0               |
|           |         | 0 - 10 in          | M-P3              |                   |                     |                   |                     |                         |                         |                  |       |       |       |                   |      |       |       |       |                  |                  |                 |                 |
| 3         | 6.6     | 0.11               | NONE              | 1.6               | 2.8                | 8                 | 12                  | 363                     | 1736                    | 227              | 12    | 6.4   | 0.17  | 13.5             | 7.8  | 0.41  | 11.5  | 0     | 8                | 75               | 16              | 0               |

**Fertilizer Recommendations In Actual Pounds of Plant Nutrients per Acre**

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<th>Sample ID</th>
<th>Crop</th>
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<th>Nitrogen N</th>
<th>Phosphorus P</th>
<th>Potassium K</th>
<th>Sulfur S</th>
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<th>Magnesium Mg</th>
<th>Iron Fe</th>
<th>Manganese Mn</th>
<th>Copper Cu</th>
<th>Boron B</th>
<th>Chloride Cl</th>
<th>Lime, ECC Tons/Acre</th>
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East field soil analysis

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<th>Nitrate Libs N/A</th>
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<th>Mg ppm</th>
<th>Mn ppm</th>
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<th>Fe ppm</th>
<th>Mn ppm</th>
<th>Zn ppm</th>
<th>Boron ppm B</th>
<th>Chloride ppm Cl</th>
<th>Sum of Cations meq/100g</th>
<th>% Base Saturation</th>
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Fertilizer Recommendations in Actual Pounds of Plant Nutrients per Acre

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(Ward) Corn, BU
(Ward) Peas, BU/A
(Ward) Wheat, BU/A
Oil site soil analysis.

```
| Sample ID | Soil pH | Modified WDRF | Soluble Salts 1:1 mmho/cm | Excess Lime Rating | Organic Matter LOI % | FIA Nitrates ppm N | Depth Nitrate Lbs N/A | Method                | Ammonium Acetate- K ppm | Ca ppm | Mg ppm | Na ppm | Zn ppm | Fe ppm | Mn ppm | Cu ppm | DTPA Ca-P Sulfate ppm S | Hot Water Boron ppm B | CaO3 Chloride ppm Cl | Sum of Cations me/100g | % Base Saturation     |
|-----------|---------|---------------|---------------------------|-------------------|----------------------|---------------------|---------------------|-----------------------|-------------------------|-------------------|--------|--------|--------|--------|--------|--------|--------|------------------------|---------------------|----------------------|----------------------|---------------------|
| OIL SITE 1| 7.5     | 0.12          | NONE                      | 0.6               | 6.6                  | 18                  | 24                  | M-P3                  | 156                     | 826               | 83      | 253     | 5      | 0.20   | 7.2    | 2.7    | 0.22   | 6.3                    | 0                   | 6                   | 65                  | 11                  |
| 95307     | 7.5     | 0.12          | NONE                      | 0.6               | 6.6                  | 18                  | 24                  | M-P3                  | 156                     | 826               | 83      | 253     | 5      | 0.20   | 7.2    | 2.7    | 0.22   | 6.3                    | 0                   | 6                   | 65                  | 11                  |
| OIL SITE 2| 7.4     | 0.86          | NONE                      | 0.6               | 21.0                 | 19                  | 19                  | M-P3                  | 135                     | 672               | 68      | 1212    | 19     | 0.61   | 4.1    | 2.6    | 0.14   | 9.5                    | 0                   | 4                   | 35                  | 6                  |
| 95308     | 7.4     | 0.86          | NONE                      | 0.6               | 21.0                 | 19                  | 19                  | M-P3                  | 135                     | 672               | 68      | 1212    | 19     | 0.61   | 4.1    | 2.6    | 0.14   | 9.5                    | 0                   | 4                   | 35                  | 6                  |
| OIL SITE 3| 7.9     | 5.01          | HIGH                      | 0.9               | 66.9                 | 24                  | 13                  | M-P3                  | 279                     | 3630              | 125     | 2601    | 54     | 0.26   | 14.2   | 0.7    | 0.23   | 32.2                   | 0                   | 2                   | 59                  | 3                  |

```

APPENDIX 3

Minor, but annoying weeds

Several minor weeds are present on the Martin farm. Their presence has not been an impediment to crop production, but they constitute an irritant to the owners, mostly because of their sharp spines. Personal experience has shown them to be responsive to economical herbicides (2, 4-D and glyphosate) that are applied with a backpack sprayer.

Goathead, aka puncturevine (*Tribulus terrestris*) is responsible for punctures of bicycle tires, athletic balls, and feet (N. Martin, 2017).
Buffalobur (*Solanum rostratum*) has stiff spines that can penetrate most clothing (N. Martin, 2017).

Field Sandbur (*Cenchrus longispinus*) spines cling to clothing and skin. Remove them with pliers (N. Martin, 2017).