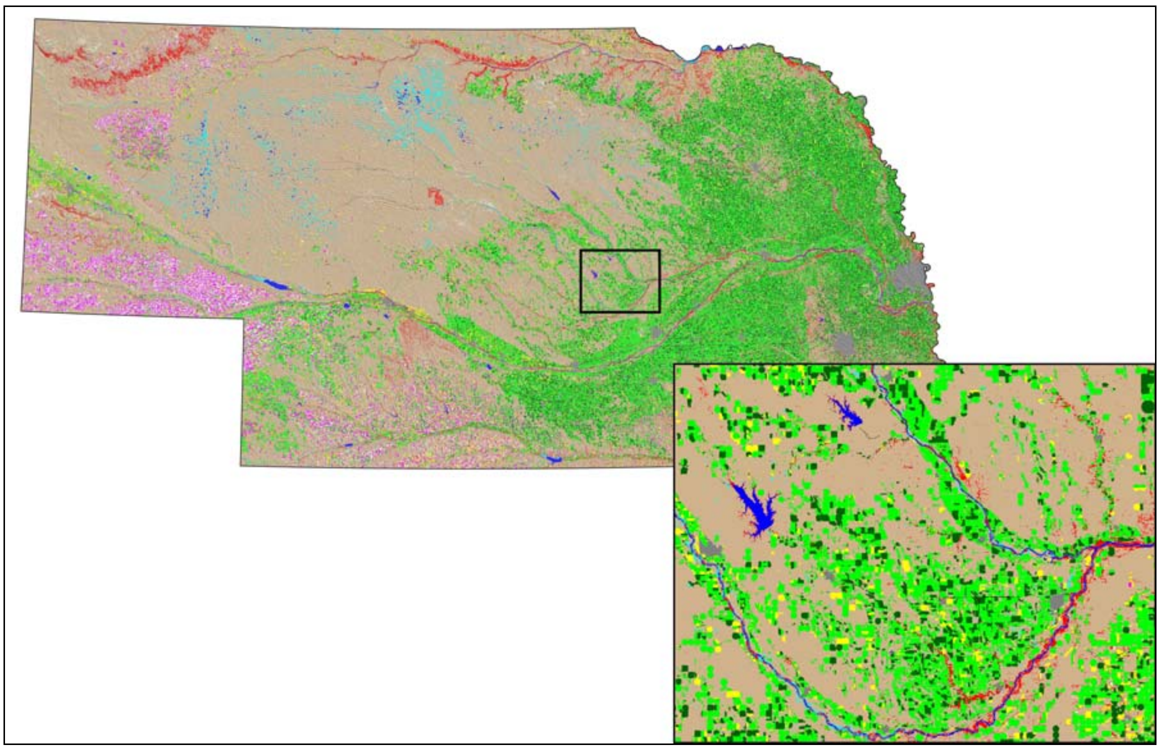
Delineation of 2005 Land Use Patterns For The State of Nebraska Department of Natural Resources

Final Report
September 2007



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INTRODUCTION

Nebraska is a leading agricultural state. According to the 2002 Census of Agriculture (USDA, 2007), the total value of agricultural products sold in Nebraska was $9.7 billion (national ranking= 4th) of which $6.3 billion came from animal products and $3.4 billion from plant products. Because of the state's agricultural economy, soil and water use is extremely important. Initially, streams and rivers were the source for irrigation in Nebraska and continue to supply water for Nebraska's cropland today. The Platte, Loup, and Republican rivers are particularly important. Irrigation ditches were constructed in Nebraska as early as 1856. However, Nebraska's irrigation systems originate from the droughts of the 1890s and 1930s (Nebraska Blue Book, 2007). Current irrigated cropland in Nebraska is extensive. These lands encompass 7,508,900 acres (30,388 km^2), which is more than 15% of the total land area of Nebraska and contribute to almost 15% of the national total (rank=2nd, USDA 2007).

On the path to becoming a leading agricultural state, Nebraska's landscapes have been repeatedly transformed since European settlement and are now dominated by human activities across a range of land use intensities. Plowing and cultivation of the prairies, suppression of periodic wildfire, drainage of wetlands, channelization of rivers and streams, emplacement of reservoirs and ponds, planting of shelterbelts, displacement of large herbivores and replacement by cattle, introduction of exotic and invasive species, intensive use of fertilizers and pesticides, expansion of irrigation, growth and development of human settlements, transportation corridors, and commercial and industrial activities have all contributed to Nebraska's current land cover.

Agricultural practices shape the landscape and influence state and region-wide policies that involve everything from water use to endangered species and environmental concerns. Comprehensive and current information on land cover and land use, notably irrigation and crop patterns, are critical as hydrologic conditions change in relation to crop dynamics. Mapping current land use can provide a basis to develop policy and procedures related to groundwater and surface water.

As an extension of The Platte River Cooperative Hydrology Study (COHYST), the delineation of 2005 statewide land use patterns for Nebraska has been developed in order to improve understanding between hydrologic conditions and crop dynamics. The Nebraska Department of Natural Resources (NDNR) sought information on land use for the entire state beyond the area originally delineated by the previous work completed for COHYST. Comprehensive and current information on land cover and land use, especially irrigation and crop patterns, are critical to NDNR since hydrologic conditions change in relation to crop dynamics. CALMIT, a unit of the Conservation and Survey Division and the School of Natural Resource Sciences at the University of Nebraska – Lincoln, completed the development of three land cover databases for the COHYST region based on 1997, 2001, and 2005 Landsat satellite imagery and ancillary data.

PROJECT OBJECTIVES

The principal objective of this project was to apply methodologies and skills developed in the 1997, 2001, and 2005 COHYST land cover research to develop an updated agricultural land cover classification for the 2005 growing season for the entire state of Nebraska.

Comprehensive and current information on land cover and land use, especially irrigation and crop patterns, are important to the Nebraska Department of Natural Resources (NDNR). By capitalizing on the seasonal dynamics of the agricultural crops and native plant communities, an accurate and important map of land use has been developed for the entire state of Nebraska for the 2005 growing season. The initial study area of the Central Platte River Basin was extended to include the entire state of Nebraska.

The creation of a statewide land use and land cover map is an important resource. Process-based hydrologic models utilize inputs based on quantifiable variables. Land cover has been identified as one of the key variables in hydrologic modeling (Bobba *et al*., 2000; Srinvasan *et al*., 1998), and an important factor in determining consumptive water use (Zheng and Baetz, 1999). An analysis of land cover and land use is critical to determine what current crops are grown, whether they're grown under irrigated or non-irrigated conditions, or whether the fields are in pasture or range, rather than cultivation. Different land uses require different kinds of water use. Creating a statewide land cover map for the year 2005 will provide a more accurate input layer for NDNR's statewide hydrologic modeling efforts.

THE STUDY AREA

Located near the center of the Great Plains of North America, Nebraska covers approximately 77,358 square miles (see Figure 1). Elevation rises gradually from southeast to northwest, with an average elevation of 2500ft. The lowest elevation is found

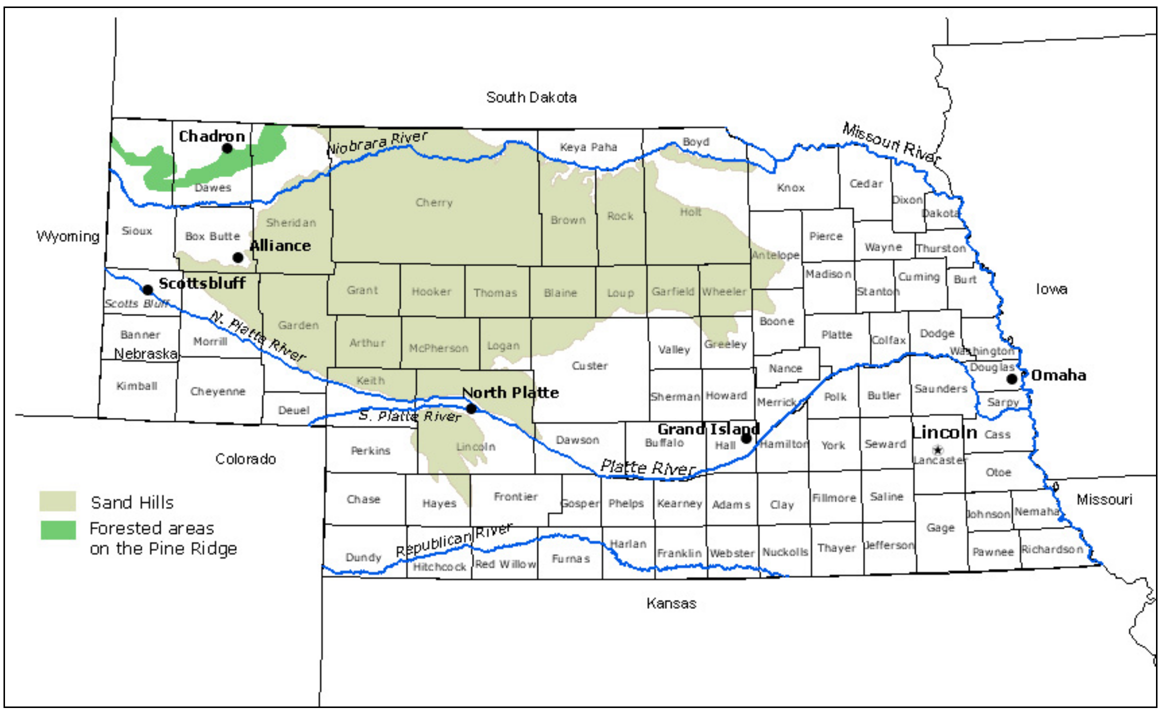


Figure 1. The Study Area.

in southeast Richardson County, at the Missouri River (840ft). The highest point is in southwestern Kimball County, near the Colorado and Wyoming borders (5424ft) (Nebraska Blue Book, 2007).

Topography and Climate

Nebraska has two major geographic regions, the Dissected Till Plains and the Great Plains (Nebraska Blue Book, 2007). The Dissected Till Plains span over the eastern fifth of Nebraska. They were formed when Ice Age glaciers left behind a rich soil-forming material called till. Windblown dust (loess) later settled on the till, and over the years, streams dissected the region, forming a rolling terrain. Along the Missouri River, the terrain includes bluffs and river-deposited lowlands. This combination makes the Dissected Till Plains well-suited for farming and is represented by the fields of corn, soybeans, sorghum grain, and other crops blanket the region.

The Great Plains encompass the rest of Nebraska into Wyoming and Colorado. They can be divided into smaller areas, among them the Loess Plains, the Loess Hills, the Sandhills, and the High Plains. The Loess Plains cover about 7,948 square miles of intensively farmed land scattered with lakes and wetlands in south-central Nebraska. The flat to gently rolling plains were formed by deep deposits of windblown silt (loess). The area is often referred to as the "Rainwater Basin" due to the interspersed lakes and wetlands, and provides critical habitat in the spring for migrating waterfowl.

The Loess Hills lie north of the Platte River and south and east of the Sandhills. Here, windblown silt has formed rolling hills where farms and ranches predominate. The hills are composed of yellow loess soil overlying older debris left from the last ice age. They are characterized by sharp edged ridge crests, and slopes ranging from gentle to very steep. Cliffs cut into the erosion resistant soil by rivers, streams or road-builders a hundred years ago still remain.

The largest of the Great Plains subregions is the Nebraska Sand Hills. The Sand Hills comprise about one-quarter of Nebraska and covers nearly 20,000 square miles, from the North Platte and Platte rivers to South Dakota. The Sand Hills is the largest sand dune area in the Western Hemisphere. This grass-stabilized dune region was formed from wind whipping sand into hills and ridges interspersed with valleys that contain streams, lakes and wetlands. The abundant water and grasslands make this area ideal for raising cattle.

The High Plains lie west of the Sandhills. Elevations of up to a mile above sea level occur in the west along the Wyoming border. In its 12,000 square miles are the scenic Wildcat Hills and Pine Ridge areas in the southern and northern Panhandle, respectively. A small area of the Badlands extends from South Dakota into the northwestern corner of Nebraska. This unusual landscape in the northwestern part of the state has been carved by erosion and is characterized by steep, mostly bare hills of siltstone and sandstone and by mushroom-like cap rocks on more narrow pedestals (Nebraska Blue Book, 2007).

Nebraska's weather is characterized by extremes in temperature and frequent changes in the weather. Tornadoes, thunderstorms, blizzards and hailstorms are part of hot summers and severely cold winters. Temperature and rainfall vary greatly during the year. Temperature gradually drops from southeastern to northwestern Nebraska, except in the coldest part of the year (Nebraska Blue Book, 2007). The highest temperature ever recorded in Nebraska, 118 °F (48 °C), was on July 15, 1934, at Geneva; on July 17, 1936, at Hartington; and on July 24, 1936, at Minden. The lowest temperature on record, -47 °F (-44 °C), was at Camp Clarke near Northport on Feb. 12, 1899, and at Oshkosh on Dec. 22, 1989 (Nebraska Blue Book, 2007).

Like temperature, Nebraska's precipitation and humidity decreases from east to west. Years of abundant rainfall may alternate with extreme drought. Nebraska's growing season ranges from about 165 days in the southeast to 120 days in the northwest. Killing frosts usually occur from about Oct. 15 to April 25 in the southeast and about Sept. 20 to May 20 in the northwest. Prevailing winds blow across Nebraska from the northwest between October and April, and from the south and southeast during other times. Average wind velocity is about 10 miles (16 kilometers) per hour. Tornadoes are not uncommon in the spring and summer. Averages of 37 are spotted every year, and some of them can cause extensive damage (Nebraska Blue Book, 2007).

The 2005 Growing Season

The previous growing season of 2004 saw much of western Nebraska mired in conditions of severe to exceptional drought (NDMC, 2005). Timely winter and spring precipitation improved drought conditions throughout the entire state for the 2005 growing season. While some areas were still affected by moderate drought conditions, soil moisture was better than the previous year, and was above the state's 5 and 10-year averages (NDMC, 2005; IANR, 2005a) (See Figure 2).

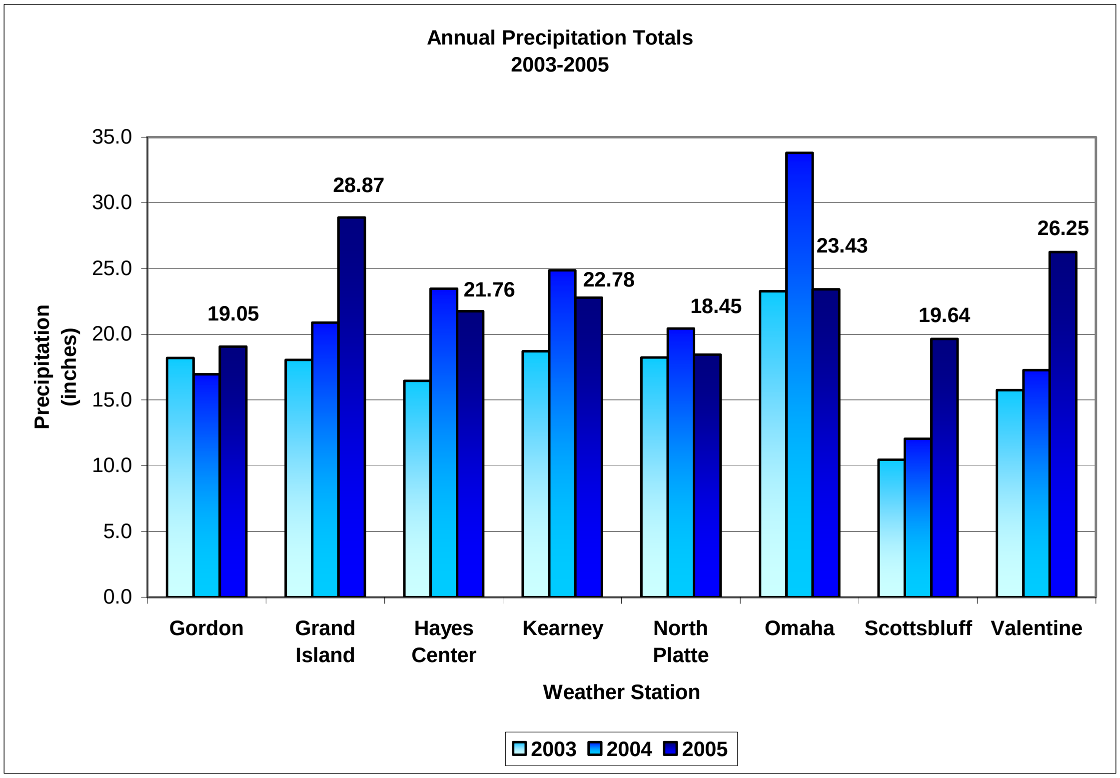


Figure 2. Precipitation Totals for Select Weather Stations 2003-2005.

Early in the 2005 growing season, widespread rainfall led to statewide precipitation levels that were above normal. This trend of above average precipitation continued until the first week in July, when the Southeast Nebraska Agricultural Statistics (NASS) District was the first district to drop below average precipitation levels. (NASS, 2005). By the middle of July, four of the eight districts had dropped below normal precipitation levels. By the 3rd week in August, however, precipitation levels were at or above normal in 6 of the 8 districts, and the two remaining districts were within 1 inch of normal precipitation levels. Toward the end of the growing season in September, only 4 of the 8 districts remain at or above the normal precipitation levels since April. This trend is reflected in Figure 2, where a majority of stations showed slightly below average annual precipitation for 2005 despite widespread early season rainfall.

Temperatures during the 2005 growing season were higher than 2004 for the majority of weather stations that were selected (Figure 3).

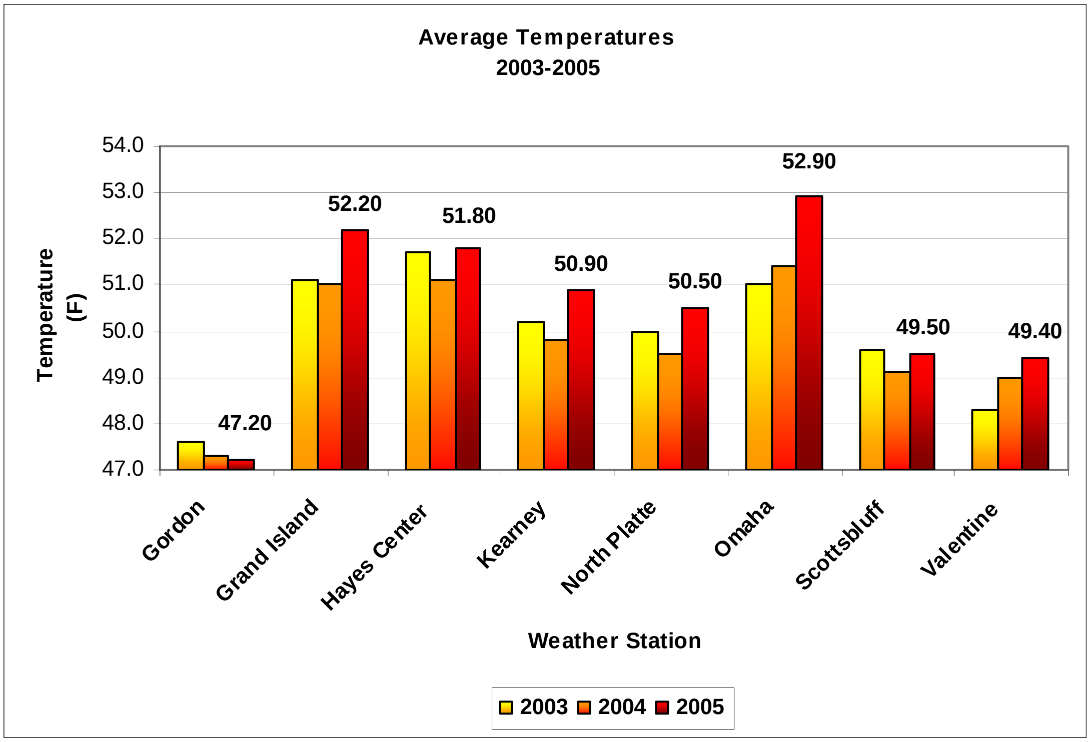


Figure 3. Average Annual Temperatures for Select Weather Stations 2003-2005.

While the 2004 growing season was considered unseasonably cool, Figure 3 shows that the annual temperatures were above normal at all weather stations, except Gordon, for all three years measured (IANR, 2005b).

Because of their reliance on soil moisture, dry land crops are more significantly affected by higher temperatures, which accelerate evaporation of water from the soil. During the 2005 growing season, the weekly NASS Weather and Crops reports (2005) indicate that higher temperatures were recorded early in the growing season when adequate rainfall was reported statewide, and late in the season when higher temperatures helped push crops toward maturity. The two weeks in the middle of the growing season had high temperatures, high winds, and lack of precipitation which stressed dry land crops. This was followed by a week of cooler temperatures and rainfall that presumably helped restore soil moisture in these stressed areas. Generally favorable and timely precipitation led to yields that were higher than average for most crops (NASS, 2006).

Throughout the growing season, corn conditions remained above average, though slightly lower than the record-setting 2004 growing season (NASS, 2005). The harvest occurred ahead of both the previous growing season and the average. Yield, while slightly lower than 2004, was still higher every other year since NASS recorded yield statistics in 1866. The highly productive corn crop was cause for some concern with producers who ran out of storage space for grain due to the high productivity coupled with the previous year's record productivity.

Soybean yields were the highest ever recorded by NASS (NASS, 2006). Soybean conditions remained at or above average for the entire growing season, while harvest occurred well ahead of both the 2004 growing season and the average. The acres harvested was higher than all years since 1987 except 2001 and 2004, while the yield and overall production were both the highest ever recorded.

Similarly high productivity and yields were recorded for Dry Edible Beans and Sunflowers (NASS, 2006). Productivity and yields for both crops were the highest ever recorded by NASS.

Overall, the 2005 growing season saw yields that were record-setting, driven by timely precipitation and temperatures that were above normal at key times in crop development. While rainfall was not significant enough to bring the state completely out of the drought conditions it has experienced since 2000, it was enough to drive a highly productive 2005 growing season.

Land Cover Classes and Their Characteristics

Since agriculture represents such a large percentage of the study area, the main focus of the land cover classification was to identify agricultural crops. The land cover classes used in this study were (Table 1): irrigated & non-irrigated corn, irrigated sugar beets, irrigated & non-irrigated soybeans, irrigated & non-irrigated sorghum, irrigated and non-irrigated dry edible beans, irrigated potatoes, irrigated & non-irrigated alfalfa, irrigated & non-irrigated small grains, irrigated and non-irrigated sunflower, summer fallow, range (grass/pasture/CRP), urban land, open water, riparian forest & woodlands, wetlands, other agricultural lands, roads, and barren areas. Each class is further detailed and described in Table 1.

Table 1. Land Cover Classes and Characteristics

(Descriptions from Nebraska Agricultural Statistics Service, 1990; National Agricultural Statistics Service, 1997, 2002; Maxwell and Hoffer, 1996).

Land Cover Classes	General Description
Irrigated & Non-Irrigated Corn	Includes corn used for grain or silage. Planted late April to early May, full cover by late July and harvested September through November.
Irrigated Sugar Beets	Sugar Beets are planted in April. Full cover in August and harvested in October. Sugar Beets are usually irrigated.
Irrigated & Non-Irrigated Sorghum	Includes sorghum for grain and silage, as well as milo, sudan, and cane. Planted in May, full cover by July and harvested September through October.
Irrigated & Non-Irrigated Dry Edible Beans	Includes great northern beans, pinto beans, white beans, and others. Planted in May to early June. Cutting starts mid-August when plants are windrowed to dry. Harvested late August to late September.
Irrigated Potatoes	Potatoes are planted in late April to early May, harvested September/October. Potatoes are usually irrigated.
Irrigated & Non-Irrigated Alfalfa	Alfalfa begins to mature during April and early May with first cut beginning in May. Harvested 3-4 times during the growing season ending in early October.
Irrigated & Non-Irrigated Small Grains	Includes winter wheat, spring wheat, oats, barley, rye and millet. Winter wheat planted September of previous year and harvest begins early July. Oats and barley are generally planted late March or early April, and harvested in July.
Irrigated & Non-irrigated Sunflower	Planted in May and harvested in October.
Summer Fallow	Cropland that is purposely kept out of production during a cropping season mainly to conserve moisture for the next season. It is common for wheat producers to rotate half their cropland to summer fallow each year.
Range/Grass/Pasture	Mostly range grasses and pasture, with some cultivated grass and hay. Includes brome grass and land in the Conservation Reserve Program. Green-up in spring and early summer. Grazing occurs at irregular intervals.
Urban Land	Areas defined as towns or cities with a population greater than 100 people.
Open Water	Lakes, streams, ponds, reservoirs. Water levels varies due to irrigation draw-downs and evaporation.
Riparian Forest & Woodlands	Forested areas including areas next to streams, lakes and wetlands
Wetlands	Emergent wetlands, lands where saturation with water is the dominant factor determining the nature of soil

	development and the types of plant and animal communities living in the soil and on its surface. This class may also include sub-irrigated grassland areas and areas of shallow water.
Other Agricultural Lands	Includes developed areas associated with farming, such as farmsteads, feedlots, etc.
Roads	Interstate and highway roads.
Barren Areas	Areas with no vegetation, including blowouts and sandbars.

LITERATURE REVIEW

Remote Sensing of Land Cover

A number of definitions exist for remote sensing. The American Society of Photogrammetry and Remote Sensing (ASPRS) adopted in 1988 the definition, "Photogrammetry and remote sensing are the art, science, and technology of obtaining reliable information about physical objects and the environment, through the process of recording , measuring, and interpreting imagery and digital representations of energy patterns derived from noncontact sensor systems" (Colwell, 1997). Jensen (2000) defined remote sensing as, "the art and science of obtaining information about an object without being in direct physical contact with the object. It is a scientific technology that can be used to measure and monitor important biophysical characteristics and human activities on the Earth".

Remote sensing systems have the ability to acquire information about the land surface at various spatial, spectral, temporal, and radiometric resolutions. These abilities make remote sensing systems essential for natural resource applications. One critical application is land cover mapping. Land cover mapping from satellites has been practiced since the early 1970s with the first launch of the Landsat series satellites. Remote sensing of land cover is based on the principles of interaction between electromagnetic radiation (EMR), land surface material, and the satellite sensor. When detected by a sensor, changes in the amount and properties of EMR become a source of information for interpretation of land cover phenomena (Jensen, 1996).

The visible and near infrared regions of the electromagnetic spectrum are frequently used to extract information on land cover characteristics. The visible region is the portion of the spectrum our eyes can detect and is represented by the three primary colors of blue (0.4 to 0.5 µm), green (0.5 to 0.6 µm), and red (0.6 to 0.7 µm). The near infrared region of the electromagnetic spectrum ranges from approximately 0.7 to 1.3 µm (Lillesand and Kiefer, 2000). This spectral region is used to analyze, monitor, and assess changes and differences among plants.

Changes in the amount and properties of EMR reflecting off of the land surface allows various kinds of surface materials to be recognized and distinguished from each other by their unique spectral patterns (see Figure 4).

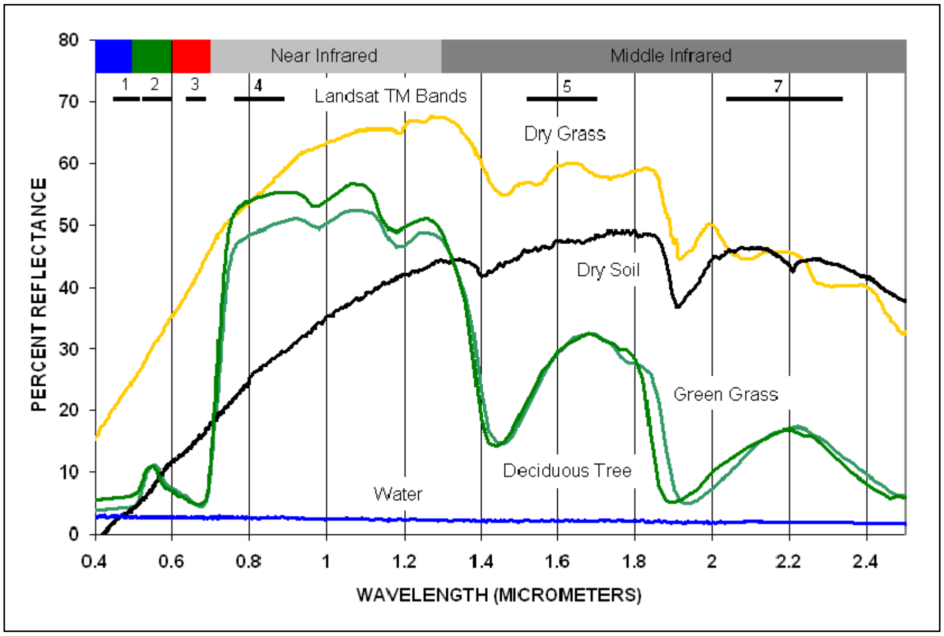


Figure 4. Spectral reflectance of Green Grass, Dry Grass and Dry Soil
(Reproduced from the ASTER Spectral Library through the courtesy of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California. Copyright © 1999, California Institute of Technology. ALL RIGHTS RESERVED).

These patterns are also known as spectral signatures. Spectral signatures are plotted as single lines (as in Figure 4), however in reality they should appear more like "ribbons" since spectral reflectance vary somewhat within a given material type. For example the spectral signature of an oak leaf will differ somewhat from another leaf on the same tree. Characteristics such as amount of total cover, health and vigor of the plant, and changes in atmospheric conditions will cause variations in spectral responses.

In spite of these external effects, there are general spectral patterns that emerge for different types of materials.

The generalized spectral signatures of green grass, dry grass, clear water, and dry soil illustrate how remote sensing can delineate materials based on their reflectance signatures (Figure 4). Remote sensing can be applied to evaluate, assess, and inventory land cover types using spectral reflectance to differentiate materials. In the visible portion of the electromagnetic spectrum, the spectral curve of healthy green vegetation is characterized by low reflectance due to absorption properties of chlorophyll and other leaf pigments (McCoy, 2005). Absorption by chlorophyll in the blue and red spectral regions is more effective than in the green region. This produces a characteristic reflectance peak in the green region. As a consequence, healthy vegetation appears green. Decreases in leaf pigment from vegetation stress or plant senescence increases reflectance across the visible region (Figure 5). If a plant is diseased or stressed, chlorophyll production decreases, resulting in less absorption of blue and red energy. When red energy is not absorbed but reflected, leaves appear yellow—a combination of red and green energy. In the near-infrared region, spectral reflectance of healthy vegetation is characterized by a steep curve near 0.70 μm. Reflectance is highest for healthy vegetation in the range between 0.70 – 1.30 μm as plants typically reflect 40%-50% of the energy incident upon it (Lillesand and Kiefer, 2000)

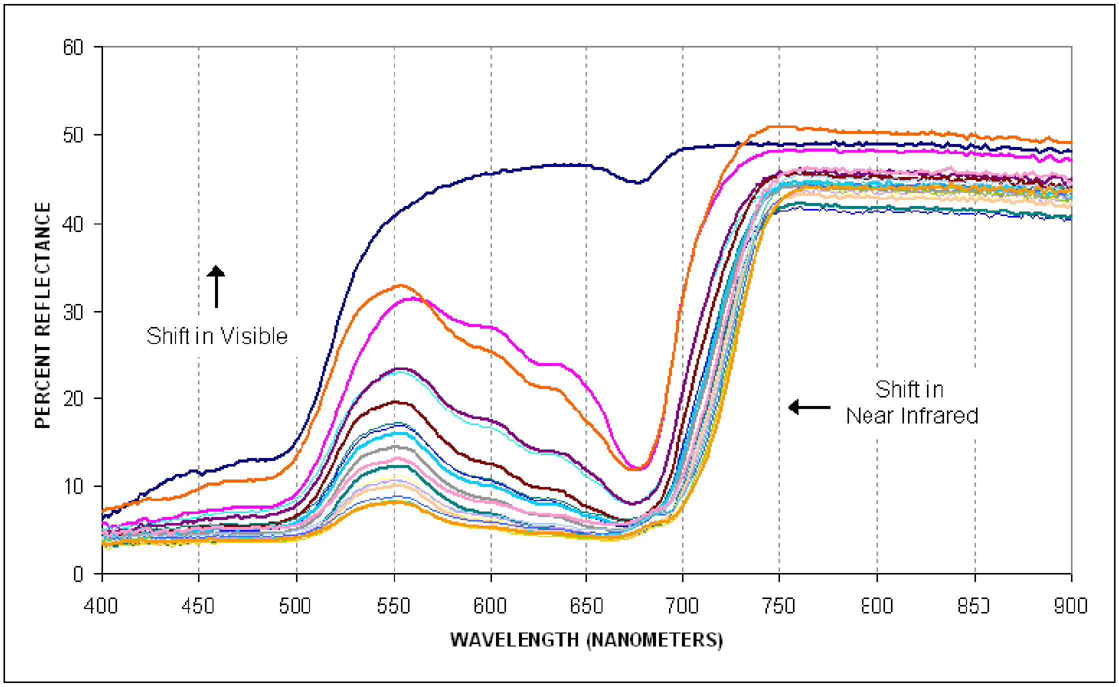


Figure 5. Spectral reflectance of corn over the course of a growing season. (CALMIT, 2003).

These high reflectance values are primarily a result of interactions with the internal cellular structure of plant leaves, but are also a signal of plant health and vigor. Therefore, reflectance in this region is not based on a plant's color but on how well a plant's cell structure reflects solar energy. Reflectance in this region allows discrimination between plant species because of the highly variable internal structure of plant species (Lillesand and Kiefer, 2000).

The near-infrared spectral region forms the basis for algorithms used to extract information about vegetation from remotely sensed data. These algorithms are collectively known as vegetation indices. They are defined as dimensionless, radiometric measures that function as indicators of relative abundance and activity of green vegetation (Jensen, 2000). Most vegetation indices take into account these unique properties found in spectral curves. Variations within spectral curves provide insight into such things as the health, condition, and type of vegetation.

Land Cover Classification

Typically land cover is mapped from remotely sensed data through the use of supervised or unsupervised classification techniques. While both use statistical algorithms in classifying satellite imagery, the steps required are quite different. For a supervised classification there are three general steps: the training stage, the classification stage, and the output stage (Lillesand and Kiefer, 2000). In the training stage the user identifies representative training areas for each land cover type desired. In identifying a training area, a numerical description of the spectral attributes of each land cover type is collected. The success of a classification is directly dependent on collection of truly representative training samples (McGwire *et al*., 1996), as these spectral attributes become a statistical representation of the samples collected. In the classification stage, each pixel (picture element) in the satellite imagery is sorted into the land cover class it most closely represents statistically. The class or value assigned to each pixel in this process results in the creation of the output classified image (the third stage). After the entire multi-band satellite image is characterized, the results are then output into a thematic map of the resulting land cover classes.

Unsupervised classifications do not involve training data as the basis for classification. Generally, this method is used when ground reference information is unavailable or knowledge of the study area is lacking. Unsupervised classification relies on the computer to group pixels with similar spectral characteristics into unique clusters according to some statistically determined criteria (Jensen, 1996). The user must then examine the resulting clusters and determine which classes they belong to. In this case, ancillary data is important in helping to identify which clusters belong to each land cover class.

Remote Sensing of Agriculture

Satellite remote sensing data have been used extensively for agricultural applications. Agricultural applications include using satellite data to estimate crop yield (*e.g*., Doraiswamy *et al*., 2003; Ferencz, *et al*. 2004), for water management (*e.g*., Moran *et al*., 1994; Nielsen, 1990; Wanjura and Upchurch, 2002), for nutrient management (*e.g*., Schepers *et al*., 1996; Bausch and Diker, 2001), for pest management (*e.g*., Hunt *et al*. 2003), and for canopy activity (*e.g*., Danson, 1998).

The timing and progression of vegetation canopy development provides information about the condition of plants relative to the local environment. Schwartz (1994) examined the fundamental feedback between canopy phenology and climate. He suggested that significant seasonal increases in temperature and relative humidity correspond with the timing of ground-observed leafing out of vegetation in the Great Plains Region. In order to capture changes in vegetation development, multi-temporal imagery is needed, as seasonal changes in the characteristics of agricultural crops can occur rapidly.

Classification methodologies capitalize on differences in crop phenology displayed by different species to increase classification accuracy. Because of changes in crop characteristics during the growing season, it is desirable to use imagery acquired on several dates throughout the growing cycle for crop identification. For agricultural land cover classifications, single date data sets rarely provide accurate classifications (Lo *et al*., 1986). In general, the best time for image acquisition is when a crop is at full canopy cover so that the soil background has less influence on spectral reflectance (Tao and Nellis, 1999). Yet, at one particular date one crop may have full canopy cover while another crop may have been harvested.

Creating a temporal-spectral profile of crops produces a phenological pattern of crop development. Once a phenological pattern is established, crop delineation and labeling can be accomplished. Odenweller *et al*. (1984) was able to identify crop types based on their distinctive profile and amplitude through three stages of development. The first stage identifies crops based on their general trajectory below vegetative greenness. In the second stage, crops are identified by the timing of initial vegetative greenness. The third and final stage allows for delineation based on a crop’s distinctive profile and amplitude. For example, during stage one, alfalfa can be delineated from fallow because its greenness is greater during July and September. In another example, during stage three, corn is distinguished from soybeans based on corn’s faster ascent to greenness and sudden decline, while soybeans tends to have a more gradual increase and decrease in greenness (Odenweller *et al*., 1984).

A multi-seasonal approach to classifying corn, soybean, sugar beets, and small grains was conducted in the "Regione del Veneto" of northeastern Italy (Ehrlich *et al*., 1994). The authors evaluated Landsat TM, Landsat MSS, and SPOT HRV imagery for use in the study. Ultimately, four Landsat TM scenes were chosen over SPOT and Landsat MSS images because TM scenes offered the best trade-off in spatial resolution and price. A sequential masking procedure (SMP) was used to delineate vegetation—a procedure in which image processing and GIS techniques are combined to identify the most distinguishable land cover types first. Once the more obvious land cover types are identified, sequential rounds of image processing are employed to classify remaining fields. The classification produced accuracies of 90% for corn, 96% for soybeans, 76% for sugar beets, and 99% for small grains (Ehrlich *et al*., 1994).

Ortiz *et al*. (1997) classified croplands by integrating GIS and remote sensing techniques. Using a land cover database with ancillary ground data in a GIS framework they were able to improve classification accuracy. Information such as field type and location were used to determine which areas were to be most useful as training sites in the digital classification. For their multi-date image classification, using the integrated GIS framework, overall accuracy increased 20 percent over conventional digital classification techniques.

In a study conducted by Oetter *et al*. (2000) in the Williamette River Basin of western Oregon, a land cover map of 20 land classes was produced using multiseasonal Landsat TM scenes. The mapped area was mainly agricultural, but included forested areas, natural cover types and urban buildings. The study relied on Landsat TM imagery to predict land cover and employed Farm Service Agency compliance photographs to train imagery pixels. This study produced an accuracy of 74% and serves as a model for other land cover studies in the basin (Oetter *et al*., 2000).

Goetz *et al*. (2004) applied multi-temporal Landsat data to map and monitor land cover changes in the Chesapeake Bay watershed. They used a combination of field data, Landsat-7 ETM+ imagery, high resolution IKONOS imagery, digital orthophotos (DOQ), and supporting geographic information system (GIS) maps to classify the imagery into 16 land cover classes. From this data, an agricultural crop type map was generated for the state of Maryland using unsupervised classification and iterative cluster labeling based on the detailed field level data. This resulted in accuracies in the range of 90-95%.

Maxwell and Hoffer (1996) evaluated dates of imagery for accuracy in mapping agricultural crops for their study area near Ft. Collins, Colorado. Eleven different crops or cover types were evaluated in different combinations of one, two and three date classifications using imagery from May, July, and September. The crops were divided into two groups according to their dates of maturity (spring to mid-summer or later summer). May was found to be the best single date for spring to mid-summer maturing crops and September was best for later summer maturing crops. For the spring to mid-summer maturing crops the combination of using both May and September dates increased the classification accuracy for alfalfa and spring grains.

Using the three dates of May, July, and September produced the highest accuracies for winter wheat, grass/hay/pasture, and range. For the late-summer maturing crops, the two-date combination of July and September produced the highest accuracies for sugar beets, dry beans, and onions. Corn was classified with the highest accuracy when using all three dates of imagery.

Knowledge of the crop growth cycle is very important in selecting the dates of imagery used in a classification. The crop calendar in Nebraska extends from March to November. This project capitalized on the seasonal dynamics of the crops in the study area by using multi-date imagery acquired from April through October of 2005 for the land cover classification (see Table 2).

There are a number of problems associated with classifying agricultural areas using satellite imagery (Tao and Nellis, 1999). First, the phase lag in planting dates between fields having the same crop can cause a large variation in spectral response. Spectral response is also affected by changes in soil moisture levels at different landscape locations, slopes, and elevations. Lastly, differences in row spacing and direction can have a serious impact on spectral response of the crop due to the affects on sun-sensor-scene geometry.

Table 2. Major Crop Planting and Harvesting Dates

(Adapted from 2002 Nebraska Agricultural Statistics Service, 2002)

Crop	Usual Planting Dates			Usual Harvesting Dates		
	Begin	Most Active	End	Begin	Most Active	End
Barley Spring	Mar 20	Mar 25 - Apr 10	Apr 18	Jul 18	Jul 20 - Jul 25	Jul 30
Beans Dry	May 26	Jun 9 - Jun 16	Jun 23	Sep 8	Sep 15 - Sep 29	Oct 13
Corn for Grain	Apr 21	May 3 - May 19	Jun 1	Sep 21	Oct 11 - Nov 6	Dec 1
Corn for Silage	Apr 21	May 3 - May 19	Jun 1	Aug 25	Sep 5 - Sep 25	Oct 10
Alfalfa Hay				May 03		Oct 03
Hay Other				Jun 03		Sep 03
Oats Spring	Mar 24	Apr 2 - Apr 27	May 9	Jul 4	Jul 15 - Aug 2	Aug 12
Rye	Aug 30	Sep 12 - Sep 26	Oct 6	Jun 30	Jul 12 - Jul 30	Aug 8
Sorghum-Grain	May 11	May 20 - Jun 8	Jun 19	Sep 19	Oct 8 - Oct 30	Nov 17
Sorghum-Silage	May 11	May 20 - Jun 8	Jun 19	Aug 25	Sep 10 - Sep 30	Oct 10
Soybeans	May 9	May 18 - Jun 4	Jun 17	Sep 19	Sep 30 - Oct 15	Oct 27
Sugar beets	Apr 1	Apr 10 - Apr 30	May 5	Oct 5	Oct 10 - Oct 30	Nov 5
Wheat Winter	Aug 30	Sep 12 - Sep 26	Oct 6	Jun 26	Jul 7 - Jul 26	Aug 8

Landsat 7 ETM+ Scan Line Corrector Failure

On May 31, 2003, image data from the ETM+ sensor onboard the Landsat 7 satellite began exhibiting "striping" artifacts (Figure 6) It was determined that the problem was a result of the failure of the Scan Line Corrector (SLC). The SLC compensates for the forward motion of the satellite.

Because Landsat 7 was still able to acquire imagery, the USGS developed new image products to fix the striping problem by combining two separate dates or by interpolation to fill in the data gaps. However, for the purpose of the COHYST study, Landsat 5 image data were used in order to avoid the issue of the SLC on Landsat 7.

Figure 6. Examples of SLC-Off and SLC corrected Landsat 7 ETM+ scenes using bands 3, 2, 1. SLC-Off scene is path 36 row 37, acquired 6/24/2003. SLC corrected scene is the same image, filled with matched data acquired 7/7/2002. (Scaramuzza *et al*., 2004)

Craig (2002) compared Landsat 5 data with that of Landsat 7 for use to discriminate crop types. Four states and eight crop were selected for the analysis: Arkansas (rice, cotton, soybeans), Iowa (corn and soybeans), Mississippi (cotton and soybeans), and North Dakota (barley, canola, sunflower, wheat, small grains). For the purpose of generating crop acreage estimates, the r-squared statistic showed that the differences between the ETM+ onboard Landsat 7 and Landsat 5 TM to be small but significantly different. However, he found the two sensors not to be significantly different for 'map and visual image creation', such as the NASS Cropland Data Layer.

METHODS

Satellite Data Acquisition and Image Processing

To cover the entire study area, seventeen Landsat 5 Thematic Mapper (TM) scenes were needed (see Figure 7). To compensate for the differences in crop types and phenology, three dates were acquired for the majority of scenes to represent spring, summer, and fall conditions.

Figure 7. Landsat 5 TM Coverage of the Nebraska by Path/Row.

A total of 37 Landsat 5 TM satellite images were purchased from the U.S. Geological Survey EROS Data Center in a geocoded and terrain-corrected format. The selection of imagery was limited due to difficulties in finding relatively cloud-free dates.

Table 3. Landsat 5 TM Data used in Classification

Path Row	Date of Acquisition	Scene ID
27/32	8/9/2005	5027032000522110
28/31	6/13/2005	5028031000516410
28/31	9/1/2005	5028031000524410
28/32	6/13/2005	5028032000516410
28/32	9/1/2005	5028032000524410
29/30	6/20/2005	5029030000517110
29/30	8/7/2005	5029030000521910
29/31	6/20/2005	5029031000517110
29/31	7/22/2005	5029031000520310
29/31	9/8/2005	5029031000525110
29/32	6/20/2005	5029032000517110
29/32	7/22/2005	5029032000520310
29/32	9/8/2005	5029032000525110
30/30	6/27/2005	5030030000517810
30/30	8/30/2005	5030030000524210
30/31	6/27/2005	5030031000517810
30/31	8/30/2005	5030031000524210
30/31	9/15/2005	5030031000525810
30/32	6/27/2005	5030032000517810
30/32	8/30/2005	5030032000524210
30/32	9/15/2005	5030032000525810
31/30	7/20/2005	5031030000520110
31/30	8/5/2005	5031030000521710
31/31	8/5/2005	5031031000521710
31/31	9/6/2005	5031031000524910
31/32	7/20/2005	5031032000520110
31/32	8/5/2005	5031032000521710
32/30	8/28/2005	5032030000524010
32/32	7/11/2005	5032032000519210
32/32	8/28/2005	5032032000524010
32/31	7/11/2005	5032031000519210
32/31	8/28/2005	5032031000524010
33/30	7/2/2005	5033030000518310
33/30	9/20/05	5033030000526310
33/31	7/2/2005	5033031000518310
33/31	8/19/2005	5033031000523110
33/31	9/20/2005	5033031000526310
33/32	7/2/2005	5033032000518310

Spectral band 6, the thermal infrared band, was removed from all dates of imagery. The thermal band was not included as it measures the amount of infrared radiant flux emitted from surfaces (Jensen, 1996). While other bands provide a measure of reflected energy, band 6 measures transmitted energy. The remaining bands, 1-5 and 7 were subset from each individual Landsat 5 scene and were layer stacked to create an 18-band image for each Path/Row for each of the three dates of imagery.

Image preprocessing was done individually for each Path/Row and included masking out urban and clouded areas. Clouded areas were on-screen digitized and removed from all bands containing cloud contamination.

Table 4. Characteristics of Landsat 5 TM

Spectral Band	**Spectral Range (μm)**	**Nominal Spectral Location**	**Ground Resolution (m)**
1	0.45- 0.52	Visible Blue	30
2	0.52 – 0.60	Visible Green	30
3	0.63 – 0.69	Visible Red	30
4	0.76 – 0.90	Near infrared	30
5	1.55 – 1.75	Mid-infrared	30
6	10.40 – 12.50	Thermal infrared	120
7	2.09 – 2.35	Mid-infrared	30

Urban areas were identified using 2005 Farm Service Agency (FSA) Ortho-Imagery collected during the 2005 growing season. FSA Ortho-Imagery was obtained from the USDA geospatial gateway website, (http://datagateway.nrcs.usda.gov/GatewayHome.html), for all counties within the study area. TIGER (Topologically Integrated Geographic Encoding and Referencing system) line data from the U.S. Census Bureau was also used to identify urban areas. TIGER is a digital database of geographic features, such as roads, railroads, rivers, lakes, political boundaries, and census statistical boundaries developed at the Census Bureau to support its mapping needs for the Census and other Bureau programs. Data were downloaded from the U.S. Census Bureau's web site, (http://www.census.gov/geo/www/tiger/) by county and re-projected into a common map projection of State Plane, fipszone 2600, and NAD 83. All urban areas were on-screen digitized and then masked from the imagery before running the classification.

Collecting Training Areas for Image Classification

The primary objective of image classification is to automatically categorize all pixels in an image into land cover classes. It is the spectral pattern present within the data for each pixel that is used as the numerical basis for the classification (Lillesand and Kiefer, 2000). For a supervised classification, the user identifies pixels that represent various land cover types present in the scene. Sites of known cover types, also called training areas, are used to develop a numerical description of the spectral attributes of each land cover type. By identifying these areas in the satellite imagery you can train the computer system to identify pixels with similar spectral characteristics. In this project, spectral signatures were collected using three dates of imagery combined into one 18-band image for each scene.

Field Data from Nebraska Natural Resource Disctricts

Since USDA Farm Service Agency (FSA) reporting records were not available for the 2005 study, the main source of crop information used to determine training areas for agricultural classes were provided by Nebraska Natural Resource Districts (NRDs). The NRDs that helped provide field data included: Central Platte NRD, Lewis and Clark NRD, Little Blue NRD, Lower Big Blue NRD, Lower Elkhorn NRD, Lower Loup NRD, Lower Niobrara NRD, Lower Platte North NRD, Lower Platte South NRD, Lower Republican NRD, Lower Republican NRD, Middle Republican NRD, Nemaha NRD, North Platte NRD, Papio-Missouri River NRD, South Platte NRD, Tri-Basin NRD, Twin-Platte NRD, Upper Big Blue NRD, Upper Elkhorn NRD, Upper Loup NRD, Upper Niobrara White NRD, and Upper Republican NRD.

During the summer of 2005, NRDs across the state were asked to collect GPS points of crop locations while they were doing field work such as chemigation inspections. GPS points were taken at a minimum of 30 feet inside field boundaries.

Once the GPS point was collected, information was recorded identifying the crop type and if the crop is irrigated or non-irrigated. Other notes, such as the date the GPS point was collected, were included to help identify crops that may be in rotation and crops with multiple harvests such as alfalfa. NRDs were requested to collect at least 50 points per county. While this was not a scientifically random way to collect field points, it was the best method available due to limited resources and time constraints.

NRDs were able to provide a representative sample of the all the crops grown within each NRD including; Corn, Soybeans, Alfalfa, Sorghum (Milo, Sudan), Small Grains, Summer Fallow, Sunflowers, Potatoes, Sugar Beets, and Dry Edible Beans**.**

Once the GPS points were received from the NRDs, they were imported into ArcGIS 9.1 and reprojected into the State Plane projection system. Approximately 5,600 GPS field points and polygons were obtained statewide. Half of the points and/or polygons were randomly set aside and reserved for the accuracy assessment. The other half were used to locate training areas for the following land use classes: Corn, Sugar Beets, Soybeans, Sorghum, Dry Edible Beans, Potatoes, Alfalfa, Small Grains, Range/Pasture, Open Water, Sunflower, and Summer Fallow. For each crop type, special attention was given to collecting signatures from homogenous areas. Spectral signatures were taken in the center of fields and not close to field boundaries where spectrally mixed pixels decrease accuracy. These boundary pixels are not reflective of a particular cover type, but are rather a mixture of adjacent cover types (Grunblatt, 1987). Field boundaries were verified using the 2003 and 2005 FSA Ortho Imagery.

USDA FSA Ortho Imagery: 2003 and 2005

Another important source of current land cover was digital ortho images collected during the 2003 and 2005 growing season. These ortho images are part of the USDA National Agricultural Imagery Program (NAIP) and are made available through the USDA_FSA_APFO Aerial Photography Field Office. Digital ortho images are a digital image of an aerial photograph with image distortion removed, corrected for aircraft pitch, yaw and altitude, landscape relief, and camera lens (optic correction) orientation.

All ortho images collected for the project were obtained from the USDA Geospatial Gateway web site: http://datagateway.nrcs.usda.gov/. These images were downloaded as MrSID files in a UTM projection system. The original files were uncompressed and reprojected to the State Plane projection system.

Since the ortho images were rectified with a high degree of positional accuracy they could be overlaid on the satellite imagery to determine exact field locations for the training areas.

National Wetlands Inventory

The National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service provides information on the characteristics, extent, and status of wetlands and deepwater habitats in the United States. NWI digital data files are records of wetland location and classification as defined by the U.S. Fish & Wildlife Service. This dataset was originally available in 7.5 minute by 7.5 minute blocks containing ground planimetric coordinates of wetland features and attributes.

Available NWI files used in this project were downloaded from the Conservation and Survey Division at the University of Nebraska (http://csd.unl.edu/csd/gisdata.html), joined together to form one coverage, and then reprojected to the State Plane projection system. Wetland polygons were then selected if they fell into any combination of the following wetland types and water regimes noted in Table 6.

Table 5. NWI Wetland types used to identify potential training areas

Wetland Type	Wetland Code	Water Regime
Emergent	**PEM**	**Permanently Flooded**
Pond with floating or submerged aquatic vegetation	**PAB**	**Intermittently Exposed**
Pond with open water	**PUB**	**Semi-permanently flooded**

Wetlands smaller than 3x3 pixels or 90 meters square were deleted. This was done to assure training areas represented homogenous wetland areas and to avoid any problems associated in the NWI. The spatial extent of wetlands may have changed since the NWI was created using 1972-1986 aerial photography. It should be stressed that in most cases, the NWI data were used as a guide, and signatures were only collected for wetlands that were visible in 2005 satellite imagery. In some cases an unsupervised classification using only the spring date of Landsat imagery proved most effective in identifying wetland areas.

<u>Spectral Signatures by Scene and Land Cover Type</u>

As mentioned previously, spectral signatures were collected using three dates of imagery (Landsat 5 TM bands 1-5 and 7) combined into one 18-band image per scene. Spectral signatures were collected for the following land cover classes; corn, sugar beets, soybeans, sorghum, dry edible beans, potatoes, alfalfa, small grains, range/pasture, open water, riparian forest/woodlands, wetlands, other agricultural lands, sunflower, summer fallow and roads. An example of spectral signatures collected for corn, soybeans, and sorghum is found in Figure 8.

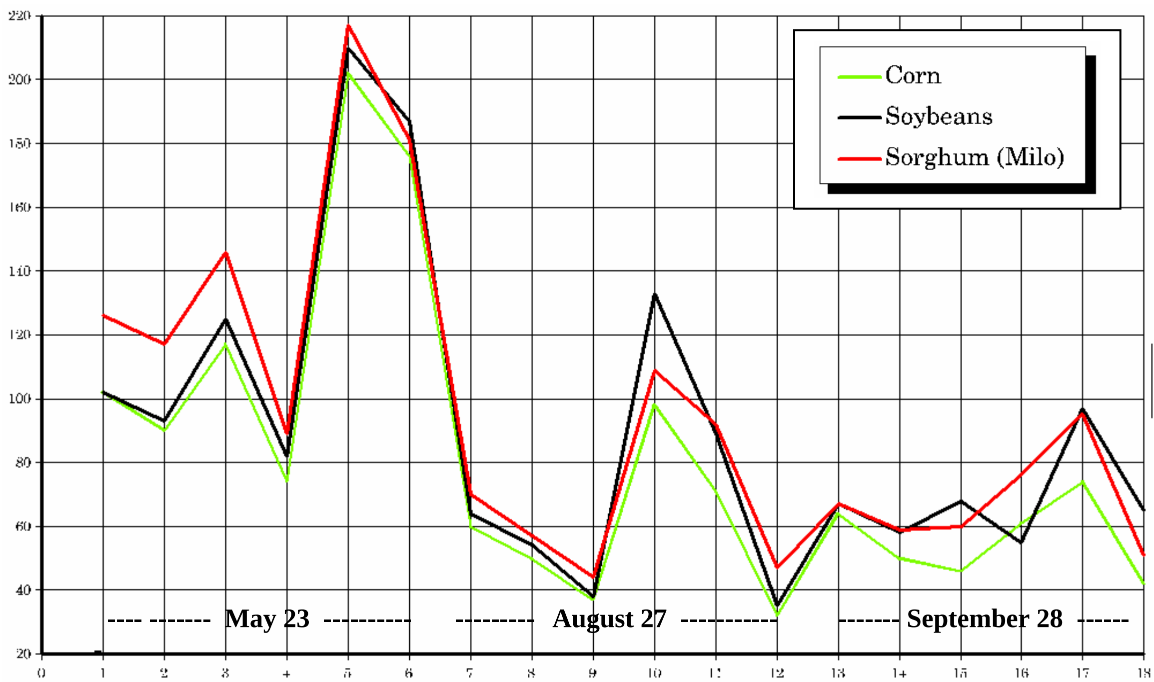


Figure 8 Spectral Reflectance Curves for Corn, Soybeans, and Sorghum.

The x-axis represents the 18-band image (or three dates of imagery: May 23, August 27, and September 28). The y-axis represents spectral reflectance values.

The spectral reflectance curves in Figure 8 are characteristic of healthy vegetation. Chlorophyll strongly absorbs energy in the wavelength bands centered between approximately 0.45 and 0.67 µm. The internal structure of plant leaves, specifically the mesophyll cells, reflects highly in the region between 0.70 – 1.30 µm (near to mid-infrared) (Lillesand & Kiefer, 2000). The high reflectance values in the near to mid-infrared correspond with bands 4 & 5 (spring), 10 & 11 (summer), and 16 & 17(fall) found in Figure 8.

The seasonal dynamics of corn, soybeans and sorghum are evident in these spectral reflectance curves. Supervised classifications incorporate these differences in crop phenologies to increase classification accuracy. Crops are identified based on their distinctive profile throughout the stages of crop development. For example, corn is distinguished from soybeans based on corn's faster ascent to greenness and sudden decline, while soybeans tends to have a more gradual increase and decrease in greenness (Odenweller *et al*., 1984). These seasonal dynamics for 2005 are verified in Figure 9.

After collecting spectral signatures for each land cover class, the signature files were examined for consistency. Signatures that diverged greatly from others of the same land cover class were deleted to prevent misclassification.

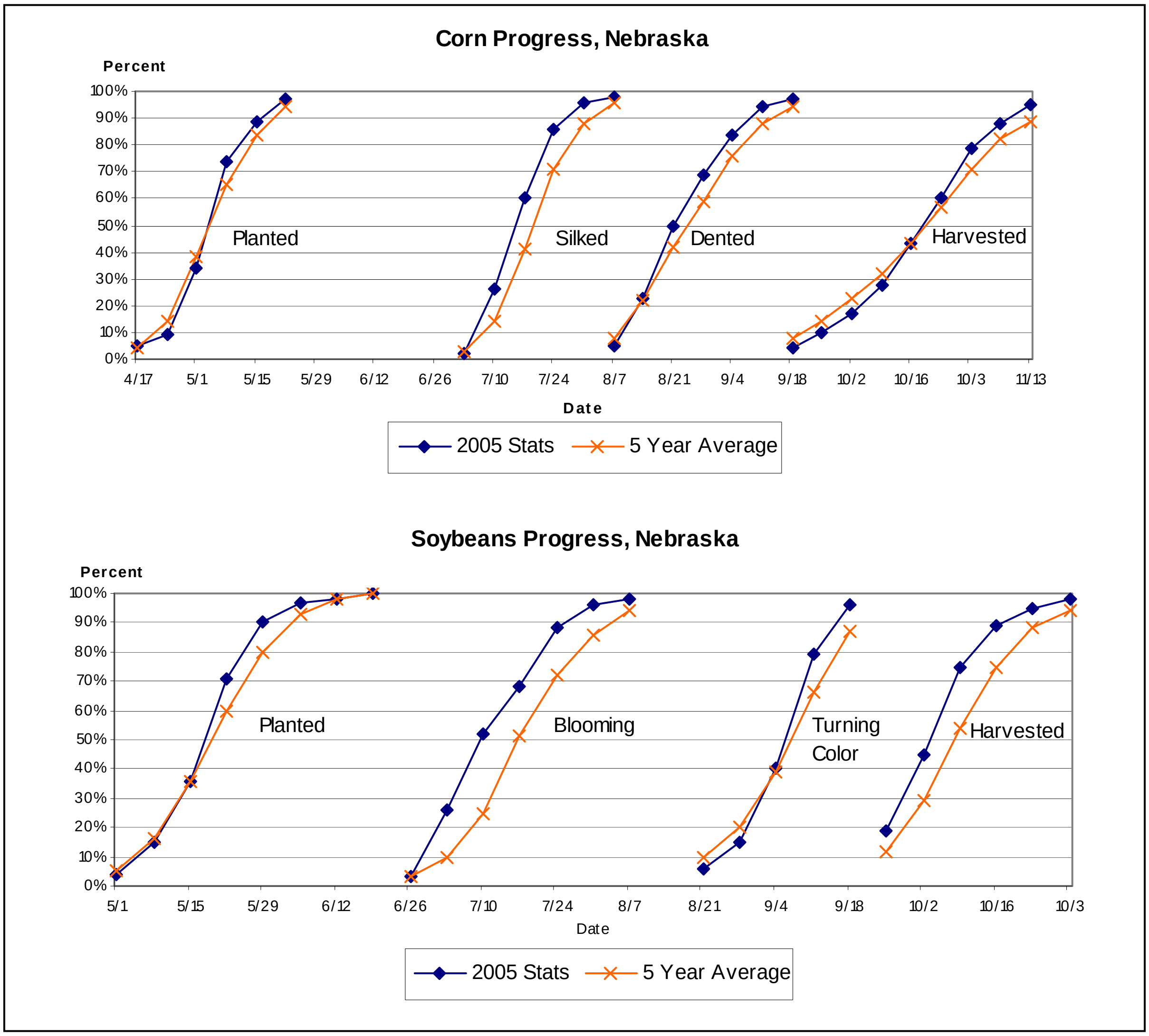


Figure 9. 2005 Crop progress for Corn and Soybeans

(Adapted from Nebraska Agricultural Statistics Service, 2005)

Image Classification

Supervised Classification

The basic steps used in a typical supervised classification can be summarized in three basic stages: the training stage, the classification stage, and the output stage. After all of the training sites (spectral signatures) were collected and evaluated, they were used to drive the supervised classification. The classification process uses different decision rules. These rules are mathematical algorithms that by using data contained in the signature, sort the pixels into separate classes. Decision rules are either parametric or nonparametric. Parametric rules are based on statistics while non-parametric rules are not. A parametric decision rule is based on statistical parameters (*e.g.*, mean and covariance matrix) of the pixels that are in the training sample or cluster. When the parametric decision rule is used, every pixel is assigned to a class

A supervised classification based on the maximum likelihood decision rule was chosen for the classification of the 2005 imagery. This decision rule is based on the probability that a pixel belongs to a particular class.

The maximum likelihood decision rule assumes that the probabilities of class membership are equal for all classes and also takes into account the variance of each of the signatures (ERDAS, 1999). This variance is important when comparing a pixel to a signature. For example, a range, pasture, or grass community may be very heterogeneous while a large body of water might be relatively homogeneous. The maximum likelihood decision rule also contains a Bayesian classifier that uses probabilities to weigh the classification towards a particular class. The maximum likelihood equation for each of the classes is given as:

$$D = -[0.51n(cov_c)] – [0.5(X-M_c)^T * (X-M_c)]$$

Where D is the weighted distance, 1n is a natural logarithm function, cov_c is the covariance matrix for a particular class, X is the measurement vector of the pixel, M_c is the mean vector of the class, and ^{T} is the matrix transpose function (ERDAS, 1999).

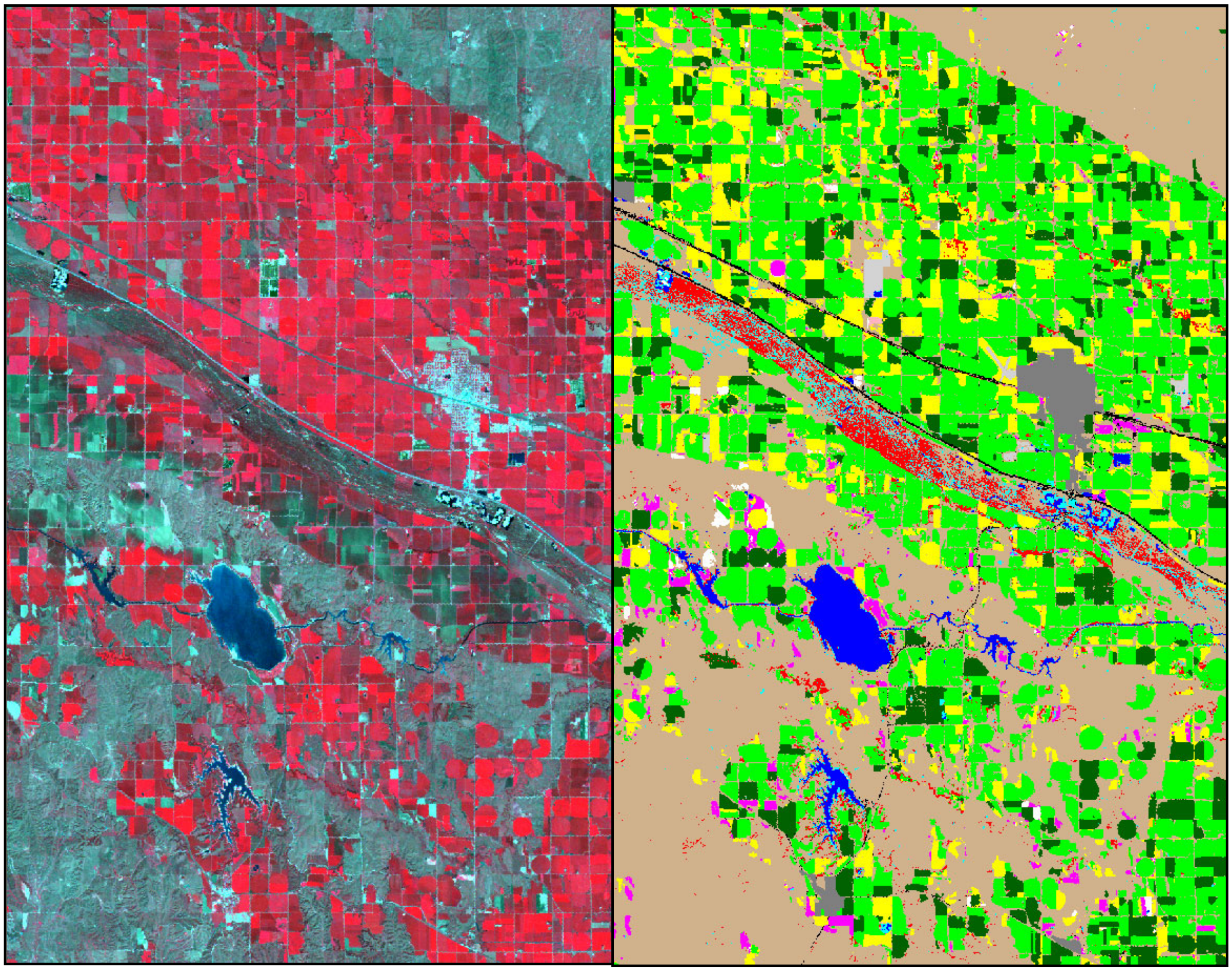
It should be emphasized that supervised classification methods are an iterative process. A supervised classification involves collecting training samples, preliminary classification, and comparison with the field data. This training, classification, and comparison are then performed several times until the classification achieves the desired accuracy for the initial classification.

In this project, after the initial classification, areas of mixed pixels were further identified, through visual inspection of the classification, digital ortho imagery, as well as by comparing the NRD field data. Mixed pixels were reclassified using a technique of splitting or merging clusters referred to as "cluster busting" (Jensen *et al.*, 1987). In this process, mixed pixels were identified and masked from the raw Landsat TM data. The raw data was then re-classified using an unsupervised classification approach. The resulting output clusters were re-assigned to the output land cover classes they most closely resembled. This method was useful in clearing up much of the confusion in the classification, although there were areas where mixed pixels could not be completely resolved due to the spectral similarities of certain crop types. An example of a resulting supervised classification is found in Figure 10.

The output of our initial classification resulted in 17 classes: Corn, Sugar Beets, Soybeans, Sorghum (Milo, Sudan), Dry Edible Beans, Potatoes, Alfalfa, Small Grains, Range/Pasture/Grass, Open Water, Riparian Forest and Woodlands, Wetlands, Other Agricultural Land, Sunflower, Summer Fallow, Barren, and Roads. Irrigated and non-irrigated crops were not distinguished in the supervised classification process. Irrigation information was collected at the field level and added to the classification at a later stage.

<u>Unsupervised Classification</u>

An unsupervised classification was performed on scenes with only one date of imagery and for areas under cloud cover. Within the multi-date imagery there were often areas of cloud and cloud shadows. These areas were subset from the imagery and not classified during the supervised classification stage. Later, using the remaining cloud-free date(s), these areas were classified using unsupervised methods. Unsupervised classifications do not use training sites as the basis for classification. Instead, the image is classified using mathematical algorithms that search for natural groupings of the spectral properties of pixels (Jensen, 1996).



Imagery 8-30-2005
(TM Bands 4,3,2)

Classified Image

Figure 10. Example of Supervised Classification

Once these data were classified, resulting clusters were identified based on the surrounding areas of overlap with the supervised classification. Clusters were also identified using ancillary data such as digital ortho imagery and field data obtained from the NRDs.

Post Classification Smoothing

Due to inherent spectral variability within satellite imagery, resulting classified scenes often have a salt-and-pepper appearance. A field of corn, for example, may have multiple soybean pixels scattered amongst the corn pixels. In these situations, a smoothing technique is often employed to show only the dominant classes within fields. One such technique is to apply a majority filter on the classified image. In this operation, a moving window is passed over the classified data and the majority class within the window is determined. If the center pixel in the window is not the majority class, it is changed to the majority class value (Lillesand and Kiefer, 2000). For this study, a majority filter using a window size of 3x3 pixels, was applied to agricultural classes. The filter was not applied to all land cover classes, so that smaller classes such as roads, wetlands and riparian/woodland areas would be retained.

Identifying 2005 Irrigated Areas

2005 Center Pivot Inventory

Due to their unmistakable pattern across the study area, center pivots were visually identified using the 2005 Landsat satellite imagery and the 2005 FSA ortho imagery (see Figure 11). Center pivot irrigation areas were on-screen digitized while the multi-date Landsat 5 TM satellite imagery and 2005 ortho imagery were displayed. Only active center pivots were digitized. If no crops were present the pivot was not included in the inventory. Accuracy was checked using 2005 NRD field data and registered irrigation well data obtained from the Nebraska Department of Natural Resources.

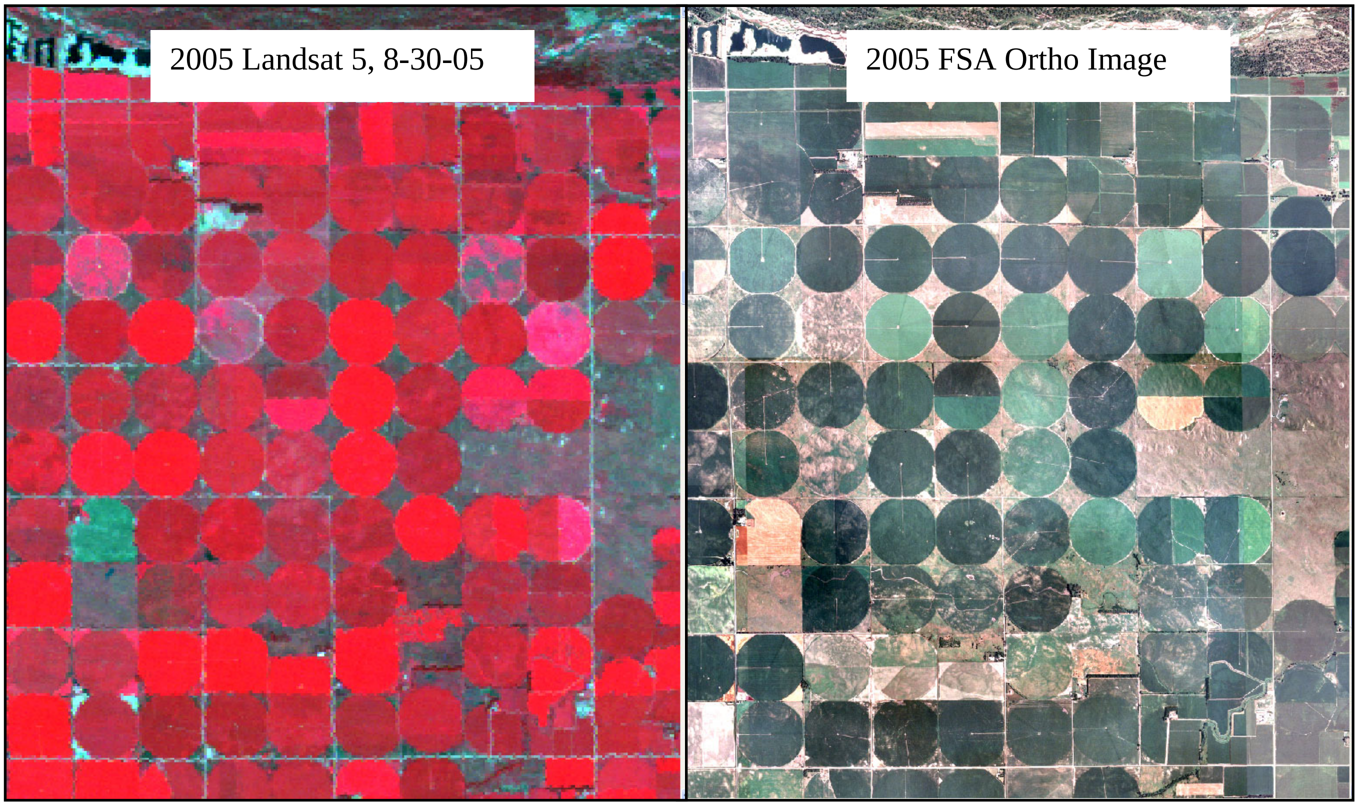


Figure 11. Center Pivots in Phelps County

Updating the 2001 COHYST Irrigation Layer

Other irrigated areas across the study area were not as easily identifiable as center pivots. To locate these areas, multiple field and ancillary sources were incorporated to provide an accurate inventory. One main task was to update the detailed irrigation base layer developed in 2001 and 1997 as part of the COHYST land cover mapping project. More information about these projects and their final reports can be found at the following web site: http://www.calmit.unl.edu/cohyst/.

The 2005 field data from the NRDs were used to add or remove irrigated areas from the 2001 base layer. Over 2,800 GPS field points were used to update the irrigation base layer. Newly registered irrigation wells, provided by the Nebraska Department of Natural Resources, installed between 2001 and 2005 were incorporated into this study to help identify new irrigated areas and validate NRD field data.

For other areas the 2005 FSA ortho images were used to visually inspect areas near irrigation canals or close to surface water sources that provide evidence of irrigation. Figure 12 provides an example of how the 2005 ortho images were useful identifying areas that were canal or surface irrigated. As the 2005 ortho images were collected during the 2005 growing season, irrigation was actively taken place. In some fields the striping pattern of flood irrigation was clearly visible as noted in Figure 12.

Figure 12. Canal Irrigated Field in Nance County, 2005 FSA Ortho Image

Previous development of 1997and 2001COHYST Irrigation Layers

The process of creating the 1997 irrigation base layer incorporated digital and paper maps of irrigated acres obtained from many sources. A majority of the maps were obtained from the Nebraska Department of Natural Resources. These paper maps identified surface water irrigation rights and included; Castle Rock, Steamboat, Chimney

Rock, Empire, Midland-Overland, Graf Canal, Keith-Lincoln, North Platte Canal (Platte Valley I.D.), Paxton-Hershey, Birdwood, Suburban, Cody-Dillon, Western Canal, Thirty Mile Canal, Six Mile Canal, Cozad Canal, and Orchard-Alfalfa Canal. Each map was individually digitized using ArcInfo and then merged into one map.

Additional irrigation data were obtained from the Pathfinder Irrigation District and the Central Nebraska Public Power and Irrigation District. These original section-sized AutoCAD files were imported into ArcInfo, edited, attributed, and appended to create one large area map.

Maps of individual NRDs were created from this large map and sent out to each NRD within the study area to be checked for accuracy. Maps were checked using existing knowledge of 1997 irrigated areas and 1997 Farm Service Agency reporting records. When these maps were returned, the original vector files were edited and all files were merged into one final vector irrigation map.

For the 2001 COHYST land use mapping project, the 1997 irrigation base layer was updated. This was done with a 2001 center pivot inventory. Other non-pivot irrigated areas were identified using a variety of sources. 2001 FSA certified reporting records were used to add or remove irrigated areas from the 1997 base layer. The final irrigation layer incorporated field data from over 5,000 sections across the study area. Newly registered irrigation wells, provided by the Nebraska Department of Natural Resources, installed between 1997-2001, were also incorporated into this study. The new irrigation wells point coverage was used to help identify irrigated areas and validate 2001 FSA data.

Obtaining Irrigated Acres from County Assessor's Offices

One new trend for county government agencies is to develop countywide digital land use maps. These maps aid in taxation as fields are digitized and acreages can be easily calculated. Fields are identified as irrigated or non-irrigated as this distinction represents different tax rates. Since irrigated and non-irrigated land has a different tax rate, it is important that the assessor's office have an accurate irrigation map. These maps have not been completed for all the counties within the study area but were obtained for the following counties; Franklin, Hamilton, Kearney, and Phelps. These datasets were an important addition to the irrigation layer. Certified irrigated acres were also obtained from Central Platte NRD and provided irrigation data for Merrick, Polk, Hall, Buffalo, Dawson, and Custer counties.

Surface Irrigation Rights Maps from NDNR

Surface irrigation rights maps were also obtained from NDNR in a digital shapefile format for areas outside of the COHYST study area. These digital files were converted from paper maps and were the most current irrigation data available. NDNR provided irrigation rights data for the following basins: Big Blue, Nemaha, Missouri Tributaries, and Lodge Pole. The irrigation rights data were compared to the Landsat satellite imagery and 2005 FSA Ortho Images to verify active crops. Only areas that were in cultivation and had associated irrigation rights were included in the final irrigation layer.

Using NDVI to Identify Irrigated Areas

As a final step to help identify other irrigated areas that may have been missed, the Normalized Difference Vegetation Index (NDVI) was calculated on all the Landsat 5 satellite imagery. NDVI derived from satellite imagery provides an estimate of the health and vigor of agricultural crops. A similar method was employed for the study: “Using Satellite Imagery to Estimate Irrigated Land: A Case Study in Scotts Bluff and Kearney Counties, Summer 2002”. More information about the project is found at the following web site: http://www.calmit.unl.edu/cohyst/2002_irr_study.shtml. The objective of this study was to test the accuracy of using satellite remote sensing techniques, mainly NDVI, to estimate irrigated lands in Scotts Bluff and Kearney Counties during the summer of 2002.

NDVI uses band ratioing of the visible red and near infrared bands of the electromagnetic spectrum. Band ratioing, also known as spectral ratioing, is an enhancement resulting from the division of digital number values in one spectral band by the corresponding values in another band (Lillesand and Keifer, 2000).

NDVI is calculated as:

$$\text{NDVI} = \frac{\textbf{Near Infrared Radiance} - \textbf{Visible Red Radiance}}{\textbf{Near Infrared Radiance} + \textbf{Visible Red Radiance}}$$

The nature of NDVI is such that the greater the amount of photosynthesizing vegetation present, the larger the digital number value for each pixel. The less sunlight a plant absorbs, the less it is photosynthesizing and the lower its productivity. If plants do not have enough water, the cells of the leaves get smaller and the cell structure changes, causing less reflection in the near infrared. Unhealthy or stressed vegetation produces less chlorophyll resulting in less absorption of visible red light (Lillesand and Keifer, 2000). To avoid using negative values in this study, the NDVI values were rescaled to values between 0-255. For the current project it was proposed that crops with high NDVI values for two or more dates of satellite imagery during the 2005 growing season had a high potential to be irrigated.

One way to classify an image is to categorize each pixel using a threshold value. The reason for selecting a threshold value is to create a binary file containing values of 1 to represent irrigated lands and values of 0 to represent non-irrigated lands. The higher the NDVI value, the more likely that pixel will represent irrigated lands. Lower NDVI values are more characteristic of non-irrigated lands. An ideal threshold value will separate non-irrigated agricultural pixels from irrigated agricultural pixels.

To determine the best threshold, many samples of NDVI values were collected from fields of known land cover. The GPS field point locations were overlaid on the NDVI image to identify irrigated and non-irrigated fields. NDVI samples were acquired by digitizing polygons within fields of known land cover. Using ERDAS Imagine software, these areas were termed ‘areas of interest’. Within each area of interest, a unique signature for each field was obtained. Minimum, maximum, and mean NDVI values were calculated for each sample. These statistics were collected from the NDVI image and used to determine how to group the pixels into their respective classes. The minimum and maximum NDVI values for each sample were plotted on a graph to determine where along the scale the various samples would group for each class. This procedure was done separately for each date of imagery.

<u>Selection of Significant NDVI Threshold Values</u>

NDVI threshold values will be different for different image dates because each pixel's value changes temporally due to variations in soil condition, soil moisture, vegetation health, leaf area, and atmospheric effects (Qi *et al*., 2002). To find the NDVI threshold it is necessary to find the best value that selects the most irrigated field pixels while not selecting pixels from non-irrigated fields.

After plotting the minimum and maximum NDVI values for each sample on a graph, certain trends were apparent. Samples from irrigated fields had much higher minimum and maximum NDVI values than those from non-irrigated fields. Yet, in all cases, several samples of non-irrigated fields had their maximum NDVI values within the range of minimum NDVI values of irrigated fields. This area of overlap was used to narrow the search for the significant threshold value.

In reality, it was not possible to find a single value that achieved 100% accuracy in distinguishing between the two classes. In some cases irrigated areas were classified as non-irrigated pixels and non-irrigated pixels were classified as irrigated. The goal was then to find the best balance that minimizes the amount of classification error.

To provide an example of this method, field points from Tri-Basin NRD were selected and NDVI was calculated for Landsat image path 30 row 32, 8-30-05. NDVI samples from irrigated areas were taken from center pivots, surface, and furrow irrigated fields. The types of fields selected were from irrigated corn, alfalfa, soybeans, sorghum, and sunflower. Non-irrigated NDVI samples were collected for areas in pasture, summer fallow, dry land corn, dry land alfalfa and dry land soybeans. Fields were identified in the imagery using the GPS points collected by Tri-Basin NRD. Once the fields were selected from the imagery, statistics were generated. Minimum and maximum NDVI values for each sample were plotted on a graph (Figure 13).

The area of overlap between the two classes was identified as being between NDVI values of 216 and 223. Using the Recode function in ERDAS Imagine, the NDVI image was recoded so that values greater than 216 were given a value of one and all other values changed to 0. This was done for all NDVI values between 216 and 223. The recoded images were displayed with the GPS field point locations to determine which threshold value had that highest accuracy. After evaluating the range of values between 216- 223, NDVI values greater than 221 were found to classify the most irrigated fields without significantly misclassifying non-irrigated fields.

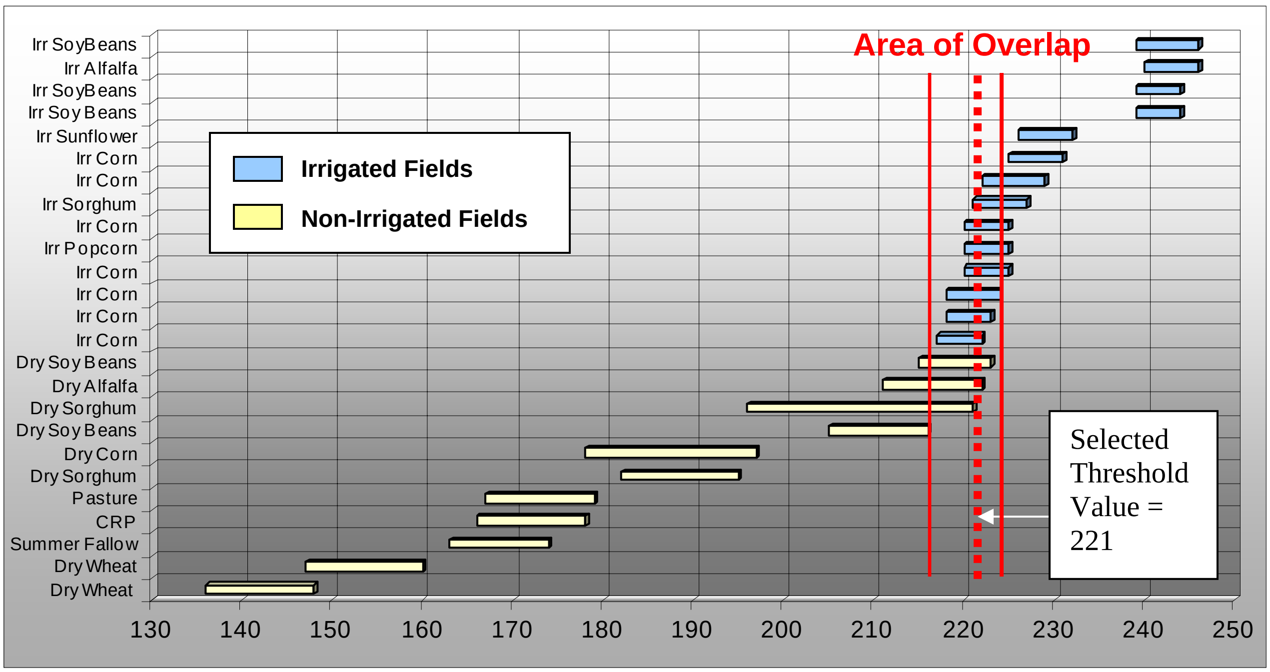


Figure 13. NDVI Field Point Values for Tri-Basin NRD, 8-30-05

There was much refinement and visual interpretation to determine NDVI threshold values throughout the study area. This procedure was done for all dates of imagery as threshold values will be different for different dates of imagery. This is due to the fact that soil conditions, vegetation health, leaf area, soil moisture and atmospheric effects all contribute to the value of NDVI. In most cases a late summer date was selected to determine the threshold values as it provided the most contrast between irrigated and non-irrigated fields. As a final check the newly identified fields were reviewed using the registered well database and the 2005 FSA ortho imagery.

Combining of Map Layers

After final edits were made to the classified imagery, all of the separate layers were combined to produce a single classified image. The order in which the layers were mosaicked is shown in Table 6. Classified cloud-covered areas were on the bottom of the mosaic while classified triple date scenes were at the very top. The order of map layers is important as those scenes with triple dates provided more information and their classifications were more accurate than scenes with single or double dates.

Table 6. Mosaic Order of Classified Scenes

Top ↓	Classified triple date scenes
	Classified double date scenes
	Classified single date scenes
Bottom	Classified cloud covered areas

Urban areas defined using the 2000 TIGER and 2005 FSA ortho imagery were digitized as polygons. These polygons were then rasterized and overlaid on the classified image.

The final irrigation vector coverage was rasterized so that it could be combined with the classified image. Using ArcInfo, the irrigation coverage was converted to a GRID file and the classified image was converted from an ERDAS Imagine file to a GRID file. An irrigation mask was created so that all irrigated areas would have a cell value of 1 and all non-irrigated areas would have a cell value of 0. The classified image and the irrigation map were compared and combined into one final map using the DOCELL command in ArcInfo GRID (see Figure 14). The DOCELL command controls cell processing on a cell-by-cell basis. This command was used to compare both GRID files and provide a set of conditional statements by which a final map would be created.

An AML (Arc Macro Language) was run from the GRID module of ArcInfo. The cell by cell analysis compared all potentially irrigated crop pixels with corresponding pixel locations within the irrigation map. If the corresponding irrigation pixel cell had a value of 1, the crop pixel would be coded as irrigated, if the irrigation cell had a value of 0, the crop pixel would be coded as dry land.

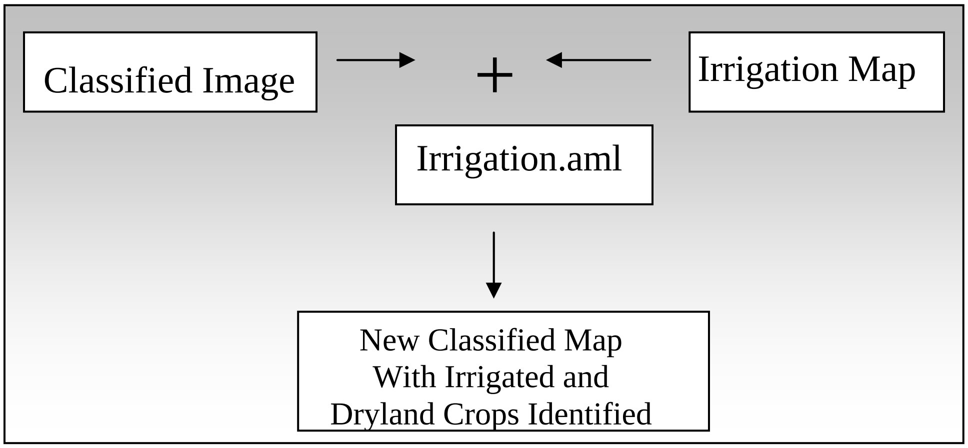


Figure 14. Flowchart of Irrigation Analysis to Create Final Map

This procedure was performed for all agricultural classes excluding sugar beets and potatoes. For this study, all sugar beet and potato fields were considered to be irrigated, as these crops rely entirely on irrigation. It should be noted that separate maps were created, one for the accuracy assessment and one for the final classification. The final land cover classification incorporated all 2005 NRD field data to update the irrigation layer (approximately 5,600 GPS field points and polygons), while the land cover classification used for the accuracy assessment only used half of the 2005 NRD field data. This allowed for an unbiased accuracy assessment to be performed.

Accuracy Assessment

An error matrix, also known as a contingency table or confusion matrix, was used to calculate the accuracy of the classified satellite imagery. Considered a standard format for evaluating classifications (Congalton, 1991; Congalton and Green, 1999), an error matrix is a cross tabulation of the classes assigned in the classified image versus the observed reference data. The descriptive statistics derived from the error matrix are the overall accuracy, producer's accuracy, and user's accuracy. The overall accuracy is computed by dividing the total number of correctly classified pixels by the total number of pixels in the error matrix. Producer's accuracy is derived by taking the total number of correct pixels in a category divided by the total number of pixels of that category. This type of accuracy indicates the probability of a referenced pixel being correctly classified and is a measure of omission error (Congalton, 1991). The user's accuracy indicates the reliability that the pixel classified on the image actually reflects that category on the ground and provides a measure of commission error (Congalton and Green, 1999).

Another measure of accuracy can be derived using KAPPA analysis, which yields a K_{HAT} statistic. KAPPA analysis is a measure of association between two categorical variables and is widely used in remote sensing classification to assess the degree of success of a classification approach (Congalton and Green, 1999). The K_{HAT} statistic measures the difference between the actual agreement between the reference data and an automated classifier, and the chance agreement between the reference data and a random classifier (Lillesand and Kiefer, 2000). The error matrix derives overall accuracy by incorporating the major diagonal and excluding the omission and commission errors. Kappa values range from 0.0 to 1.0, with 0.0 indicating agreement no greater than that expected by chance alone and 1.0 indicating perfect agreement.

RESULTS

Mapping Results

The final 2005 land cover maps were produced in both digital and paper formats. An example of the final land cover classification is found in Figure 15. In this figure irrigation appears as a separate vector layer (black outlined areas), while in fact the digital land cover classification specifies irrigated and non-irrigated crops for each associated grid cell.

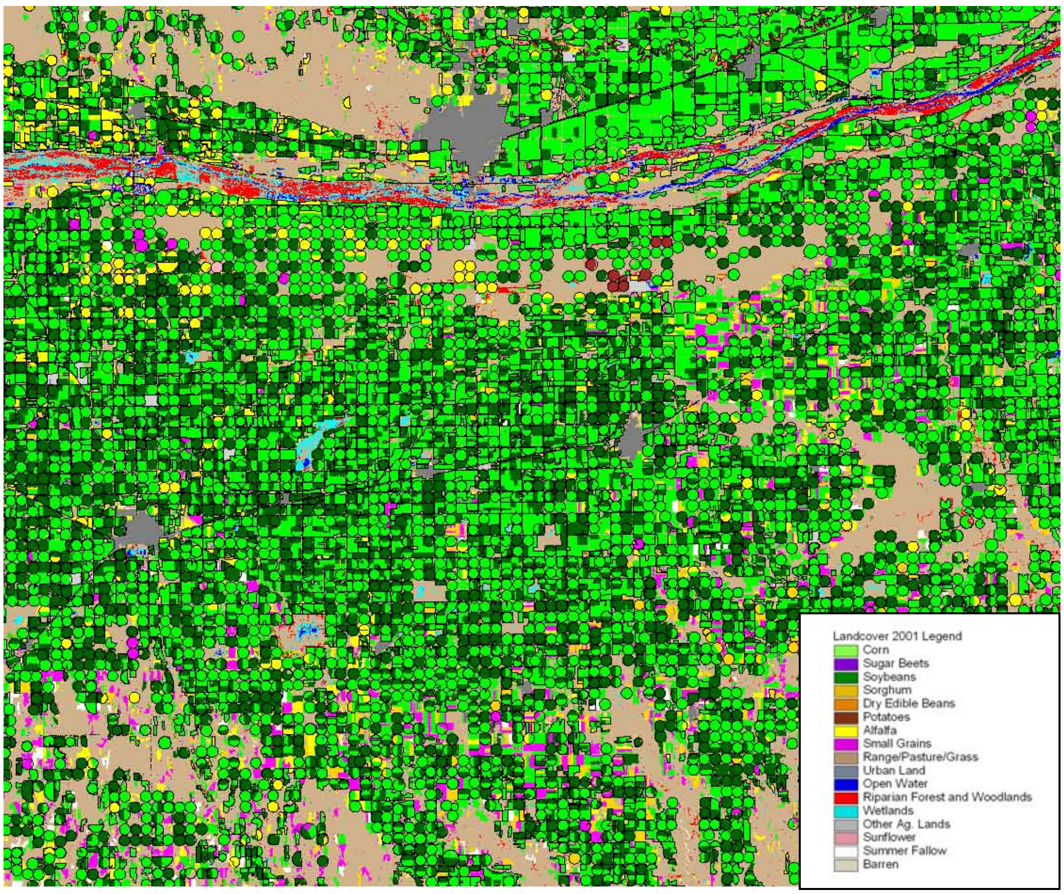


Figure 15. Example of 2005 Land Use Classification

(Kearney County, Nebraska)

Table 7 details the diversity and acreage totals of each land cover class found in the study area. Range/Pasture/Grass represented the largest land cover class at 57% of the study area. Irrigated Corn was the largest agricultural class representing 9.5% of the study area, followed by Dryland corn (7.2%), Dryland soybeans(4.7%), Irrigated soybeans (4.1%), and Dryland small grains (2.7%). All crops and other land cover classes can be found in Table 7.

Table 7. 2005 Acreage Totals by Land Cover Class

Land Use Class	2005 Acres	Percent of Total Study Area
Irrigated Corn	4,740,277.63	9.58%
Irrigated Sugar Beets	46,464.18	0.09%
Irrigated Soybeans	2,067,147.01	4.18%
Irrigated Sorghum (Milo, Sudan)	36,958.58	0.07%
Irrigated Dry Edible Beans	155,729.23	0.31%
Irrigated Potatoes	19,021.43	0.04%
Irrigated Alfalfa	603,824.86	1.22%
Irrigated Small Grains	169,485.30	0.34%
Range, Pasture, Grass	28,699,210.25	57.99%
Urban Land	489,183.12	0.99%
Open Water	284,344.10	0.57%
Riparian Forest and Woodlands	1,513,923.06	3.06%
Wetlands	876,452.46	1.77%
Other Agricultural Land	32,102.86	0.06%
Irrigated Sunflower	29,481.52	0.06%
Summer Fallow	1,010,191.26	2.04%
Roads	101,229.30	0.20%
Dryland Corn	3,606,148.46	7.29%
Dryland Soybeans	2,331,000.63	4.71%
Dryland Sorghum	156,186.61	0.32%
Dryland Dry Edible Beans	79,183.31	0.16%
Dryland Alfalfa	758,591.37	1.53%
Dryland Small Grains	1,377,882.49	2.78%
Dryland Sunflower	34,355.09	0.07%
Barren	270,999.87	0.55%

Digital land cover maps were distributed in ERDAS Imagine, ArcInfo GRID, and Geo Tiff formats. Vector irrigation data were also distributed as separate ESRI Shapefiles. All data layers are available on line at the following website: **http://calmit.unl.edu/2005landuse/.** The digital land cover data were converted into tabular format to be used for NDNR modeling efforts.

Accuracy Assessment of the Classified Imagery

An error matrix was computed to determine the accuracy of the classified satellite imagery. Table 8 lists the accuracy totals by land cover class and additional information is contained in the error matrix found in Table 10. The overall classification accuracy for the entire image was 80.43% and the overall K_{HAT} statistic was .7761. These accuracy results are considered better than average when taking into account the types of land cover classes identified in the classification (Congalton *et al*., 1998; Maxwell and Hoffer, 1996).

The land cover class that had the highest overall accuracy was Open Water (96.84%) followed by Irrigated Potatoes (92.74%), Irrigated Corn (90.42%), Riparian Forest & Woodlands (88.60%), Summer Fallow (87.90%), Irrigated Small Grains (83.29%), Range/Pasture/Grasslands (82.80%), Irrigated Sugar Beets (80.73%), Irrigated Soybeans (80.22%), Irrigated Dry Edible Beans (76.80%), Irrigated Sunflowers (70.00%), Irrigated Alfalfa (69.48), Dry land Soybeans (67.83%), Dry land Corn (59.63%), Dry land Small Grains (57.55%), Dry land Alfalfa (56.60%), Irrigated Sorghum (40.18%), Dry land Sorghum (39.43) and Dry land Sunflower (25.00%).

The error matrix details the classification accuracy in rows and columns. The classified land cover classes are listed in the rows and the reference data are found in the columns. The training set pixels that were classified correctly are found along the major diagonal and are shaded in blue. The causes of lower accuracies for the land use classes can also be explained by examining the error matrix.

Those classes with a low accuracy often had errors associated with the irrigation layer, while the crop itself was classified correctly. Looking at just the crop classification, the overall accuracy was very high at 83.88% (see Table 9).

Looking at the Dryland Corn classification, the bulk of the error arose from Dryland Corn class mixing with Irrigated Corn and, to a lesser degree with Dryland Sorghum and Dryland Soybeans. Similar errors were found with the Dryland Soybeans class. The bulk of the error arose from misclassification with Irrigated Soybeans and

Table 8. 2005 Accuracy Totals by Land Use Type

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Overall Accuracy
Irrigated Corn	913	914	826	90.47%	90.37%	90.42%
Irrigated Sugar Beets	32	30	25	78.13%	83.33%	80.73%
Irrigated Soybeans	309	338	259	83.82%	76.63%	80.22%
Irrigated Sorghum	16	14	6	37.50%	42.86%	40.18%
Irrigated Dry Edible Beans	125	108	89	71.20%	82.41%	76.80%
Irrigated Potatoes	20	21	19	95.00%	90.48%	92.74%
Irrigated Alfalfa	115	134	86	74.78%	64.18%	69.48%
Irrigated Small Grains	140	125	110	78.57%	88.00%	83.29%
Range, Pasture, Grass	366	521	356	97.27%	68.33%	82.80%
Open Water	271	258	256	94.46%	99.22%	96.84%
Riparian Forests & Woodlands	280	240	229	81.79%	95.42%	88.60%
Irrigated Sunflowers	30	15	14	46.67%	93.33%	70.00%
Summer Fallow	72	76	65	90.28%	85.53%	87.90%
Dryland Corn	263	229	146	55.51%	63.76%	59.63%
Dryland Soybeans	234	187	141	60.26%	75.40%	67.83%
Dryland Sorghum	32	21	10	31.25%	47.62%	39.43%
Dryland Alfalfa	100	71	47	47.00%	66.20%	56.60%
Dryland Small Grains	45	49	27	60.00%	55.10%	57.55%
Dryland Sunflowers	4	4	1	25.00%	25.00%	25.00%
Totals	3367	3355	2712			

Overall Classification Accuracy = 80.43
Overall Kappa Statistics = 0.7761

Table 9. Accuracy Totals for Crops

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Overall Accuracy
Corn	1176	1143	1032	87.76%	90.29%	89.02%
Sugar Beets	32	30	25	78.13%	83.33%	80.73%
Soybeans	543	525	448	82.50%	85.33%	83.92%
Sorghum	48	35	19	39.58%	54.29%	46.93%
Dry Edible Beans	125	109	89	71.20%	81.65%	76.43%
Potatoes	20	21	19	95.00%	90.48%	92.74%
Alfalfa	215	205	148	68.84%	72.20%	70.52%
Small Grains	185	174	149	80.54%	85.63%	83.09%
Sunflowers	34	19	15	44.12%	78.95%	61.53%
Summer Fallow	72	71	61	84.72%	85.92%	85.32%
Totals	2450	2332	2005			

Overall Classification Accuracy = 83.88%
Overall Kappa Statistics = 0.8034

Table 10. Error Matrix for the 2005 Land Use Classification

Crop Type	Irr Corn	Irr S.B.	Irr Soy	Irr Sorgh	Irr D.E.B.	Irr Pots	Irr Alfa	Irr Sm Grains	Range	Open Water	Rip	Irr Sunflw	Sum Fallow	Dry Corn	Dry Soy	Dry Sorgh	Dry Alfa	Dry Sm Grains	Dry Sunflw	Row Total
Irrigated Corn	826	2	18	1	9	0	7	5	0	0	0	1	0	36	6	1	1	0	0	914
Irrigated Sugar Beets	2	25	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30
Irrigated Soybeans	24	0	259	2	6	0	4	0	1	0	0	1	0	5	33	0	0	1	0	338
Irrigated Sorghum	0	0	0	6	1	0	1	0	0	0	0	1	0	1	1	3	0	0	0	14
Irrigated Dry Edible Beans	7	2	2	0	89	1	2	3	0	0	0	2	0	0	0	0	0	0	0	108
Irrigated Potatoes	1	0	0	0	0	19	0	1	0	0	0	0	0	0	0	0	0	0	0	21
Irrigated Alfalfa	11	1	5	3	11	0	86	5	0	0	0	0	1	0	1	0	10	0	0	134
Irrigated Small Grains	1	0	0	1	2	0	2	110	0	0	0	4	0	2	0	0	0	2	0	125
Range, Pasture, Grass	10	2	1	1	4	0	6	2	356	11	37	5	3	46	9	1	23	3	1	521
Open Water	0	0	0	0	0	0	0	0	0	256	2	0	0	0	0	0	0	0	0	258
Riparian Forest	1	0	0	0	0	0	0	0	2	2	229	0	0	1	1	0	3	1	0	240
Wetlands	0	0	0	0	0	0	0	0	1	2	9	0	0	0	0	0	0	0	0	12
Irrigated Sunflower	0	0	0	1	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	15
Summer Falllow	1	0	0	0	0	0	1	4	0	0	1	1	65	1	0	0	0	2	0	76
Dryland Corn	24	0	8	1	0	0	1	0	2	0	2	0	0	146	31	3	9	2	0	229
Dryland Soybeans	3	0	15	0	0	0	0	0	1	0	0	0	0	12	141	8	6	0	0	187
Dryland Sorghum	1	0	0	0	0	0	0	0	1	0	0	0	1	3	2	10	1	2	0	21
Dryland Dry Edible Beans	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Dryland Alfalfa	0	0	0	0	0	0	5	0	0	0	0	1	0	4	8	3	47	3	0	71
Dryland Small Grains	0	0	0	0	1	0	0	10	2	0	0	0	1	3	1	2	0	27	2	49
Dryland Sunflower	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	1	4
Barren	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	3
Column Total	913	32	309	16	125	20	115	140	366	271	280	30	72	263	234	32	100	45	4	3373

irrigated corn. The Dryland Alfalfa class also had errors caused by mixing with Irrigated Alfalfa and Dryland Corn and Dryland Sorghum. The error associated with the Irrigated Sorghum class was caused by a mixing with Dryland Sorghum and a low number of reference points. This was also the case for Sunflowers (both Dryland and Irrigated).

Accuracy Assessment of the Irrigation Layer

Determining the accuracy of the irrigation layer provided greater insight into the overall classification accuracy. Irrigated and non-irrigated pixel reference points were collected using the 2005 NRD field data reserved for the accuracy assessment. The land cover classification was recoded so that irrigated pixels were given a value of 1 and non-irrigated pixels a value of 2. The reference points were also recoded so that reference points found to be irrigated were recoded to a value of 1 and non-irrigated reference points were recoded to a value of 2. A total of 3,375 reference points were used for this analysis. The overall classification accuracy for the irrigation layer was calculated at 93.63% (Table 11).

Table 11. Accuracy Totals For 2005 Statewide Irrigation Layer

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Overall Accuracy
Non-Irrigated Pixels	1671	1657	1556	93.12%	93.90%	93.51%
Irrigated Pixels	1704	1717	1603	94.07%	93.36%	93.72%
Totals	3375	3374	3159			

Overall Classification Accuracy = 93.63%
Overall Kappa Statistics = 0.8720

Causes of Lower Accuracies and Sources of Error

While error matrices derive a percentage of classification accuracy, there are other sources of error they cannot measure. Error can enter into a project during steps such as data acquisition, conversion, processing, and analysis.

Although certified NRD GPS field point data were the best available choice for ground truth on crop types, in some cases this data did not provide sufficient information. In some cases only corn, soybeans, and alfalfa would be identified and some NRDs did not distinguish fields as irrigated or non-irrigated fields. In most areas there were limited field data for crops such as sunflowers, potatoes, dry edible beans, sorghum and sugar beets.

The availability of cloud free satellite imagery was also a problem. In the central and southeast portion of the State, the spring dates were contaminated with clouds to such a degree that some areas were unusable. This reduced the accuracy in classifying alfalfa and winter wheat.

Although the classification techniques used were based on standard procedures (Jensen, 1996; Lillesand and Kiefer, 2000), error still remained a factor. An accuracy estimate is only as good as the ground or sampling information used to compare known land cover types to the results of the classification. Classification systems often fail to categorize mixed classes and transition zones. When dealing with mixed pixels or polygons in transition zones, labeling inconsistencies will occur with all classification systems (Lunetta *et al.*, 1991). This introduces an element of error that is difficult to quantify. While all types of error cannot be controlled, it is important to note the limitations of one's final accuracy assessment and to document sources of error throughout the stages of the project.

PROJECT EXPOSURE

WWW Page

The Center for Advanced Land Management Information Technologies (CALMIT) has developed a web site for The Delineation of 2005 Land Use Patterns for the State of Nebraska at: **http://www.calmit.unl.edu/2005landuse/**. The web page provides information regarding the project's goals and methodologies, as well as allowing data sets and metadata to be downloaded over the Internet. The printed versions of the 2005 land cover maps and this report can also be downloaded over the Internet and are available in Adobe .PDF format. Internet mapping is also available to view the land cover data. The 2005 land cover data, 2005 FSA ortho imagery, and topographic maps are viewable through any web browser though a link on the above-mentioned web site.

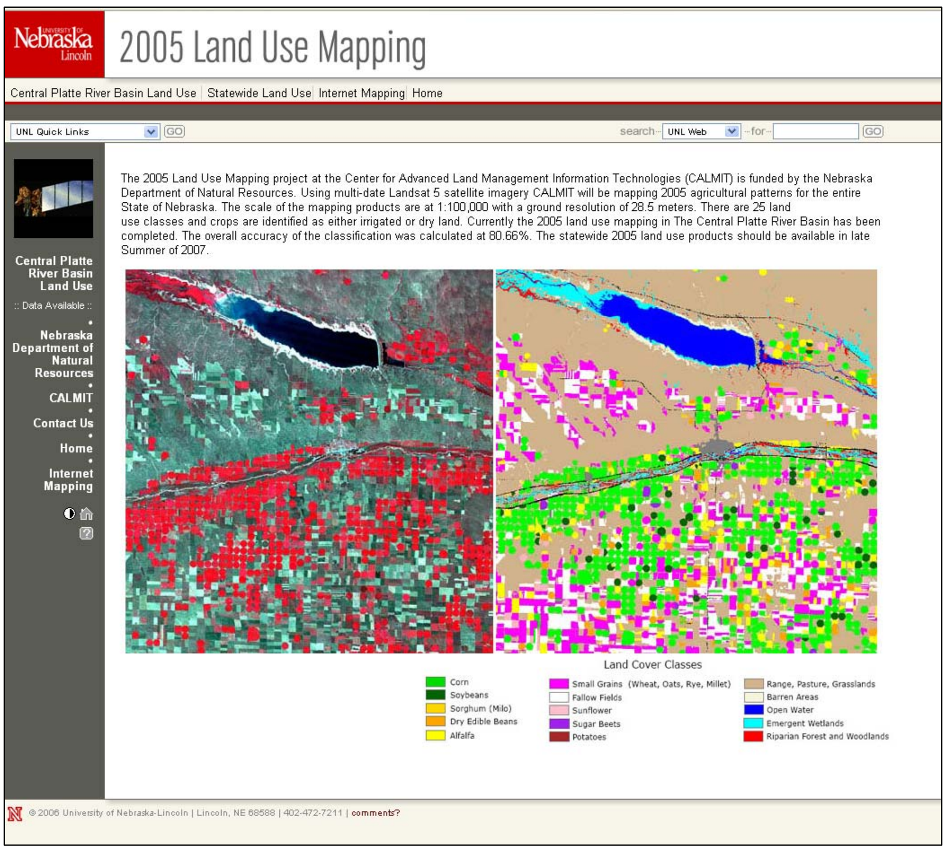


Figure 16. 2005 Land Use Mapping Web Page

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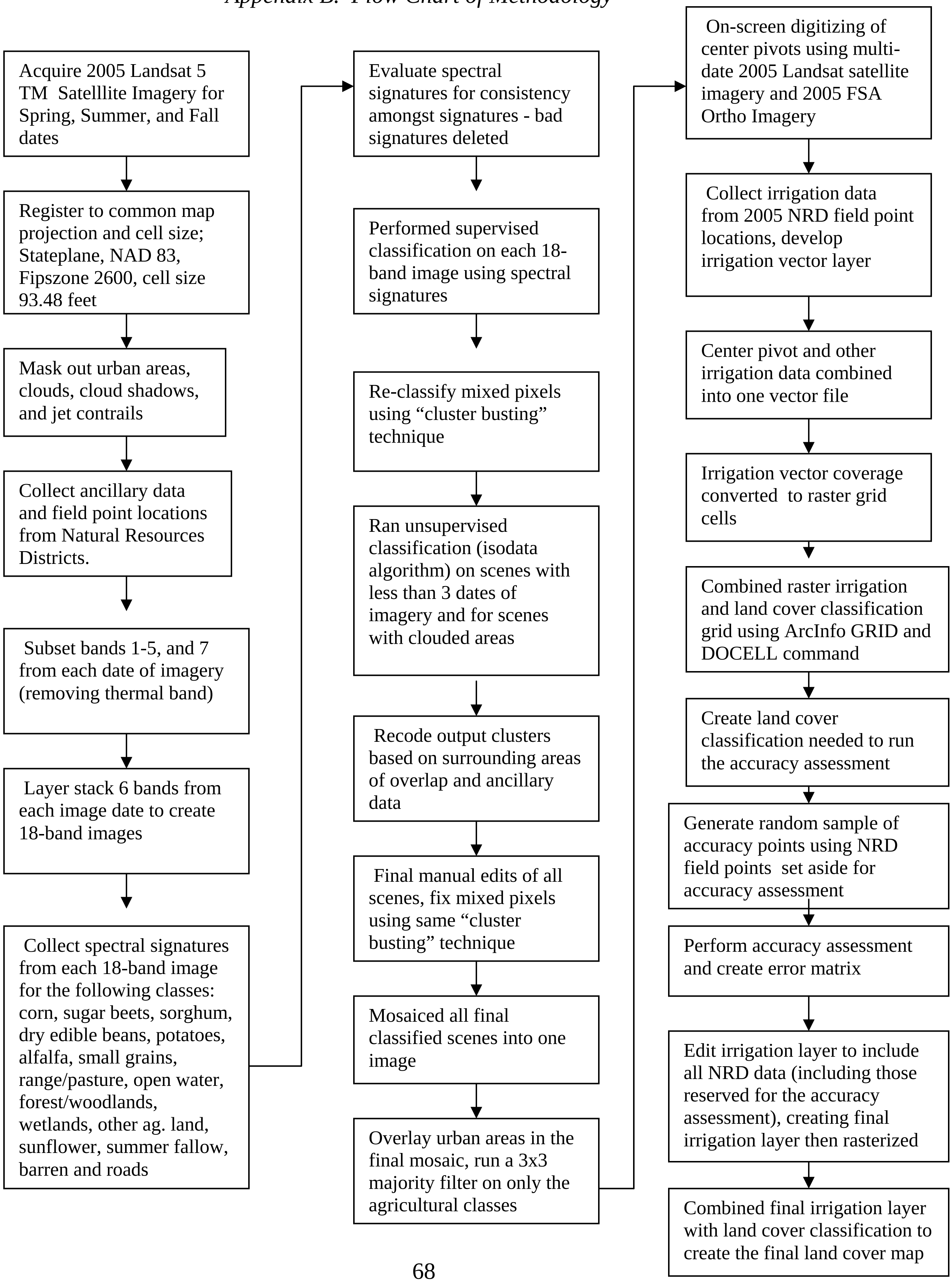
APPENDICES

Appendix A. Monthly Temperature and Precipitation Totals from Select Weather Stations

WEATHER STATION	PARAMETER	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
Gordon 6 N	Monthly average temperature (F)	2005	22.50	32.50	35.30	44.00	52.10	65.60	73.50	69.60	62.30	47.60	38.80	22.20	47.20
Gordon 6 N	Monthly average temperature (F)	2004	24.60	27.90	39.00	47.20	55.40	60.80	70.60	67.20	61.60	48.50	34.70	30.40	47.30
Gordon 6 N	Monthly average temperature (F)	2003	28.00	22.20	35.10	47.10	54.90	62.10	76.50	74.60	59.50	52.50	28.90	29.40	47.60
Gordon 6 N	Monthly average temperature (F)	1971-2000 normal	20.50	26.10	33.90	43.60	54.90	65.10	71.80	70.20	59.60	47.20	32.00	23.20	45.60
Gordon 6 N	Monthly total precipitation (In.)	2005	0.38	0.04	0.97	2.73	3.87	6.03	0.90	2.40	0.34	0.78	0.33	0.28	19.05
Gordon 6 N	Monthly total precipitation (In.)	2004	0.30	0.20	1.14	0.83	2.10	1.70	3.08	1.57	3.14	2.24	0.60	0.05	16.95
Gordon 6 N	Monthly total precipitation (In.)	2003	0.46	0.19	1.74	1.87	3.13	6.02	0.20	1.43	1.24	0.69	0.74	0.47	18.18
Gordon 6 N	Monthly total precipitation (In.)	1971-2000 normal	0.40	0.46	0.97	1.98	3.05	3.10	3.08	1.46	1.54	1.29	0.61	0.43	18.47
Grand Island WSO AP	Monthly average temperature (F)	2005	21.60	34.50	40.90	51.9	61.20	72.70	77.40	73.80	69.70	55.10	41.90	26.40	52.20
Grand Island WSO AP	Monthly average temperature (F)	2004	21.90	24.00	44.50	52.90	63.50	68.10	72.20	70.60	69.40	53.30	40.00	31.10	51.00
Grand Island WSO AP	Monthly average temperature (F)	2003	25.40	25.80	41.30	51.90	58.70	68.40	77.90	76.70	62.40	55.90	37.40	31.50	51.10
Grand Island WSO AP	Monthly average temperature (F)	1971-2000 normal	22.05	27.70	38.10	50.80	61.40	71.30	76.45	73.85	64.15	52.20	36.85	25.40	50.15
Grand Island WSO AP	Monthly total precipitation (In.)	2005	0.76	0.86	1.54	1.76	8.51	4.11	2.51	3.77	1.10	2.49	0.99	0.47	28.87
Grand Island WSO AP	Monthly total precipitation (In.)	2004	0.60	1.72	1.77	1.04	2.23	1.20	4.70	0.81	3.67	1.08	2.00	0.07	20.89
Grand Island WSO AP	Monthly total precipitation (In.)	2003	0.63	1.01	0.57	3.36	4.06	3.57	0.22	1.01	2.47	0.64	0.34	0.17	18.05
Grand Island WSO AP	Monthly total precipitation (In.)	1971-2000 normal	0.53	0.82	1.87	2.51	3.74	3.80	2.93	3.04	2.59	1.43	1.02	0.76	25.03
Hayes Center	Monthly average temperature (F)	2005	25.90	36.60	40.60	49.10	58.30	69.30	76.80	74.30	68.20	52.50	42.40	27.70	51.80
Hayes Center	Monthly average temperature (F)	2004	27.20	29.00	44.60	50.00	61.50	66.50	72.50	69.80	67.50	53.60	38.50	32.60	51.10
Hayes Center	Monthly average temperature (F)	2003	30.70	27.50	40.60	51.40	58.70	67.50	78.40	77.00	63.00	57.40	36.90	31.80	51.70
Hayes Center	Monthly average temperature (F)	1971-2000 normal	25.90	32.20	38.60	48.40	58.70	69.10	74.80	72.90	63.60	51.80	37.30	28.60	50.10
Hayes Center	Monthly total precipitation (In.)	2005	0.47	0.10	2.91	1.43	2.89	3.68	2.47	3.25	1.33	2.11	0.85	0.27	21.76
Hayes Center	Monthly total precipitation (In.)	2004	0.43	0.55	1.28	2.03	1.15	3.10	8.62	1.11	2.16	1.70	1.27	0.07	23.47
Hayes Center	Monthly total precipitation (In.)	2003	0.27	0.83	1.40	5.12	0.93	3.58	0.83	1.89	0.72	0.20	0.53	0.15	16.45
Hayes Center	Monthly total precipitation (In.)	1971-2000 normal	0.51	0.60	1.56	2.18	3.16	3.38	3.22	2.63	1.48	1.45	0.93	0.49	21.59
Kearney 4 NE	Monthly average temperature (F)	2005	19.00	33.70	39.00	49.90	59.40	71.40	76.20	73.40	68.80	54.00	41.00	25.00	50.90
Kearney 4 NE	Monthly average temperature (F)	2004	21.80	23.30	42.90	50.50	61.30	67.00	71.70	69.00	67.70	53.00	39.70	30.00	49.80
Kearney 4 NE	Monthly average temperature (F)	2003	25.90	25.20	38.20	51.20	58.00	67.80	76.70	75.90	61.60	55.00	35.60	31.20	50.20
Kearney 4 NE	Monthly average temperature (F)	1971-2000 normal	22.35	27.75	37.50	49.80	60.55	70.45	75.65	72.95	63.50	51.60	36.40	25.40	49.65
Kearney 4 NE	Monthly total precipitation (In.)	2005	0.55	0.63	2.05	1.03	3.61	6.21	0.84	3.74	0.23	2.47	1.10	0.32	22.78
Kearney 4 NE	Monthly total precipitation (In.)	2004	0.55	0.60	2.68	1.54	3.07	2.32	4.82	0.67	4.75	1.26	2.59	0.02	24.87
Kearney 4 NE	Monthly total precipitation (In.)	2003	0.29	0.70	0.35	4.02	4.58	3.28	0.33	0.57	2.20	1.73	0.56	0.10	18.71
Kearney 4 NE	Monthly total precipitation (In.)	1971-2000 normal	0.49	0.75	1.81	2.33	3.66	3.90	3.45	2.82	2.44	1.56	0.94	0.72	24.87

WEATHER STATION	PARAMETER	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
North Platte WSO ARPT	Monthly average temperature (F)	2005	23.80	34.20	38.70	47.70	57.10	70.90	77.20	72.80	67.90	50.90	39.50	25.50	50.50
North Platte WSO ARPT	Monthly average temperature (F)	2004	23.90	27.10	42.10	48.80	61.70	64.90	71.90	67.80	66.20	51.90	37.70	30.50	49.50
North Platte WSO ARPT	Monthly average temperature (F)	2003	27.90	25.80	40.40	49.50	57.90	66.10	77.40	75.60	60.90	53.80	34.80	29.90	50.00
North Platte WSO ARPT	Monthly average temperature (F)	1971-2000 normal	27.45	27.75	36.85	48.25	58.20	67.90	73.85	71.65	61.75	49.45	34.70	24.50	48.20
North Platte WSO ARPT	Monthly total precipitation (In.)	2005	0.41	0.17	1.76	2.33	3.04	5.07	1.26	2.78	0.17	0.78	0.46	0.22	18.45
North Platte WSO ARPT	Monthly total precipitation (In.)	2004	0.26	0.77	0.16	1.90	1.77	5.06	4.97	1.25	1.98	0.96	1.30	0.06	20.44
North Platte WSO ARPT	Monthly total precipitation (In.)	2003	0.35	0.49	1.28	3.84	2.02	5.45	1.90	0.59	1.08	0.49	0.73	0.03	18.25
North Platte WSO ARPT	Monthly total precipitation (In.)	1971-2000 normal	0.38	0.51	1.23	1.91	3.37	3.42	2.93	1.87	1.60	0.99	0.63	0.50	19.33
Omaha Eppley Airfield	Monthly average temperature (F)	2005	20.90	32.90	40.70	55.50	61.80	75.60	79.70	75.00	71.10	55.00	42.60	24.40	52.90
Omaha Eppley Airfield	Monthly average temperature (F)	2004	21.10	24.90	43.50	54.00	63.90	68.70	73.10	70.00	70.40	54.80	42.10	30.40	51.40
Omaha Eppley Airfield	Monthly average temperature (F)	2003	22.80	23.70	39.60	53.50	59.60	69.10	78.40	78.00	63.40	55.40	37.90	30.20	51.00
Omaha Eppley Airfield	Monthly average temperature (F)	1971-2000 normal	21.70	28.00	39.30	51.40	62.20	72.20	76.70	74.50	65.40	53.20	38.00	25.60	50.60
Omaha Eppley Airfield	Monthly total precipitation (In.)	2005	0.52	1.90	0.98	2.63	4.60	2.69	1.93	4.66	0.92	0.75	1.04	0.81	23.43
Omaha Eppley Airfield	Monthly total precipitation (In.)	2004	1.25	1.31	4.49	0.97	8.21	2.70	6.83	3.77	1.66	0.26	2.02	0.34	33.81
Omaha Eppley Airfield	Monthly total precipitation (In.)	2003	0.35	1.32	0.50	3.66	4.37	3.25	2.49	0.74	1.41	1.43	2.91	0.84	23.27
Omaha Eppley Airfield	Monthly total precipitation (In.)	1971-2000 normal	0.77	0.80	2.13	2.94	4.44	3.95	3.86	3.21	3.17	2.21	1.82	0.92	30.22
Scottsbluff WSO AP	Monthly average temperature (F)	2005	28.40	34.50	39.00	45.70	55.30	66.30	75.30	69.30	64.00	49.50	40.20	26.80	49.50
Scottsbluff WSO AP	Monthly average temperature (F)	2004	28.30	30.60	42.90	47.90	58.20	63.90	71.60	67.70	62.00	50.50	34.50	31.00	49.10
Scottsbluff WSO AP	Monthly average temperature (F)	2003	32.00	26.40	39.10	48.70	57.60	64.50	78.00	74.60	59.20	52.20	33.70	29.00	49.60
Scottsbluff WSO AP	Monthly average temperature (F)	1971-2000 normal	24.90	30.25	37.45	47.30	57.10	67.45	74.00	71.45	61.50	49.45	35.50	26.35	48.70
Scottsbluff WSO AP	Monthly total precipitation (In.)	2005	0.66	0.25	1.22	2.62	2.39	5.58	1.67	1.91	0.76	2.18	0.26	0.14	19.64
Scottsbluff WSO AP	Monthly total precipitation (In.)	2004	0.13	0.73	0.14	0.90	0.57	1.70	2.24	0.21	2.81	1.20	1.35	0.06	12.04
Scottsbluff WSO AP	Monthly total precipitation (In.)	2003	0.12	0.77	1.79	1.42	1.27	1.63	0.47	0.59	0.94	0.31	0.71	0.44	10.46
Scottsbluff WSO AP	Monthly total precipitation (In.)	1971-2000 normal	0.53	0.55	1.07	1.63	2.76	2.55	1.96	1.25	1.07	0.83	0.61	0.53	15.32
Valentine Miller Field	Monthly average temperature (F)	2005	21.20	33.10	36.80	48.50	55.80	69.70	75.30	73.00	67.20	49.70	39.00	23.00	49.40
Valentine Miller Field	Monthly average temperature (F)	2004	23.00	26.50	41.40	49.40	58.80	62.40	73.30	68.90	65.60	50.30	37.40	30.70	49.00
Valentine Miller Field	Monthly average temperature (F)	2003	24.20	21.80	36.20	48.50	56.80	65.60	75.80	76.60	60.60	52.60	31.40	29.00	48.30
Valentine Miller Field	Monthly average temperature (F)	1971-2000 normal	20.80	26.60	35.30	46.10	57.50	67.60	73.70	72.10	61.15	48.30	33.00	24.60	47.20
Valentine Miller Field	Monthly total precipitation (In.)	2005	0.56	0.20	1.29	4.57	2.63	7.71	3.31	2.40	2.39	0.61	0.35	0.23	26.25
Valentine Miller Field	Monthly total precipitation (In.)	2004	0.08	0.97	1.07	0.91	3.71	3.32	1.66	1.14	3.11	0.82	0.48	0.01	17.28
Valentine Miller Field	Monthly total precipitation (In.)	2003	0.31	0.27	1.17	2.27	3.14	4.14	1.68	0.87	0.59	0.43	0.48	0.41	15.76
Valentine Miller Field	Monthly total precipitation (In.)	1971-2000 normal	0.30	0.48	1.23	2.57	3.20	3.01	3.37	2.20	1.61	1.22	0.72	0.33	19.52

Appendix B. Flow Chart of Methodology



Appendix C. 2005 Land Use Acreage by County

Land Cover Class	Adams	Antelope	Arthur	Banner	Blaine	Boone	Box Butte
Irrigated Corn	135,358.91	135,209.66	3,103.00	4,947.59	2,781.03	97,722.28	44,091.39
Irrigated Sugar Beets	0.00	0.00	1.40	627.90	0.00	0.00	22,174.78
Irrigated Soybeans	59,776.11	86,482.22	496.50	0.00	967.53	52,383.31	0.00
Irrigated Sorghum (Milo, Sudan)	1,386.00	150.46	0.00	0.00	0.00	55.37	59.78
Irrigated Dry Edible Beans	0.00	226.69	0.00	4,703.85	0.00	0.00	30,654.88
Irrigated Potatoes	0.00	49.35	0.00	3.81	0.00	6.02	3,135.90
Irrigated Alfalfa	4,181.07	10,332.51	5,838.29	5,467.57	4,505.45	7,215.86	11,373.26
Irrigated Small Grains	705.14	186.97	160.49	5,876.20	0.00	1.81	25,752.02
Range/Pasture/Grass	74,663.61	188,048.75	430,973.56	324,143.89	416,966.92	160,605.60	377,243.97
Urban Land	8,305.76	2,761.77	145.24	156.07	231.10	2,247.01	3,338.92
Open Water	530.21	763.31	1,068.24	8.02	2,140.08	514.96	177.54
Riparian Forest and Woodlands	6,415.04	15,100.55	280.45	16,363.38	1,717.80	5,439.68	248.55
Wetlands	1,240.96	4,226.81	13,958.69	537.63	8,163.13	1,830.14	8,103.55
Other Agricultural Lands	1,437.96	597.81	0.00	313.95	0.00	288.07	779.76
Irrigated Sunflower	36.71	4.61	0.00	1,249.59	0.00	17.65	4,425.81
Summer Fallow	1,000.83	22.27	592.19	50,977.85	0.00	0.60	62,414.30
Roads	625.50	821.69	0.40	920.59	173.33	250.96	1,203.65
Dryland Corn	40,413.44	60,804.42	237.52	1,713.59	973.75	70,366.40	4,626.62
Dryland Soybeans	12,101.26	35,955.34	31.90	0.00	351.67	32,473.99	7.82
Dryland Sorghum (Milo, Sudan)	3,696.80	549.67	0.00	0.00	1.00	415.66	3.41
Dryland Dry Edible Beans	0.00	75.83	0.00	2,935.09	0.00	0.00	10,962.21
Dryland Alfalfa	3,329.09	6,135.59	1,838.17	1,532.64	953.49	7,969.95	1,948.30
Dryland Small Grains	5,589.94	456.38	15.85	52,129.94	0.00	2.81	73,981.35
Dryland Sunflower	192.58	24.27	0.00	353.47	0.00	127.39	756.09
Barren	0.00	307.53	734.43	2,263.86	16,950.56	114.75	1,085.09
Total Irrigated Acres	201,443.93	232,642.46	9,599.68	22,876.51	8,254.01	157,402.30	141,667.82

Land Cover Class	Boyd	Brown	Buffalo	Burt	Butler	Cass	Cedar	Chase
Irrigated Corn	3,344.73	31,099.22	149,930.06	25,289.02	63,449.84	2,712.02	48,991.43	125,036.23
Irrigated Sugar Beets	0.00	0.00	0.00	167.11	0.00	0.00	0.00	3,187.06
Irrigated Soybeans	3,128.68	8,259.02	58,113.47	21,991.03	39,397.37	4,407.55	35,204.06	7,768.14
Irrigated Sorghum (Milo, Sudan)	86.26	276.04	637.73	1.20	46.14	0.00	94.89	1,670.46
Irrigated Dry Edible Beans	0.00	6.02	0.00	0.00	0.00	0.00	0.00	18,756.43
Irrigated Potatoes	0.00	68.61	3.61	0.00	0.00	0.00	0.00	1,499.14
Irrigated Alfalfa	4,252.89	8,536.06	16,781.44	769.53	1,348.29	437.12	4,071.13	6,078.42
Irrigated Small Grains	60.98	77.43	957.50	39.52	62.79	1.00	93.08	11,688.41
Range/Pasture/Grass	237,955.55	654,077.31	283,036.74	46,495.47	94,093.08	61,382.58	142,490.11	300,229.43
Urban Land	1,119.39	1,421.51	10,915.47	2,711.21	2,942.72	8,933.27	3,375.63	1,538.06
Open Water	4,774.26	6,507.12	3,783.46	1,670.06	925.60	4,676.97	4,059.10	800.63
Riparian Forest and Woodlands	28,589.22	31,452.69	18,545.79	8,770.37	15,951.73	33,011.22	16,586.45	2,558.15
Wetlands	5,700.07	22,125.23	5,290.23	159.88	576.55	2,790.25	730.21	3,317.05
Other Agricultural Lands	329.40	750.87	329.40	0.00	0.00	8.22	178.54	756.49
Irrigated Sunflower	0.00	0.00	167.11	1,226.72	0.00	0.00	0.00	1,109.16
Summer Fallow	1,802.86	183.36	1,436.15	144.64	1.40	78.24	4,834.25	26,527.97
Roads	169.91	568.72	4,801.75	111,099.21	324.98	314.55	356.68	864.42
Dryland Corn	6,846.14	5,044.08	31,946.59	90,028.57	101,264.41	108,319.38	113,108.29	17,321.48
Dryland Soybeans	13,163.68	962.92	13,350.65	30.69	46,799.79	120,917.96	77,229.39	1,182.98
Dryland Sorghum (Milo, Sudan)	3,514.25	29.89	1,434.95	0.00	1,103.14	371.53	1,739.07	553.48
Dryland Dry Edible Beans	251.56	52.56	0.00	0.00	0.00	0.00	0.00	7,149.86
Dryland Alfalfa	27,055.17	1,479.08	16,553.55	6,526.37	4,262.31	8,886.52	24,498.63	4,349.78
Dryland Small Grains	3,050.44	36.11	3,364.79	1,078.87	558.29	1,751.31	1,535.45	26,866.80
Dryland Sunflower	0.00	0.00	342.64	2.61	159.48	0.00	0.00	1,472.86
Barren	3,129.88	10,576.24	180.15	180.15	0.00	3,316.45	0.00	1,954.52
Total Irrigated Acres	10,873.54	48,322.41	226,590.92	49,484.13	104,304.42	7,557.70	88,454.60	176,793.45

Land Cover Class	Cherry	Cheyenne	Clay	Colfax	Cuming	Custer	Dakota	Dawes
Irrigated Corn	12,749.23	19,262.36	130,634.39	39,455.54	28,909.59	147,014.02	9,956.17	1,788.82
Irrigated Sugar Beets	399.41	1,441.17	0.00	0.00	0.00	0.00	0.00	435.52
Irrigated Soybeans	900.53	127.79	65,371.86	21,116.58	22,071.87	39,578.92	9,710.02	0.00
Irrigated Sorghum (Milo, Sudan)	52.16	382.56	890.10	3.81	1.20	607.24	5.02	0.00
Irrigated Dry Edible Beans	2,369.98	3,708.64	0.00	0.00	0.00	0.00	0.00	521.58
Irrigated Potatoes	6.22	62.99	0.00	0.00	0.00	26.68	0.00	1.40
Irrigated Alfalfa	19,454.14	11,664.94	4,595.92	1,632.75	1,904.97	23,481.74	247.55	7,382.57
Irrigated Small Grains	976.96	12,933.59	679.06	16.65	0.80	745.66	0.00	1,399.64
Range/Pasture/Grass	3,381,867.33	332,793.89	86,791.96	54,993.42	41,081.67	1,235,284.45	42,520.43	710,412.40
Urban Land	2,496.36	3,141.32	3,508.43	3,224.97	2,585.43	5,257.33	5,752.63	2,989.46
Open Water	33,754.87	153.67	357.88	3,032.19	1,338.86	3,190.67	1,217.69	2,341.09
Riparian Forest and Woodlands	43,859.08	1,073.25	7,015.25	10,058.68	7,937.45	25,363.45	15,262.64	80,755.27
Wetlands	288,178.12	2,702.39	2,829.57	745.66	910.36	6,742.83	203.22	10,179.24
Other Agricultural Lands	324.38	443.95	784.78	497.51	2,661.46	947.27	0.00	0.00
Irrigated Sunflower	589.99	4,251.68	28.29	2.21	0.00	57.57	0.00	111.94
Summer Fallow	519.98	156,115.80	291.48	387.37	382.76	1,786.01	748.47	24,360.41
Roads	2,942.52	5,094.23	1,044.36	537.43	666.82	1,236.55	214.45	380.35
Dryland Corn	1,292.32	16,098.58	39,580.72	82,270.06	137,828.59	74,313.75	46,958.27	703.73
Dryland Soybeans	273.23	22.47	12,912.32	42,963.17	104,347.75	28,429.74	34,588.80	0.00
Dryland Sorghum (Milo, Sudan)	69.81	2,249.82	3,526.69	139.22	17.85	564.51	232.71	0.00
Dryland Dry Edible Beans	447.56	4,257.10	0.00	0.00	0.00	0.00	0.00	2,884.74
Dryland Alfalfa	5,693.05	6,225.26	2,652.84	6,901.31	14,535.84	37,741.15	2,290.54	7,191.79
Dryland Small Grains	1,490.32	169,587.41	3,395.29	238.92	185.56	6,008.40	63.39	31,212.77
Dryland Sunflower	190.58	9,223.34	67.60	38.32	84.46	113.54	0.00	270.42
Barren	43,735.51	1,736.06	0.00	0.00	0.00	8,596.45	0.00	11,204.15
Total Irrigated Acres	37,498.61	53,835.71	202,199.62	62,227.54	52,888.44	211,511.84	19,918.75	11,641.47

Land Cover Class	Dawson	Deuel	Dixon	Dodge	Douglas	Dundy	Filmore	Franklin
Irrigated Corn	170,722.85	12,042.89	13,997.61	56,212.51	7,590.80	72,146.59	118,121.08	58,310.67
Irrigated Sugar Beets	0.00	192.18	0.00	0.00	0.00	15.45	0.00	0.00
Irrigated Soybeans	46,005.59	368.52	9,333.88	38,765.85	3,830.20	2,222.94	73,423.66	31,563.63
Irrigated Sorghum (Milo, Sudan)	586.58	47.54	28.09	26.88	5.22	1,642.58	70.21	1,665.04
Irrigated Dry Edible Beans	0.00	1,332.24	0.00	0.00	0.00	9,875.72	0.00	0.00
Irrigated Potatoes	0.00	7.42	0.00	0.00	0.00	3,301.40	0.00	0.00
Irrigated Alfalfa	34,569.14	3,272.31	388.38	1,164.53	269.82	5,484.62	1,385.60	4,257.70
Irrigated Small Grains	1,245.77	1,328.42	0.40	91.08	229.50	17,717.48	333.21	1,573.57
Range/Pasture/Grass	309,644.36	86,687.04	102,360.13	42,925.05	22,697.37	371,285.92	62,229.54	190,480.11
Urban Land	5,787.74	657.79	1,641.57	9,200.68	108,768.55	750.47	3,004.10	1,691.52
Open Water	3,668.11	168.91	4,815.59	4,694.22	4,227.81	73.42	390.58	325.79
Riparian Forest and Woodlands	16,374.21	934.23	22,204.68	15,560.55	11,587.31	2,545.31	4,634.84	13,218.45
Wetlands	7,046.15	1,972.58	519.37	1,050.58	271.02	7,960.92	1,337.65	1,358.32
Other Agricultural Lands	1,068.84	75.63	483.26	224.88	0.00	481.66	0.60	47.95
Irrigated Sunflower	227.29	1,657.62	0.00	13.84	0.00	2,171.38	2.21	174.13
Summer Fallow	2,233.77	77,293.38	1,855.62	85.66	76.83	27,391.99	5.82	4,096.81
Roads	5,226.43	2,672.50	102.91	1,196.42	146.84	127.99	253.97	1,205.65
Dryland Corn	19,140.59	4,174.45	81,979.78	106,936.59	31,914.69	12,295.25	58,866.35	24,540.15
Dryland Soybeans	6,777.74	42.93	60,020.45	64,022.17	22,765.37	760.10	37,028.59	7,462.61
Dryland Sorghum (Milo, Sudan)	663.21	272.22	665.01	122.17	27.08	797.22	557.29	5,891.05
Dryland Dry Edible Beans	0.00	171.32	0.00	0.00	0.00	9,397.07	0.00	0.00
Dryland Alfalfa	17,220.57	4,547.38	8,204.26	3,564.40	1,079.87	5,350.01	4,183.68	6,278.02
Dryland Small Grains	3,697.20	77,551.16	245.74	538.63	1,648.19	30,164.39	2,828.57	14,028.90
Dryland Sunflower	310.94	3,941.54	40.72	48.95	0.00	409.44	80.64	280.05
Barren	9.23	535.02	0.00	442.94	6.82	4,729.53	0.00	129.99

Total Irrigated Acres	253,357.22	20,249.15	23,748.35	96,274.69	11,925.53	114,578.15	193,335.97	97,544.74

Land Cover Class	Frontier	Furnas	Gage	Garden	Garfield	Gosper	Grant	Greeley
Irrigated Corn	39,014.81	29,414.52	26,710.53	16,802.91	10,589.68	52,160.03	0.00	56,248.42
Irrigated Sugar Beets	0.00	0.00	0.00	269.82	0.00	0.00	0.00	0.00
Irrigated Soybeans	16,071.89	13,538.22	27,659.00	638.33	2,792.86	21,355.90	0.00	21,903.36
Irrigated Sorghum (Milo, Sudan)	2,272.49	434.72	1,317.19	335.82	0.00	215.45	0.00	139.22
Irrigated Dry Edible Beans	518.97	0.00	0.00	1,007.05	0.00	0.00	0.00	0.00
Irrigated Potatoes	0.00	0.00	0.00	233.51	0.00	0.00	0.00	0.00
Irrigated Alfalfa	11,009.56	6,973.33	2,491.95	11,133.13	3,699.41	6,032.48	1,549.09	4,838.86
Irrigated Small Grains	3,472.32	3,817.17	706.54	2,628.97	0.00	1,836.56	0.00	0.00
Range/Pasture/Grass	399,730.10	239,550.39	188,408.24	899,226.26	318,535.90	159,500.85	457,240.94	243,728.44
Urban Land	882.07	2,718.64	7,491.10	731.42	652.78	475.04	288.07	1,213.28
Open Water	2,605.49	463.40	2,932.28	13,967.12	1,473.46	2,513.01	4,968.65	778.56
Riparian Forest and Woodlands	10,144.54	8,032.74	33,243.72	5,206.78	3,509.83	2,988.65	77.84	2,846.02
Wetlands	1,274.06	1,214.28	8,473.87	49,793.46	7,799.03	1,137.85	33,995.20	2,256.24
Other Agricultural Lands	313.55	78.24	253.37	253.97	0.00	0.00	0.00	72.82
Irrigated Sunflower	167.51	67.40	0.00	377.54	0.00	65.20	0.00	0.00
Summer Fallow	26,810.43	37,002.71	165.30	43,405.71	0.00	5,845.51	0.00	0.00
Roads	563.11	1,524.62	400.01	965.93	0.00	742.85	707.94	35.51
Dryland Corn	15,679.71	12,595.56	94,745.26	5,278.99	5,155.82	8,746.30	0.00	21,481.89
Dryland Soybeans	3,826.39	5,116.10	95,803.46	42.33	1,916.01	3,149.74	0.00	6,772.52
Dryland Sorghum (Milo, Sudan)	3,803.52	7,425.70	19,434.48	17.65	16.05	620.88	1.60	33.10
Dryland Dry Edible Beans	256.98	0.00	0.00	1,197.23	0.00	0.00	0.00	0.00
Dryland Alfalfa	26,391.16	35,196.04	7,139.23	4,713.88	2,724.05	9,671.90	170.12	2,282.52
Dryland Small Grains	61,822.11	55,637.57	31,585.10	42,918.43	0.00	19,047.31	13.24	0.00
Dryland Sunflower	200.61	397.81	1,353.30	2,045.40	0.00	104.72	0.00	0.00
Barren	110.74	0.00	0.00	3,532.50	6,711.33	0.00	2,094.95	232.30
Total Irrigated Acres	72,527.54	54,245.35	58,885.21	33,427.08	17,081.95	81,665.63	1,549.09	83,129.87

Land Cover Class	Hall	Hamilton	Harlan	Hayes	Hitchcock	Holt	Hooker	Howard
Irrigated Corn	159,341.97	162,014.87	47,646.16	39,962.68	16,705.61	143,361.55	11.03	76,209.90
Irrigated Sugar Beets	0.00	0.00	0.00	0.20	0.00	0.00	0.60	0.00
Irrigated Soybeans	28,149.89	71,777.87	28,271.46	6,326.97	3,361.99	75,734.86	0.00	23,388.46
Irrigated Sorghum (Milo, Sudan)	499.71	358.29	635.53	3,260.68	1,397.63	1,065.23	0.00	492.09
Irrigated Dry Edible Beans	0.00	0.00	0.00	4,424.00	1,342.07	4,184.08	66.20	0.00
Irrigated Potatoes	56.37	0.00	0.00	2.41	26.08	3,099.99	0.20	0.00
Irrigated Alfalfa	5,348.40	2,989.26	5,331.15	7,369.73	3,465.70	14,713.38	3,241.82	8,246.59
Irrigated Small Grains	813.26	980.97	1,365.14	2,539.90	2,671.49	3,896.00	119.96	47.95
Range/Pasture/Grass	92,524.53	47,606.04	166,331.55	299,494.00	254,924.77	1,117,326.86	440,370.43	197,367.58
Urban Land	14,599.83	2,600.68	1,771.77	213.05	1,080.27	5,342.79	638.33	1,810.08
Open Water	3,177.83	1,402.25	8,547.90	202.81	2,858.66	6,623.47	440.13	3,359.78
Riparian Forest and Woodlands	10,166.60	9,452.24	11,227.22	5,721.13	8,112.98	53,415.84	3,033.99	13,680.05
Wetlands	2,406.69	1,732.05	5,052.71	1,783.20	5,139.17	52,389.73	4,810.98	2,941.91
Other Agricultural Lands	2,783.03	96.09	0.40	244.34	67.40	1,040.35	70.01	0.00
Irrigated Sunflower	19.46	10.03	41.12	208.23	165.90	0.00	1.20	15.85
Summer Fallow	168.51	86.26	13,704.12	29,350.33	50,026.57	1,710.58	3.41	267.01
Roads	4,094.81	2,443.20	1,794.04	362.30	589.19	857.00	814.07	517.57
Dryland Corn	20,470.42	32,023.22	23,877.54	7,789.80	22,691.35	17,017.16	8.02	28,739.88
Dryland Soybeans	3,617.36	10,833.22	6,805.42	404.63	4,805.36	11,008.75	0.20	6,301.69
Dryland Sorghum (Milo, Sudan)	596.01	581.56	4,730.73	3,719.67	883.68	533.01	4.01	770.74
Dryland Dry Edible Beans	0.00	0.00	0.00	2,468.68	8,025.72	258.18	7.62	0.00
Dryland Alfalfa	3,297.19	1,976.39	13,549.25	10,683.37	8,756.53	10,511.45	354.67	3,609.54
Dryland Small Grains	1,119.39	1,115.58	26,542.22	28,609.88	58,831.05	5,128.34	12.64	18.46
Dryland Sunflower	74.02	9.43	149.85	156.07	517.17	0.00	0.20	147.85
Barren	0.00	0.00	0.00	1,157.71	3,309.23	17,498.62	8,069.65	94.49
Total Irrigated Acres	194,229.07	238,131.29	83,290.55	64,094.79	29,136.48	246,055.09	3,441.03	108,400.83

Land Cover Class	Jefferson	Johnson	Kearney	Keith	Keya Paha	Kimball	Knox	Lancaster
Irrigated Corn	38,517.10	6,406.01	129,109.57	67,917.58	5,203.97	8,713.60	28,316.39	6,711.94
Irrigated Sugar Beets	0.00	0.00	0.00	1,046.97	0.00	2,757.35	0.00	0.00
Irrigated Soybeans	32,094.64	3,921.88	66,013.01	9,822.16	4,787.91	0.00	19,208.60	6,335.80
Irrigated Sorghum (Milo, Sudan)	135.81	396.00	2,080.30	250.96	270.62	0.00	181.95	172.92
Irrigated Dry Edible Beans	0.00	0.00	0.00	2,513.82	0.00	1,129.02	0.20	0.00
Irrigated Potatoes	0.00	0.00	996.82	428.50	571.33	0.00	20.46	0.00
Irrigated Alfalfa	2,320.23	939.45	3,792.09	13,788.18	9,220.74	8,630.75	8,270.26	1,276.47
Irrigated Small Grains	799.42	332.61	1,047.37	2,277.70	391.19	6,100.88	639.94	259.19
Range/Pasture/Grass	150,543.31	137,822.97	62,723.44	467,795.72	382,518.75	342,317.75	395,701.89	204,489.36
Urban Land	2,832.78	1,464.64	1,835.36	2,552.33	346.45	1,828.34	3,909.24	67,788.79
Open Water	1,354.91	728.41	241.13	16,806.12	2,258.64	151.26	17,269.12	3,913.46
Riparian Forest and Woodlands	24,667.74	21,035.73	3,194.48	9,926.68	58,247.48	472.83	69,211.70	32,405.18
Wetlands	2,049.81	1,722.02	1,100.13	18,971.68	13,586.76	691.70	15,140.67	2,981.23
Other Agricultural Lands	19.26	6.42	696.51	654.78	110.53	24.47	761.11	64.80
Irrigated Sunflower	13.24	0.00	37.11	1,211.07	0.00	3,830.00	0.00	0.00
Summer Fallow	28.89	67.40	884.68	34,012.25	0.00	104,647.06	1,056.40	138.82
Roads	546.86	171.32	1,107.96	5,504.28	211.04	3,684.36	410.44	1,286.10
Dryland Corn	41,914.79	25,599.76	30,739.53	6,605.21	587.18	2,002.07	74,163.70	89,664.26
Dryland Soybeans	43,889.98	24,568.24	11,175.26	630.51	1,696.94	0.00	47,522.78	107,070.40
Dryland Sorghum (Milo, Sudan)	3,247.44	7,450.17	3,612.14	194.19	575.34	1,285.90	3,532.90	3,008.52
Dryland Dry Edible Beans	0.00	0.00	0.00	3,371.62	18.86	1,019.49	68.61	0.00
Dryland Alfalfa	6,275.81	3,510.64	4,664.53	8,414.90	7,485.28	3,382.65	40,524.58	5,037.26
Dryland Small Grains	16,671.71	4,348.78	6,486.25	30,143.73	698.92	111,446.06	2,664.07	6,815.45
Dryland Sunflower	166.71	0.00	150.05	1,684.30	0.00	1,850.81	0.00	5.82
Barren	266.01	534.02	0.00	3,084.95	6,712.14	3,181.44	859.40	1,936.07

Total Irrigated Acres	73,880.44	11,995.95	203,076.28	99,256.93	20,445.75	31,161.61	56,637.80	14,756.31

Land Cover Class	Lincoln	Logan	Loup	Madison	McPherson	Merrick	Morrill	Nance
Irrigated Corn	156,789.84	13,519.76	5,692.45	50,839.83	3,038.41	113,551.44	50,750.36	44,079.15
Irrigated Sugar Beets	130.40	0.00	0.00	0.00	2.21	0.00	2,974.81	0.00
Irrigated Soybeans	35,285.11	3,939.34	2,807.71	44,326.90	987.99	45,723.33	126.98	22,260.44
Irrigated Sorghum (Milo, Sudan)	2,828.17	3.21	29.69	83.65	85.86	1,155.30	114.95	381.76
Irrigated Dry Edible Beans	3,226.98	0.00	0.00	0.00	2.61	0.00	17,626.40	0.00
Irrigated Potatoes	3,597.50	0.00	0.00	0.00	1.60	0.00	593.60	0.00
Irrigated Alfalfa	27,684.08	5,150.40	4,443.66	3,495.99	5,364.85	6,449.34	24,495.01	2,561.56
Irrigated Small Grains	5,387.32	580.16	0.00	6.62	1,594.03	1,230.73	8,727.24	156.27
Range/Pasture/Grass	1,201,496.48	309,027.09	330,109.56	95,592.63	521,952.60	91,299.62	705,015.85	121,100.31
Urban Land	10,753.98	173.53	180.15	9,963.99	168.11	2,204.48	1,383.59	1,424.52
Open Water	9,930.29	295.70	5,275.99	1,465.84	710.15	2,842.21	3,151.55	2,683.13
Riparian Forest and Woodlands	61,533.83	3,323.47	2,023.33	7,883.69	1,416.89	17,620.79	11,935.16	22,150.51
Wetlands	13,045.93	7,256.39	6,058.56	609.65	9,536.69	2,513.82	29,494.76	1,377.57
Other Agricultural Lands	965.12	8.22	0.00	339.63	22.87	227.69	1,358.32	26.88
Irrigated Sunflower	345.45	0.20	0.00	0.00	0.00	6.22	570.53	11.84
Summer Fallow	15,602.47	1,935.06	0.00	0.00	749.07	53.16	15,370.17	86.26
Roads	5,938.59	213.65	0.80	954.09	2.01	2,093.14	3,747.15	0.40
Dryland Corn	18,410.78	3,488.97	3,651.26	79,223.03	285.46	19,632.68	6,526.98	41,774.37
Dryland Soybeans	4,248.07	994.41	1,584.80	64,224.99	63.99	5,238.27	8.43	17,316.67
Dryland Sorghum (Milo, Sudan)	2,577.01	75.83	10.83	1,724.83	29.69	582.97	7.62	1,725.43
Dryland Dry Edible Beans	779.56	0.00	0.00	0.00	27.68	0.00	4,347.17	0.00
Dryland Alfalfa	40,449.75	6,198.78	1,530.84	7,085.07	776.95	2,514.62	3,905.03	5,517.52
Dryland Small Grains	22,376.40	2,734.89	0.00	43.53	252.57	695.51	15,485.52	1,036.94
Dryland Sunflower	195.19	7.42	0.00	95.29	0.20	14.44	312.95	112.74
Barren	3,322.87	6,488.86	1,952.92	0.00	2,860.87	1.00	6,481.64	406.43

Total Irrigated Acres	235,274.83	23,193.07	12,973.51	98,753.00	11,077.56	168,116.36	105,979.90	69,451.02

Land Cover Class	Nemaha	Nuckolls	Otoe	Pawnee	Perkins	Phelps	Pierce	Platte
Irrigated Corn	4,353.59	35,482.91	1,688.52	531.41	97,592.48	136,999.48	68,654.61	120,030.47
Irrigated Sugar Beets	0.00	0.00	0.00	0.00	1,616.10	0.00	0.00	0.00
Irrigated Soybeans	6,228.67	18,328.73	3,220.76	2,128.45	10,671.53	81,184.97	51,907.07	63,992.08
Irrigated Sorghum (Milo, Sudan)	32.50	906.95	117.96	17.85	1,439.76	278.24	61.99	113.14
Irrigated Dry Edible Beans	0.00	0.00	0.00	0.00	5,579.30	0.00	0.00	0.00
Irrigated Potatoes	0.00	0.00	0.00	0.00	208.03	0.00	0.00	0.00
Irrigated Alfalfa	535.22	1,670.26	407.03	138.02	5,488.83	11,129.32	5,168.46	5,094.44
Irrigated Small Grains	0.00	1,357.11	86.06	47.54	5,186.31	1,589.21	16.85	123.17
Range/Pasture/Grass	74,082.65	152,406.16	132,046.47	167,790.97	214,578.53	64,493.40	116,431.76	78,374.66
Urban Land	2,211.30	2,231.76	5,137.77	1,458.62	1,183.59	2,841.01	2,195.25	8,486.51
Open Water	1,511.58	264.40	2,468.68	1,186.60	156.07	596.61	857.80	3,721.48
Riparian Forest and Woodlands	25,246.49	17,879.37	29,290.14	33,368.30	500.92	2,661.66	5,406.98	16,019.94
Wetlands	1,939.68	1,103.34	2,501.98	1,952.52	479.45	2,556.35	122.57	1,871.07
Other Agricultural Lands	91.48	6.02	22.27	70.81	115.75	1,445.78	0.00	12.44
Irrigated Sunflower	0.00	11.64	0.00	0.00	2,260.45	261.39	0.80	7.62
Summer Fallow	47.54	1,621.91	11.23	67.60	79,627.25	976.36	178.54	52.16
Roads	8.43	854.79	30.89	231.90	1,224.91	1,405.66	1,229.12	1,141.86
Dryland Corn	69,622.94	48,572.97	85,215.58	22,548.32	31,514.48	15,871.09	63,469.70	92,025.02
Dryland Soybeans	65,039.66	14,106.94	115,254.80	23,860.89	996.22	11,301.04	44,581.27	44,011.14
Dryland Sorghum (Milo, Sudan)	906.75	17,497.61	3,518.46	6,588.36	1,666.45	429.70	1,071.25	732.22
Dryland Dry Edible Beans	0.00	0.00	0.00	0.00	9,027.75	0.00	0.00	0.00
Dryland Alfalfa	3,402.91	11,982.71	9,151.33	5,501.67	19,407.60	7,011.24	5,837.69	5,327.94
Dryland Small Grains	2,606.90	42,247.20	4,189.69	8,739.48	70,984.07	2,851.04	253.37	137.82
Dryland Sunflower	0.00	52.76	0.00	0.00	4,160.41	117.96	86.66	40.12
Barren	684.47	0.00	1,373.96	743.65	207.23	0.00	0.60	2.21
Total Irrigated Acres	11,149.98	57,757.59	5,520.33	2,863.28	130,042.80	231,442.62	125,809.78	189,360.92

Land Cover Class	Polk	Red Willow	Richardson	Rock	Saline	Sarpy	Saunders	Scotts Bluff
Irrigated Corn	102,857.24	24,233.22	4,315.47	18,107.66	55,046.18	4,735.15	49,296.76	73,583.74
Irrigated Sugar Beets	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5,700.87
Irrigated Soybeans	50,580.65	8,301.55	2,753.54	14,556.10	40,344.43	4,435.64	45,408.18	0.00
Irrigated Sorghum (Milo, Sudan)	364.50	298.50	0.00	0.00	232.50	5.82	31.90	0.00
Irrigated Dry Edible Beans	0.00	12.84	0.00	48.35	0.00	0.00	0.00	33,659.78
Irrigated Potatoes	0.00	0.00	0.00	740.24	0.00	0.00	0.00	25.28
Irrigated Alfalfa	3,002.90	9,358.76	615.26	6,962.29	1,296.93	626.30	1,942.08	33,390.77
Irrigated Small Grains	520.98	3,333.50	1.40	153.06	241.73	136.81	700.72	4,295.61
Range/Pasture/Grass	49,576.41	239,399.33	118,372.64	546,442.80	108,242.15	22,618.33	94,647.76	240,730.16
Urban Land	1,705.77	3,586.87	3,123.66	726.20	4,252.28	40,793.19	5,297.85	8,943.30
Open Water	527.40	284.66	2,071.68	5,027.63	692.30	3,940.74	3,475.33	4,989.12
Riparian Forest and Woodlands	14,148.47	4,788.91	37,332.11	14,249.77	19,249.72	14,759.32	24,172.84	14,653.20
Wetlands	554.88	1,044.16	3,125.67	16,768.00	812.26	924.60	1,248.18	10,210.54
Other Agricultural Lands	79.64	150.26	94.09	300.51	80.04	605.43	641.54	1,002.04
Irrigated Sunflower	8.02	184.56	0.00	0.00	16.45	0.00	1.00	420.07
Summer Fallow	26.28	43,089.15	303.12	259.39	38.72	24.88	171.72	16,857.07
Roads	82.85	1,783.60	122.97	264.40	0.00	420.27	421.28	3,105.01
Dryland Corn	40,318.96	17,530.91	91,267.32	1,485.50	77,359.18	30,238.62	138,332.12	7,349.87
Dryland Soybeans	14,243.96	2,144.30	83,372.40	1,067.23	42,600.67	30,397.10	106,550.83	0.00
Dryland Sorghum (Milo, Sudan)	385.97	4,079.76	1,486.70	73.22	741.05	13.44	976.56	0.00
Dryland Dry Edible Beans	0.00	235.71	0.00	193.79	0.00	0.00	0.00	2,210.10
Dryland Alfalfa	1,617.50	32,632.47	2,965.99	3,513.65	6,903.72	1,686.91	8,452.61	6,453.35
Dryland Small Grains	1,138.25	62,507.38	3,697.60	55.77	10,455.88	1,098.53	2,900.59	4,709.27
Dryland Sunflower	6.62	277.04	0.00	0.00	120.77	0.00	101.51	27.88
Barren	0.00	14.04	933.43	15,866.07	10.03	854.79	1,329.63	4,563.83
Total Irrigated Acres	157,334.29	45,722.93	7,685.69	40,567.71	97,178.23	9,939.72	97,380.64	151,076.13

Land Cover Class	Seward	Sherman	Sheridan	Sioux	Stanton	Thayer	Thomas	Thurston
Irrigated Corn	69,909.01	47,536.83	16,012.31	10,842.65	18,420.61	75,595.04	87.47	5,423.83
Irrigated Sugar Beets	0.00	0.00	2,563.57	757.90	0.00	0.00	0.00	0.00
Irrigated Soybeans	52,177.69	15,416.31	1.40	0.00	11,566.44	48,759.33	67.40	7,529.01
Irrigated Sorghum (Milo, Sudan)	12.04	0.00	32.10	0.00	0.00	53.16	426.89	0.00
Irrigated Dry Edible Beans	0.00	0.00	4,396.72	3,827.60	0.00	0.00	0.00	0.00
Irrigated Potatoes	0.00	16.65	100.91	125.98	0.00	0.00	0.00	0.00
Irrigated Alfalfa	1,376.37	9,242.80	26,286.44	12,335.17	1,351.90	2,038.98	1,822.32	167.91
Irrigated Small Grains	89.47	0.00	7,742.66	1,433.14	2.41	779.96	0.00	0.00
Range/Pasture/Grass	102,668.66	245,924.70	1,298,258.85	1,180,009.98	105,143.56	128,079.25	419,540.32	38,411.58
Urban Land	4,179.46	1,805.27	2,434.78	193.59	1,482.69	2,933.89	697.31	1,696.34
Open Water	786.38	3,974.04	14,380.17	846.36	1,652.21	305.53	492.29	809.05
Riparian Forest and Woodlands	17,745.77	4,727.72	52,071.16	41,755.51	13,345.03	11,046.07	16,562.58	21,153.69
Wetlands	507.14	4,102.63	65,078.37	15,249.00	363.90	430.70	4,461.92	240.93
Other Agricultural Lands	273.83	0.00	340.63	445.35	192.78	0.00	17.65	401.01
Irrigated Sunflower	20.06	0.00	2,312.21	398.21	1.40	20.66	0.00	2.21
Summer Fallow	16.65	0.00	23,934.92	2,793.46	3.41	104.12	4.01	1,733.05
Roads	1,842.38	227.69	1,563.34	2,165.96	632.92	908.35	839.74	91.28
Dryland Corn	78,104.24	21,258.01	2,458.45	4,253.89	70,422.57	31,776.28	2.41	94,554.28
Dryland Soybeans	33,609.43	7,411.86	1.20	0.00	45,721.33	34,363.31	8.63	69,932.48
Dryland Sorghum (Milo, Sudan)	406.23	13.84	84.05	0.00	230.10	1,171.55	28.69	74.63
Dryland Dry Edible Beans	0.00	0.00	4,498.03	2,568.58	0.00	0.00	0.00	0.00
Dryland Alfalfa	3,268.90	4,124.50	11,630.04	5,068.56	4,914.29	10,789.69	247.95	10,430.20
Dryland Small Grains	1,440.56	0.00	36,894.78	6,522.16	167.51	18,022.81	0.00	750.07
Dryland Sunflower	63.59	0.00	1,163.73	39.52	65.60	558.89	0.00	66.40
Barren	0.00	84.46	7,137.02	31,072.34	0.00	0.00	10,579.45	0.00

Total Irrigated Acres	123,584.63	72,212.59	59,448.32	29,720.65	31,342.76	127,247.13	2,404.08	13,122.96

Land Cover Class	Valley	Washington	Wayne	Webster	Wheeler	York
Irrigated Corn	56,480.52	8,776.99	20,256.77	34,521.79	30,551.77	169,764.95
Irrigated Sugar Beets	0.00	0.00	0.00	0.00	0.00	0.00
Irrigated Soybeans	17,529.51	8,349.30	15,926.85	14,626.72	14,257.60	75,068.04
Irrigated Sorghum (Milo, Sudan)	18.86	2.01	0.20	836.13	5.82	620.28
Irrigated Dry Edible Beans	0.00	0.00	0.00	0.00	0.00	0.00
Irrigated Potatoes	0.00	0.00	0.00	0.00	0.00	0.00
Irrigated Alfalfa	10,421.98	383.36	1,255.60	3,330.89	5,757.24	2,470.08
Irrigated Small Grains	0.00	37.91	0.00	1,733.85	0.00	516.77
Range/Pasture/Grass	231,825.78	42,393.44	53,736.21	192,373.05	288,752.86	40,392.58
Urban Land	1,950.51	6,085.64	2,431.57	1,751.31	463.00	4,924.12
Open Water	2,605.29	1,772.77	75.23	628.10	294.09	536.43
Riparian Forest and Woodlands	5,910.31	17,843.66	1,701.56	16,945.74	3,430.79	8,495.74
Wetlands	3,245.83	132.80	47.74	974.75	11,287.80	2,019.32
Other Agricultural Lands	0.00	258.78	65.80	583.97	421.68	33.30
Irrigated Sunflower	0.00	0.00	0.20	41.93	0.00	48.15
Summer Fallow	0.00	468.62	1,500.35	4,047.06	0.00	151.66
Roads	40.32	31.09	252.77	606.24	1.60	1,633.55
Dryland Corn	23,597.50	88,166.93	90,543.33	40,354.06	8,233.55	45,275.37
Dryland Soybeans	6,685.25	70,081.73	82,562.15	7,448.97	2,174.99	12,899.08
Dryland Sorghum (Milo, Sudan)	8.43	38.32	67.00	10,715.87	13.24	1,064.22
Dryland Dry Edible Beans	0.00	0.00	0.00	0.00	0.00	0.00
Dryland Alfalfa	4,399.73	6,258.96	12,774.70	10,283.16	1,106.75	2,135.47
Dryland Small Grains	0.00	1,229.73	163.50	25,931.37	0.00	308.33
Dryland Sunflower	0.00	0.00	164.30	257.78	0.00	42.73
Barren	204.82	0.00	0.00	0.00	1,304.55	0.00
Total Irrigated Acres	84,450.87	17,549.57	37,439.63	55,091.31	50,572.42	248,488.27