Delineation of 1982 Land Use Patterns For the Cooperative Hydrology Study in the Central Platte River Basin

Final Report
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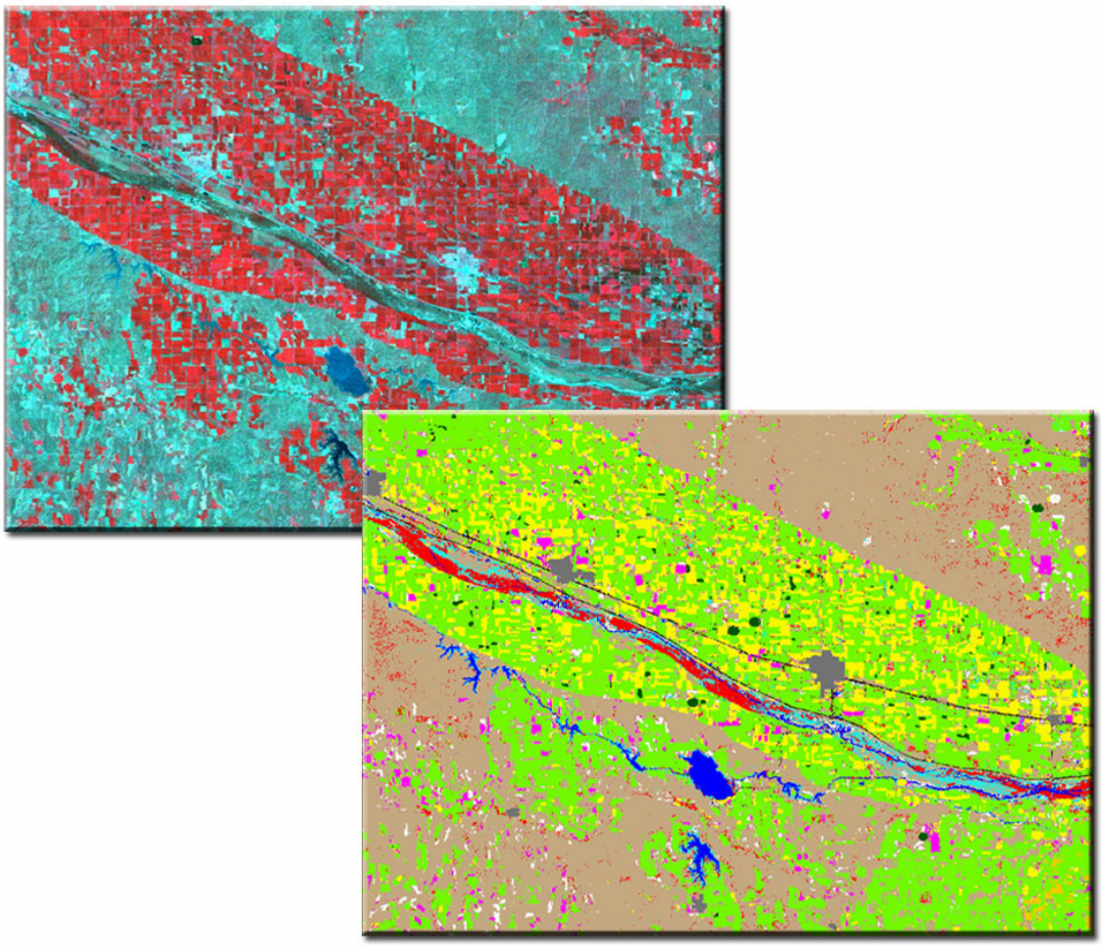

Principal Investigators:

Patti Dappen and Jim Merchant
Center for Advanced Land Management
Information Technologies (CALMIT)
School of Natural Resources
University of Nebraska - Lincoln
113 Nebraska Hall
Lincoln, NE 68588-0517

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INTRODUCTION

The Central Platte River Valley in Nebraska is an internationally significant staging area for migratory water birds of the Central Flyway and is best known for the one-half million sandhill cranes and the several million other waterfowl that migrate annually through the valley. Changes in water and land use have transformed the river channel and altered adjacent wet meadows (U.S. Bureau of Reclamation *et al*., 1983). Changes in the Platte River have been caused by shrinkage of the river channel and associated woody vegetation encroachment. In addition, adjoining native grasslands have been destroyed and water table levels have declined due to the conversion of these lands to cropland (U.S. Fish and Wildlife Service, 1981). All of these factors have altered and reduced habitat for migratory birds.

The Platte River Cooperative Hydrology Study (COHYST) is a multi-agency effort that seeks to improve the understanding of the hydrological conditions in the Platte River watershed in Nebraska upstream of Columbus, NE. COHYST seeks to produce scientifically supportable hydrologic databases, analyses, and modeling to: 1. assist Nebraska in meeting its obligations under the Cooperative Agreement among Colorado, Nebraska, Wyoming, and the U.S. Department of the Interior; 2. assist the Natural Resources Districts within the Platte River Basin in providing appropriate management and regulation of groundwater; 3. provide the citizens of Nebraska with a basis to develop policies and procedures related to groundwater and surface water; 4. help the citizens of Nebraska analyze the proposed activities developed under the Three-State Cooperative Agreement and understand the hydrologic consequences of these activities. The results of COHYST will provide a basis to develop policy and procedures related to groundwater and surface water. This will enable existing and new water uses in the Platte River Basin to proceed without additional actions required for the four species covered under the Endangered Species Act: *Grus Americana* (Whooping Crane), *Charadrius melodus* (Piping Plover), *Sterna antillarum* (Least Tern), and *Scaphirhynchus albus* (Pallid Sturgeon).

PROJECT OBJECTIVES

Comprehensive information on land cover and land use, especially irrigation and crop patterns, are critical to COHYST, since hydrologic conditions change in relation to crop dynamics. In January of 2001, The Center for Advanced Land Management Information Technologies (CALMIT) completed the development of a land cover database for the COHYST region based on 1997 Landsat-5 satellite imagery and ancillary data. To identify changes in crop patterns, this land cover map was updated using 2001 Landsat-7 satellite imagery as the primary data source and was completed in September of 2003. In order to assess historical changes in land cover and land use, another land cover database was assembled using 1982 Landsat 3 satellite imagery. The objective of this study was to capitalize on the seasonal dynamics of the agricultural crops and native plant communities in order to develop a historic land use and land cover map of the Platte River Basin in Nebraska for the year 1982.

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 all yield different kinds of water use. Creating a historic land cover map for the year 1982 will identify changes in land cover patterns over time to supplement the COHYST hydrologic modeling efforts.

THE STUDY AREA

The study area includes parts of 42 counties in Nebraska and covers approximately 28,800 square miles (see Figure 1). Elevation in this area ranges from 1,427 feet above sea level in Platte County to approximately 5,424 feet in Kimball County.

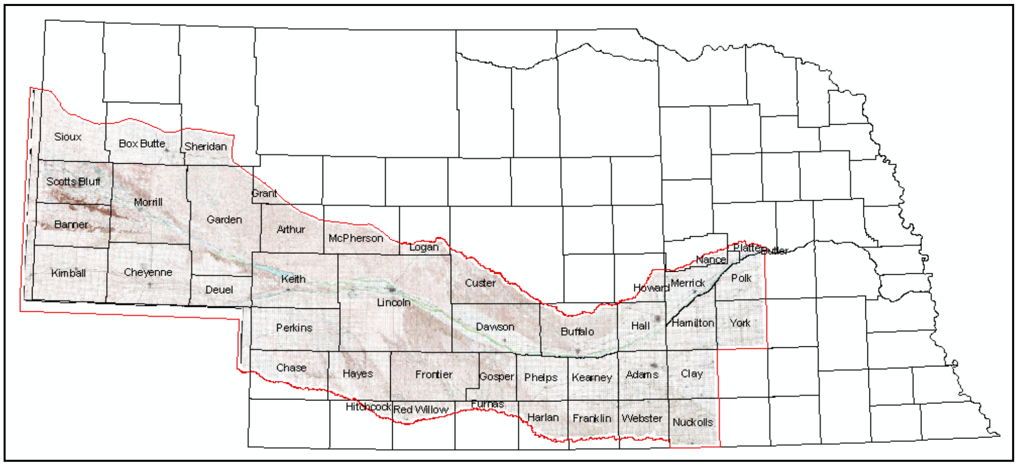


Figure 1. The COHYST Study Area.

Topography and Climate

The general topography of the study area consists of gently rolling hills broken by isolated buttes, mesas, ravines, and shallow streams flowing to the east-southeast. The geography of the western half of the study area is characterized by relic sand dunes and rolling loess hills. The eastern half of the study area consists of a terraced landscape. The Platte River, along with its tributaries, forms a distinct basin between plains, sand hills and rolling hills. Years of erosion have left the central portion of the valley broad and well developed, while the eastern end of the basin is more narrow. (Jenkins, 1993).

The climate of the Platte River basin is typical of the interior of the mid-latitude United States. Two-thirds of the precipitation falls during the growing season, and summers are generally hot, and winters severe. Temperature and precipitation vary widely between years. Short-term weather changes are influenced by large masses of warm, moist air from the Gulf of Mexico; cold, dry air from central Canada; cool, dry air from the northern Pacific Ocean; and hot, dry air from the southwestern United States.

The 1982 Growing Season

The 1982 growing season was cooler than normal with an average temperature of 47°F, almost 4° cooler than the previous two years as indicated in Figure 2. Precipitation for 1982 averaged 26.25 inches, an increase of almost 8 inches over the 1980 and 1981 average (see Figure 3). The cooler days slowed corn growth and a wet planting season influenced some corn producers to plant sorghum and soybean as an alternative crop. Wet weather during the growing and harvesting season delayed crop progress into mid-December.

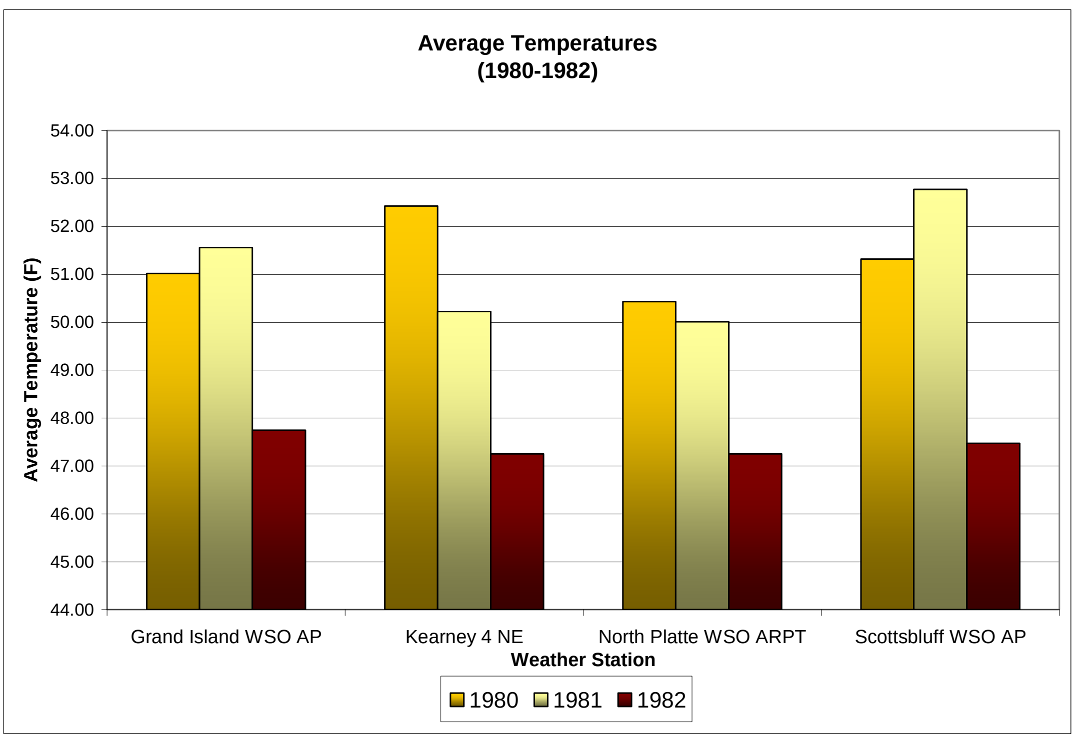


Figure 2. Average Temperatures for Select Weather Stations 1980-1982.

A wet spring characterized the 1982 planting season. Topsoil moisture levels rated 17% short at the start of the season, but ended with a rating of 0% short and a 57% surplus. Increased moisture helped replenish subsoil moisture supplies. The spring season ended with 5% of subsoils exhibiting a moisture shortage, an improvement of 18% from the start of the season (Nebraska Agricultural Statistics Service, 1982). The wet planting season had an adverse impact on fieldwork progress.

By June 6th, producers were two and one-half weeks behind a normal corn planting schedule. Only two-thirds of the corn slated for the season had been planted. Wet soil delayed planting and farmers averaged 2.5 days of fieldwork for the first part of June (Nebraska Agricultural Statistics Service, 1982). The delay was enough for some producers to resort to alternative crops such as, sorghum and soybeans.

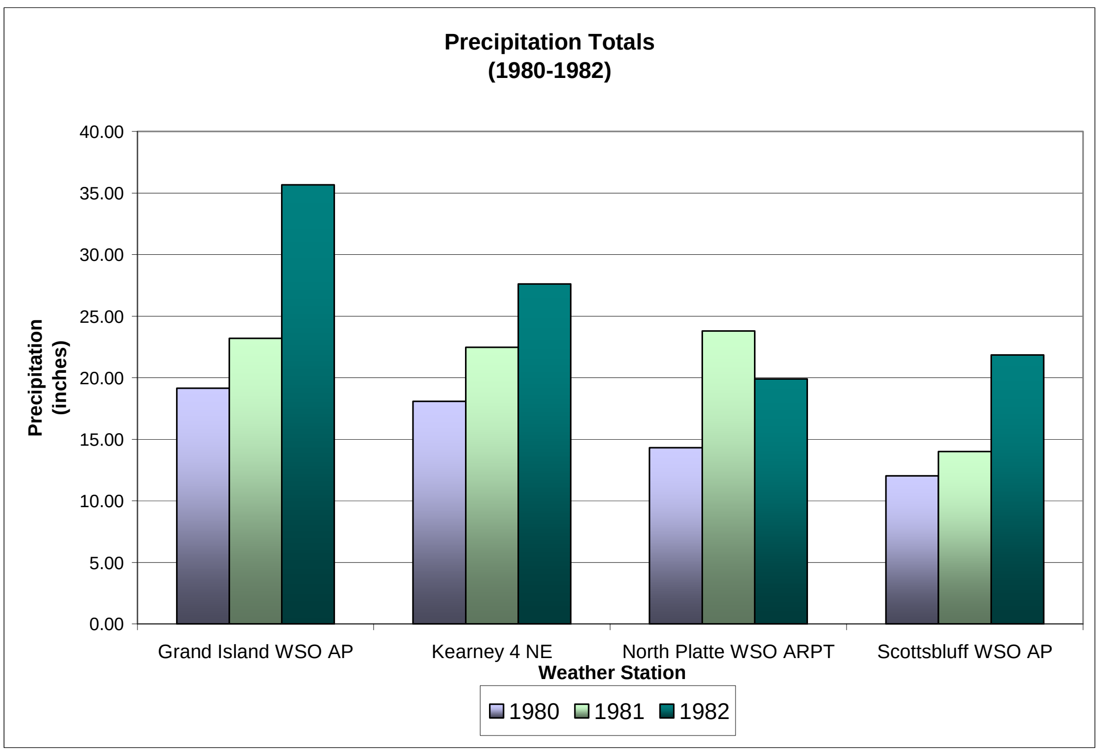


Figure 3. Precipitation Totals for Select Weather Stations 1980-1982.

The summer growing season started with heavy rains, flooding low lying areas, especially in the east central and southeast parts of the state. Some farmers were forced to replant where rain induced erosion washed away newly planted crops. During the last week of June, there was little precipitation, but previous wet weeks caused widespread soil crusting. The first days of July were warm with temperatures ranging up to six degrees above normal. However, the short spell of dry weather was not enough to dry out winter wheat for harvesting.

By mid-July, winter wheat harvesting was well underway and approximately 10% complete, despite cooler than normal temperatures. Warm and dry conditions characterized the end of July with an average temperature of 80° F, favoring row crop development. Two-thirds or better of the corn, sorghum, and soybean crop conditions were rated good (Nebraska Agricultural Statistics Service, 1982).

Beginning to mid-August was characterized by cool temperatures and dry conditions and marked the near completion (99%) of winter wheat harvesting. The eastern portion of the state averaged temperatures 10° F below normal. The latter half of August was wet, further delaying crop development and maturation.

Above normal temperatures and dry conditions encouraged row crop development during the first two weeks of September. The warmer weather helped spur corn and sorghum maturation, closing the gap on crop development to about one and one-half weeks behind normal. Historically for corn, the crop was in late maturation, a record setting stage since growing season progress was first recorded in 1957 (Nebraska Agricultural Statistics Service, 1982). By the end of September, silage cutting was widespread and only isolated corn fields had been harvested.

Early October heavy rains and some snow in the eastern parts of the state impeded fieldwork, crop development and harvesting. By this time, topsoil shortage moisture levels were rated at 2%. However, silage and high moisture corn harvesting continued. By mid-October, fall harvest momentum picked up as soil moisture levels dropped. The potential for a late harvest and possible field losses spurred some of the harvesting activities, especially soybean fields in the eastern parts of the state (Nebraska Agricultural Statistics Service, 1982).

Freezing weather and dry conditions marked the end of the 1982 growing season. Producers scrambled to take advantage of the dry conditions bringing soybean harvest to 85% complete and corn harvest to a lagging 30% complete (Nebraska Agricultural

Statistics Service, 1982). The end of October ended with corn and sorghum harvests three full weeks behind normal progress.

Excellent fieldwork condtions marked the beginning of November. Steady progress was made towards completing the 1982 fall crop harvests. Soybean harvest was 85% complete while corn harvest was 65% complete. However, a combination of freezing weather and snow brought harvest operations to a halt during mid-November. By early to mid-December, the 1982 harvesting season came to a conclusion approximately two weeks later than normal (Nebraska Agricultural Statistics Service, 1982).

Plant Community Characteristics

Biologically, the Platte River Basin contains a wide variety of plant species. Four distinct plant communities exist in the region: (1) mixed-grass prairie; (2) tallgrass prairie; (3) sandhills prairie; and (4) floodplain or riparian forest (Jenkins, 1993). Mixed-grass prairie is particularly dominant in the loess hills on the northern side of the Platte River. The most common grasses include *Agropyron smithii* (western wheatgrass), *Bouteloua gracilis* (blue gramma), *Panicum virgatum* (switchgrass), and *Elymus canadensis* (Canadian wildrye). Common forbs include *Amorpha canescens* (leadplant), *Aster ericoides* (white aster), *Ratibida pinnata* (prairie coneflower), Solidago missouriensis (Prairie goldenrod), *Chondrilla juncea* (skeltonweed), and *Erigeron strigosus* (daisy fleabane). Much of the original mixed-grass prairie is under cultivation or used for grazing cattle.

The tallgrass prairie, found in central and eastern Nebraska, is made up of upland and lowland prairies. Upland tallgrass prairie is dominated by *Andropogon gerardii* (big bluestem), *Schizachyrium scoparium* (little bluestem), *Panicum virgatum* (switchgrass), and *Sorghastrum nutans* (Indian grass). Characteristic forbs of the tallgrass prairie are *Helianthus rigidus* (stiff sunflower), *Silphium integrifolium* (rosin weed), *Silphium lacianatum* (compass plant), and *Liatris punctata* (dotted gayfeather) (Great Plains Flora Association, 1986). Lowland prairies are a combination of marshes, sedge meadows, and well-drained prairies. Many of these have been drained and cultivated. Dominate species include grasses such as *Andropogon gerardii* (big bluestem), *Sorghastrum nutans* (Indian grass), *Spartina pectinata* (prairie cordgrass), *Sporobolus asper* (tall dropseed), and *Panicum virgatum* (switchgrass), as well as sedges.

In the sandhills prairie, grass types include *Andropogon scoparius* (sand bluestem), *Schizachyrium scoparium* (little bluestem), *Calamovilfa longifolia* (sand reedgrass), *Stipa comata* (needle and thread), and *Panicum virgatum* (switchgrass), usually with an understory of *Koeleria macrantha* (junegrass), *Sporobolus cryptandrus* (sand dropseed), and grama grasses (Jenkins, 1993). On the windward side of dunes where blowouts occur, *Redfieldia flexuosa* (blowout grass) and *Muhlenbergia pungens* (sandhills muhly) act as stabilizers.

The floodplain or riparian forest communities have open canopies and are dominated by *Populus deltoides* (cottonwood) with an understory of *Juniperus virginiana* (red cedar) and *Cornus drummondii* (rough-leaf dogwood). Other species include: *Fraxinus pennsylvanica* (Green ash), *Celtis occidentalis* (hackberry), *Ulmus americana* (American elm), *Morus rubra* (red mulberry), and *Ulmus rubra* (slippery elm) (U.S. Fish and Wildlife Service, 1981). Common to the major river channels are low shrub islands and vegetated sandbars. *Salix amygdaloides* (peach-leaf willow), *Salix hindsiana* (sandbar willow), and *Dalea pulchra* (indigo bush) are the dominant shrub species. *Eragrostis* sp.(lovegrass), *Cyperus* sp.(nutsedge), *Echinochloa crusgalli* (barnyard grass), *Xanthium strumarium* (cocklebur), and scattered *Salix sp*. (willow) and *Populus deltoides* (cottonwood) seedlings characterize the vegetation on the low shrub islands and sandbars (Great Plains Flora Association, 1986).

Agriculture has transformed the pre-settlement landscape of the Platte River Basin. Agriculture represents the primary economic base of the study area and accounts for 97% of the Platte River Basin lands. Of this, 57.7% is used for pasture and range (U.S. Fish and Wildlife Service, 1981). The major crops include corn, wheat, soybeans, sorghum, and hay. Other crop types include oats, sugar beets, dry beans, sunflowers, and potatoes. Nearly two-thirds of the non-agricultural lands are urban developed areas. Remaining lands include privately owned irrigation and power structures, state and federal lands that are not cropped, canals, and other non-agricultural lands.

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 the study were (Table 1): irrigated & non-irrigated corn, irrigated sugar beets, irrigated & non-irrigated soybeans, irrigated & non-irrigated sorghum, irrigated & non-irrigated alfalfa, irrigated & non-irrigated small grains, summer fallow, irrigated and non-irrigated other agricultural crops (sunflower, potatoes, dry edible beans), range (grass/pasture/CRP), urban and built up areas, open water, riparian forest & woodlands, wetlands, 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 Soybeans	Soybeans are planted in May and are at full cover by July. They are harvested September through October.
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 Alfalfa	Alfalfa green-ups 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 Other Agricultural Crops	Includes Potatoes, Sunflowers, and Dry Edible Beans. Potatoes are planted in late April to early May, harvested September/October. Sunflowers are generally planted in May and harvested in October. 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.

Land Cover Classes	**General Description**
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 and Built up Areas	Areas including towns or cities with a population greater than 100 people. This class also includes built up areas such as feedlots.
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.
Roads	Interstate and highway roads.
Barren Areas	Areas with no vegetation, including blowouts and sandbars.

The land cover classes identified in the 1982 classification are slightly different than those in the 1997 and 2001 COHYST classifications. Other agricultural lands, such as feedlots and farmsteads, were not mapped in the 1982 classification. Due to the increased cell size in the Landsat MSS satellite imagery, these features were not easily identifiable in the imagery. When possible, these features were included in the Urban and Build Up Areas land cover class. Crop data obtained from 1982 grouped potatoes, sunflowers, and dry edible beans into one class. A new class, other agricultural crops, was developed to include these three crops instead of putting them in separate classes.

LITERATURE REVIEW

Remote Sensing of Land Cover

There are a variety of definitions available for remote sensing. The Canada Centre for Remote Sensing defines remote sensing as a ‘group of techniques for collecting image or other forms of data about an object from measurements made at a distance from the object, and the processing and analysis of the data’. Remote sensing systems acquire data at a variety of spatial, spectral, temporal, and radiometric resolutions, which make them extremely valuable for natural resource mapping and monitoring applications.

One important application is land use and land cover mapping. Since early in the 1970s, it was determined that general vegetation and land cover types could be mapped from satellite imagery faster and at a lower cost than with aerial photography (e.g., Belward and Hoyos, 1987; Campbell, 1981; Chuvieco and Congalton, 1988; Green, 1992). In recent years, more detailed vegetation classification studies have improved classification results utilizing satellite data with higher resolution.

Remote sensing of land cover is based on principles of interaction between matter and electromagnetic energy (EMR). “In principle, remote sensing systems could measure energy emanating from the earth’s surface in any sensible range of wavelengths (Richards et al., 1999).” Detection of changes in the amount and properties of EMR reflected or reradiated from matter allows for interpretation of land cover phenomena (Jensen, 1996). This basic principle enables various kinds of surface materials to be recognized and distinguished from each other by differences in spectral reflectance. These differences are also known as spectral signatures. While spectral signatures are often plotted as single lines (as in Figure 4), in reality they should appear more like “ribbons” since spectral reflectances vary somewhat within a given material type. The spectral signature of one tree species, for example, will not be identical to a different tree species, or even the same tree species. Variables such as the amount of total cover, the health and vigor of the plant, and changes in atmospheric conditions will cause differences in spectral responses. In spite of these external effects, there are general spectral patterns that emerge for different types of materials.

The visible and near infrared regions of the electromagnetic spectrum are frequently used for analysis of land cover types. The visible region, the portion of the spectrum our eyes can detect, determines what color an object appears to us. The visible region of the spectrum 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). For example, in the visible region of the spectrum, green grass appears green to us because it is reflecting green and absorbing blue and red light. On the other hand, an object appearing black is absorbing all three primary colors of the visible region while an object appearing white is reflecting all three primary colors of the visible region. The near-infrared region of the spectrum is energy beyond what our eyes can detect.

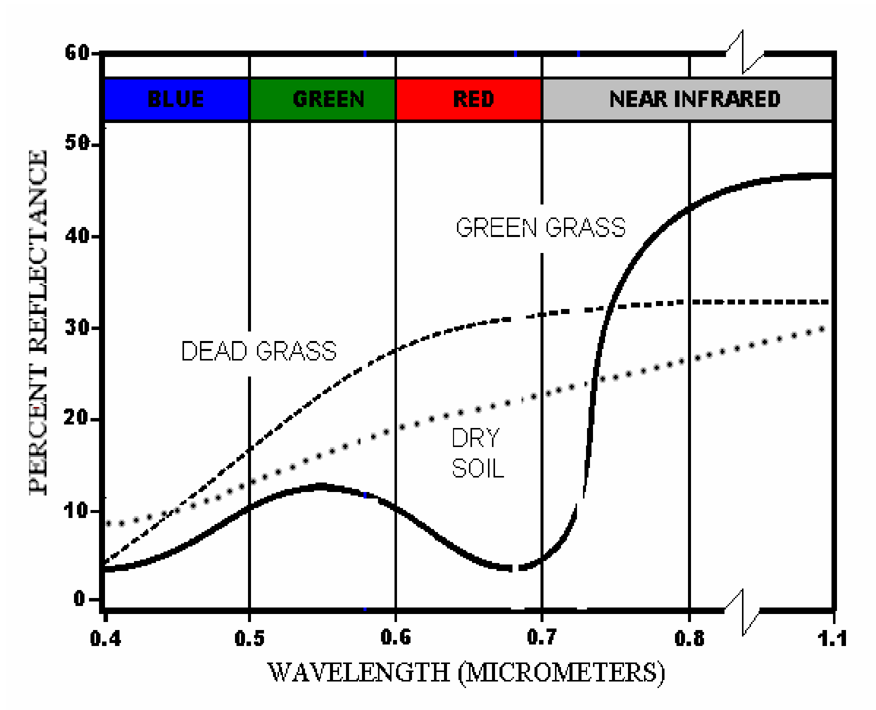


Figure 4. Spectral reflectance of Green Grass, Dead Grass and Dry Soil

(Adapted from the U.S. Geological Survey, 2002).

The near infrared region of the electromagnetic spectrum ranges from approximately 0.7 to 1.1 μm. Reflectance in the near infrared region is an indication of plant health and vigor. For example, the near-infrared region in Figure 4 depicts healthy green grass reflecting strongly while dead grass has a weaker reflectance in that range.

Near-infrared reflectance is based on a plants physiological structure and health. 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. This region is used to analyze, monitor and assess changes or differences among plants.

The general spectral signatures of green grass, dead grass, and dry soil illustrate a basic example of how remote sensing can delineate materials based on their reflectance signatures. Using spectral reflectance to differentiate materials, remote sensing can be used to evaluate, assess and inventory land cover types. Reflectance signatures of like materials tend to have similar spectral characteristics.

Absorption characteristics of vegetation vary due to seasonal cycles. Healthy green vegetation absorbs in the blue and red regions of the spectrum because of chlorophyll absorption bands in the blue and red regions (Gibson, 2000). Our eyes see green vegetation because of the high absorption of blue and red energy and the reflection of green energy. 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. For vegetation, spectral reflectance is highest in the range between 0.70 – 1.30 μm, as plant leaves typically reflect 40%-50% of the energy incident upon it (Lillesand and Kiefer, 2000).

These high reflectance values result from the internal structure of plant leaves. Algorithms used to extract information about vegetation from remotely sensed data are collectively known as vegetation indexes. Most vegetation indexes take into account these unique properties found in the spectral curves. Variations within the spectral curves provide insight into such things as the health, condition, and type of vegetation.

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, Estes, and Star, 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, monitoring of crop conditions, and delineating agricultural cover types.

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).

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 1982 for the land cover classification (see Table 2).

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.

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

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.

DeGloria (1984) compared Landsat MSS and TM for delineating agricultural and forest cover types in San Joaquin and Plumas Counties, California. The following cover types were investigated: sugar beets, alfalfa, mixed pasture, orchard, vineyard, grain stubble, bare soil, native vegetation, and several forest types. Although variation within agricultural fields, such as, canopy structure, soil moisture, surface roughness, and stages of crop development, pose classification challenges, the research concluded the added bands on the Landsat TM sensor improved delineation of crop types, especially in small fields (<5 ha). MSS imagery was less effective in discriminating different crop types, field and forest boundary conditions, road and stream networks in rough terrain, and small forest clearings (DeGloria, 1984).

Batista et al. (1985) evaluated the accuracy of Landsat MSS imagery for classifying corn and soybeans of 23 test sites in the Corn Belt. The study employed a systematic supervised sampling method where the pixel at every 10^{th} line and column was examined. If the pixel fell within a field, the cover type was identified by a ground inventory. One-half of the pixels within fields were chosen for classification while the remaining pixels were reserved for accuracy assessment. The overall accuracy of the classification was a 72.7%. Classification of smaller fields tended to be less accurate. Other factors affecting accuracy were the proportion of corn to soybeans, crop diversity, soil order, soil drainage class, yield, weather, position within the Corn Belt, and slope (Batista et al. 1985).

Serra et al. (2003) developed a post classification protocol for land cover and land use change detection in Northeast Spain. The research compared Landsat MSS imagery from the 1970s to TM imagery from the 1990s. Several challenges were noted in the comparison, mainly, the difference in spatial resolution of the two sensors—80m for MSS and 30m for TM imagery. This difference can complicate overlay analyses when the higher resolution sensor (TM) is capable of detecting features undetected by the coarser resolution sensor (MSS) (Serra et al. 2003). A hybrid classification using unsupervised methods was first employed, followed by a supervised classification, resulting in an accuracy of 85.1% (Serra et al. 2003).

A study classifying rural and urban land cover in the Midwest compared the quality of Landsat Thematic Mapper (TM) and MSS imagery. The TM imagery had few errors while noise in MSS imagery at times was problematic. Classification of TM imagery resulted in twice the classes of MSS data. This was primarily due to the greater number of bands and higher spatial resolution of the TM sensor. Fore example, TM imagery was capable of spectrally characterizing differences between roads, field edges and other small features, while MSS tended to mix these features, creating mixed pixels, therefore confusing features (Anuta et al. 1984).

While Landsat Thematic Mapper (TM) provides better spatial and spectral resolution for land cover classification, Landsat MSS (Multi-Spectral Scanner) data was the only option for this study. Since this classification was based on field data collected in 1982, Landsat MSS was the only data available. The TM sensor was not launched until the fall of 1982, missing the complete growing season for that year.

METHODS

Data Collection and Initial Processing

Satellite Data Acquisition and Image Preprocessing

To cover the entire study area, eleven Landsat 3 MSS path/row scenes were needed (see Figure 5). 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.

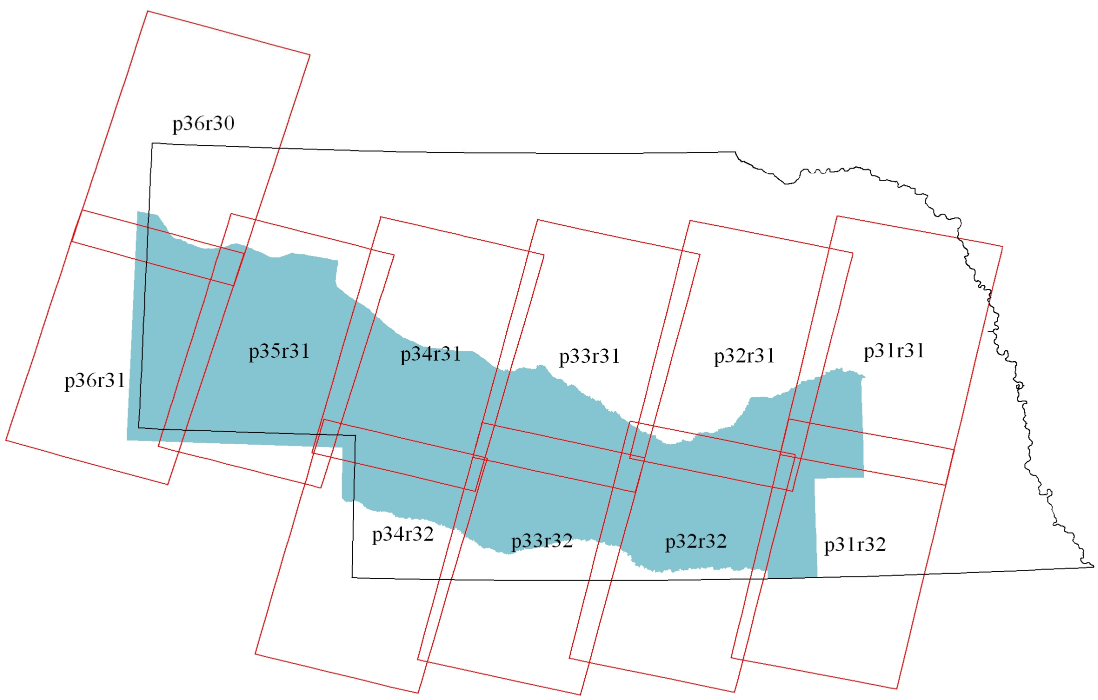


Figure 5. Landsat 3 MSS Coverage of the Study Area by Path/Row.

A total of 29 Landsat-3 MSS 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). All data were processed using MSS spectral Bands 4, 5, 6, and 7. Spectral band 8 (thermal infrared) was not used as it provides a measure of the amount of infrared radiant flux emitted from surfaces (Jensen, 1996). While other bands provide a measure of reflected energy, band 8 measures transmitted energy. All of the spectral bands available for Landsat 3 are listed in Table 4.

Table 3. Landsat 3 MSS Data used in Classification

No.	Path/Row	Date of Image Acquisition Year/month/day	Scene ID
1	31/32	4/13/1982	LM3031032008210390
	31/32	7/12/1982	LM3031032008219390
	31/32	9/22/1982	LM3031032008226590
2	31/31	4/13/1982	LM3031031008210390
	31/31	7/12/1982	LM 3031031008219390
	31/31	9/22/1982	LM 3031031008226590
3	32/31	7/31/1982	LM 3032031008221290
	32/31	1982/0607	LM3032031008215890
4	32/32	4/14/1982	LM 3032032008210490
	32/32	6/7/1982	LM 3032032008215890
	32/32	8/18/1982	LM 3032032008223090
5	33/31	5/3/1982	LM 3033031008212390
	33/31	8/1/1982	LM 3033031008221390
	33/31	8/19/1982	LM 3033031008223190
6	33/32	5/3/1982	LM 3033032008212390
	33/32	8/1/1982	LM 3033032008221390
	33/32	9/24/1982	LM 3033032008226790
7	34/31	5/22/1982	LM 3034031008214290
	34/31	7/15/1982	LM 3034031008219690
	34/31	8/2/1982	LM 3034031008221490
8	34/32	5/22/1982	LM 3034032008214290
	34/32	7/15/1982	LM 3034032008219690
9	35/31	6/28/1982	LM 3035031008217990
	35/31	7/16/1982	LM 3035031008219790
	35/31	8/3/1982	LM 3035031008221590
10	36/30	9/9/1982	LM3036030008225290
11	36/31	6/11/1982	LM3036031008216290
	36/31	7/17/1982	LM3036031008219890

Table 4. Characteristics of Landsat 3 MSS

Spectral Band	Spectral Range (μm)	Nominal Spectral Location	Ground Resolution (meters)
4	0.50 – 0.60	Visible Green	80
5	0.60 – 0.70	Visible Red	80
6	0.70 – 0.80	Near infrared	80
7	0.80 – 1.10	Mid-infrared	80
8	10.40 – 12.60	Thermal infrared	237

All images were re-projected to State Plane, zone 2600, NAD 83 datum, and a cell size of 187 feet. Further image rectification was performed on the imagery to achieve greater positional accuracy. Images were rectified using the 1993, 1:12,000 scale DOQQs and multiple Ground Control Points (GCPs). The Polynomial Geometric Model was used in the image-to-image rectification process and set was to an order of 2 or 3 depending on the spatial distortion of the Landsat images. For each Landsat image, 80-120 Ground Control Points were selected to match the corresponding locations on the DOQQ. The 2 and 3 order polynomial models were used to fit the Ground Control Points and transform all pixel locations of the image being rectified. The GCPs were evenly distributed throughout the Landsat MSS image. Features such as roads and airports served as effective GCP targets. The GCPs were further analyzed to lower the Root Mean Square (RMS) error. The lower the RMS error, the more accurate the spatial transformation. For all images, the RMS error of the model was calculated below 1.0. As a final step, the GCPs were reviewed to assure their spatial position relative to each associated point in the DOQQ and the satellite image.

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

Urban areas were identified using 1:100,000 scale Digital Raster Graphics (DRG). A DRG is a scanned image of a USGS topographic map. The scanned image includes all map collar information. The horizontal positional accuracy and datum of the DRG matches the accuracy and datum of the source map. The map is scanned at a minimum resolution of 250 dots per inch. Twenty- six scenes of 1:100,000-scale GRG images were downloaded from the UNL Conservation and Survey Division’s website (http://csd.unl.edu/csd/genlinfo/datasets. html). The DRGs were reprojected to Stateplane zone 2600, NAD 83. Once reprojected the collar information was clipped and adjacent DRGs coverng the entire study area were mosaiced and compressed into one file using Mr. SID compression software. Urban areas were on-screen digitized using the DRGs. These areas were then masked from the imagery. The original topographic maps for the study area were produced in 1985, which are in or close to 1982 when the Landsat MSS images were collected.

Correction for Image Line-Drops

A line-drop is a type of image noise, that happens to a number of adjacent pixels along a line or entire line contains spurious DNs (digital numbers). This is not uncommon in the Landsat MSS data, especially in Landsat 3 data. A frequently used technique to correct line-drops is replacing the defective pixels with average (or majority) DNs of adjacent pixels (Avery and Berlin 1992, Lillesand and Kiefer, 1994, p.537). This method, however, is only effective when the defective line is one or two pixels wide. When the line is more than three pixels wide, the pixels in the center of the line-drop can not obtain appropriate DN values estimated from the surrounding neighbor pixels.

Based on the principle that different bands of Landsat MSS data are correlated to each other, we designed a multiple regression procedure to correct line-drops. Because the DN of a pixel in a band is correlated to other bands, it can be predicted from those bands. The multiple regression procedure included the following steps: (1) Subset the defective image that covers line-drops; (2) Export the pixel values to tabular data format for each band; (3) In a statistical software (here we used SAS® software) to create multiple regression model using the correct pixel values:

$$DN_a = b_0 + b_1(DN_b) + b_2(DN_c) + b_3(DN_d) + \varepsilon$$

where DN_a is the DN of band containing line-drops, DN_b, DN_c and DN_d are DNs of other bands, b_0, b_1, b_2, and b_3 are regression coefficients. It is important to avoid multicollinearity (high dependency among predictor variables) in the regression analysis (Little et al. 1996). A stepwise procedure can be used to select useful predictor variables and create the best model, if multicollinearity is week. R^2 is a measure of the accuracy of the regression estimation; (4) Apply the regression function to the area of line-drop, then the regression-estimated DNs replace the defective DNs in the line-drop. Figures 6 and 7 show an example of a line-drop on Landsat MSS image (Path/Row 33/32, August 1, 1982). The defective pixels were replaced with the estimated DNs using a regression model.

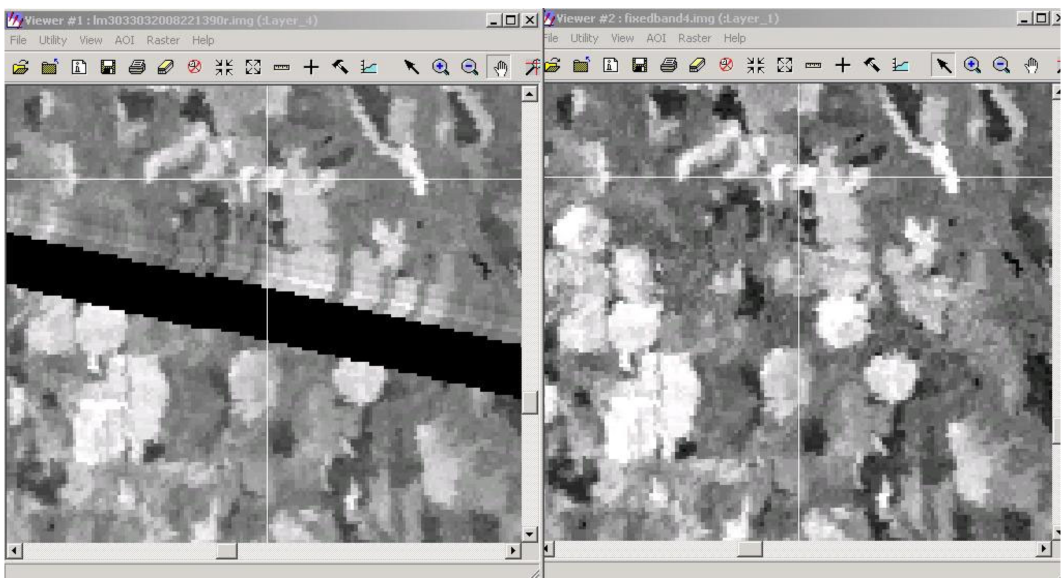


Figure 6. A close view of line-drop correction Landsat MSS image with regression method.

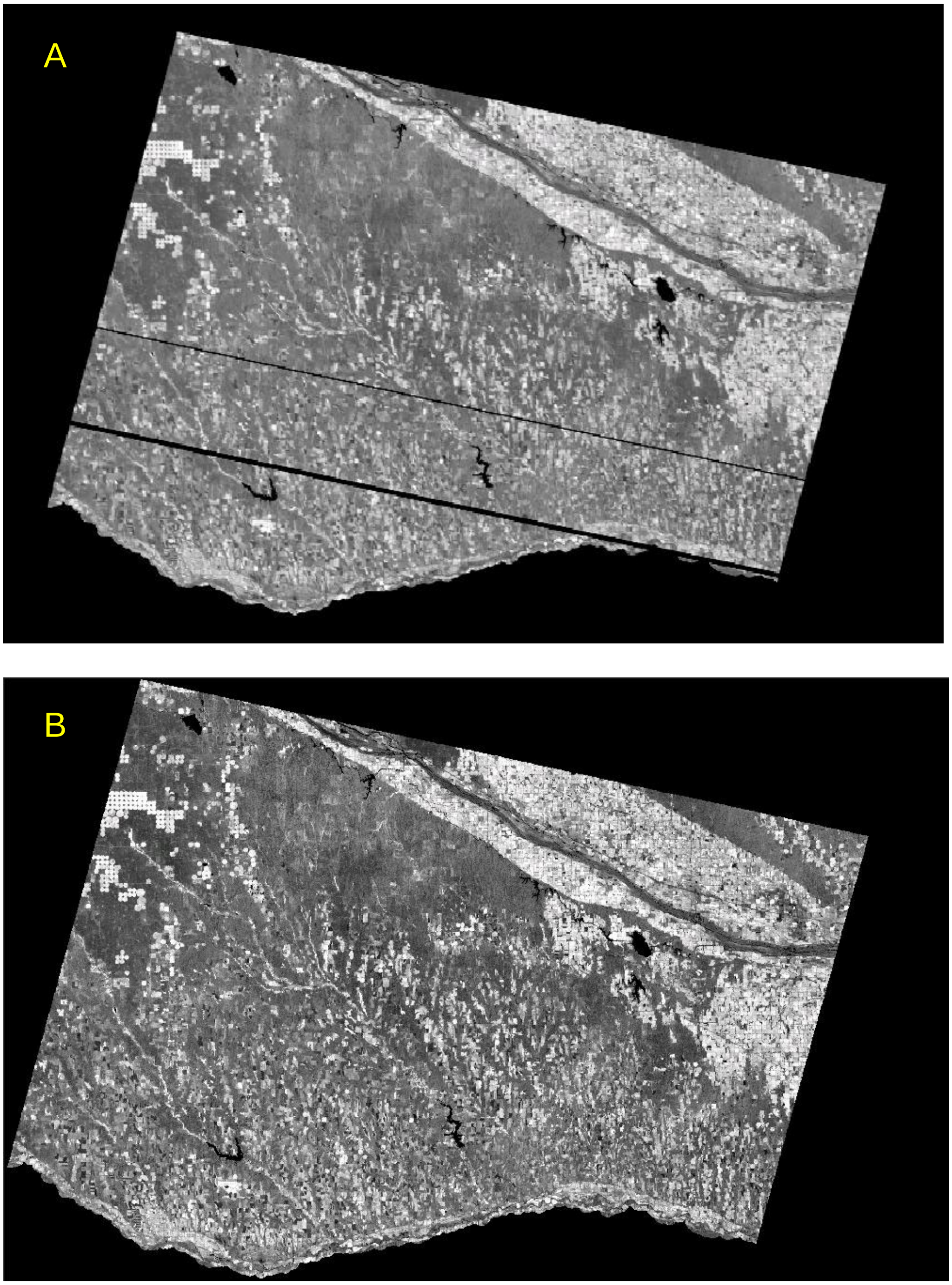


Figure 7. Line-drop correction for band 4 of Landsat MSS image with regression method. ***A: Image with line-drops. B: Image after line-drop correlation.***

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 12-band image for each scene.

Natural Resources Conservation Service Data

The Natural Resources Conservation Service (NRCS) provided the COHYST group with limited access to field data points from the 1982 growing season. These points were collected as part of the National Resources Inventory for Nebraska. The NRI field data points provide information on the location and type of crop or land cover found across the study area, as well as distinctions between irrigated and non-irrigated crop types. Over 8,000 field reference points were available for the study area. These points were randomly divided and approximately 6,000 of the points were used to drive the classification and 2,000 points were used for the accuracy assessment.

NRI field data points were used to locate training areas for the following land cover classes: Corn, Sugar Beets, Soybeans, Sorghum, Other Agricultural Crops (Dry Edible Beans, Potatoes, Sunflowers), Alfalfa, Small Grains, Range/Pasture, 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). The spectral and tonal variations in the imagery were used to help determine field boundaries. In some cases, 1993 Digital Ortho-photography were used to identify field boundaries.

Digital Orthophoto Quarter Quadrangles

Another source of land cover data were digital orthophoto quarter quadrangles (DOQQs). A digital orthophoto is 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. The DOQQs used in this project were developed from 1993 National Aerial Photography Program (NAPP) aerial photos mapped to 1:12,000 scale accuracy specifications. DOQQs have the positional accuracy of a map while providing the spatial detail of a photograph. Because of these features, DOQQs were used to locate training sites for open water and riparian forest and woodland areas.

1993 DOQQs were obtained from the Nebraska Department of Natural Resources and were re-projected to a common State Plane projection. The DOQQs were then mosaiced for the entire study area using MrSID image compression software. The 1993 MrSID files were mosaiced in three pieces due to the large file sizes. Since the DOQQ's 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.

Collecting Spectral Signatures by Land Cover Type

Spectral signatures were collected using three dates of imagery (Landsat MSS bands 5, 6, 7, and 8) combined into one 12-band image per scene. Spectral signatures were collected for the following land cover classes; corn, sugar beets, soybeans, sorghum, alfalfa, small grains, range/pasture, open water, riparian forest/woodlands, barren land, wetlands, other agricultural crops (dry edible beans, potatoes, sunflowers), and summer fallow. An example of spectral signatures collected for corn, sorghum, alfalfa, summer fallow, small grains and other natural vegetation is found in Figure 8. The x-axis represents the 12-layer image (four spectral band and three date imagery). The y-axis represents Brightness Value's. These spectral reflectance curves are characteristic of healthy vegetation. Chlorophyll strongly absorbs energy in the wavelength bands centered at about 0.45 and 0.67 μm. The internal structure of the plant leaves, specifically the mesophyll cells, reflects highly and in the region between 0.70 – 1.30 (near to mid-infrared) (Lillesand & Kiefer, 1994). The high reflectance values near to mid-infrared hand correspond with layers 3-4, 7-8, and 11-12 found in Figure 8.

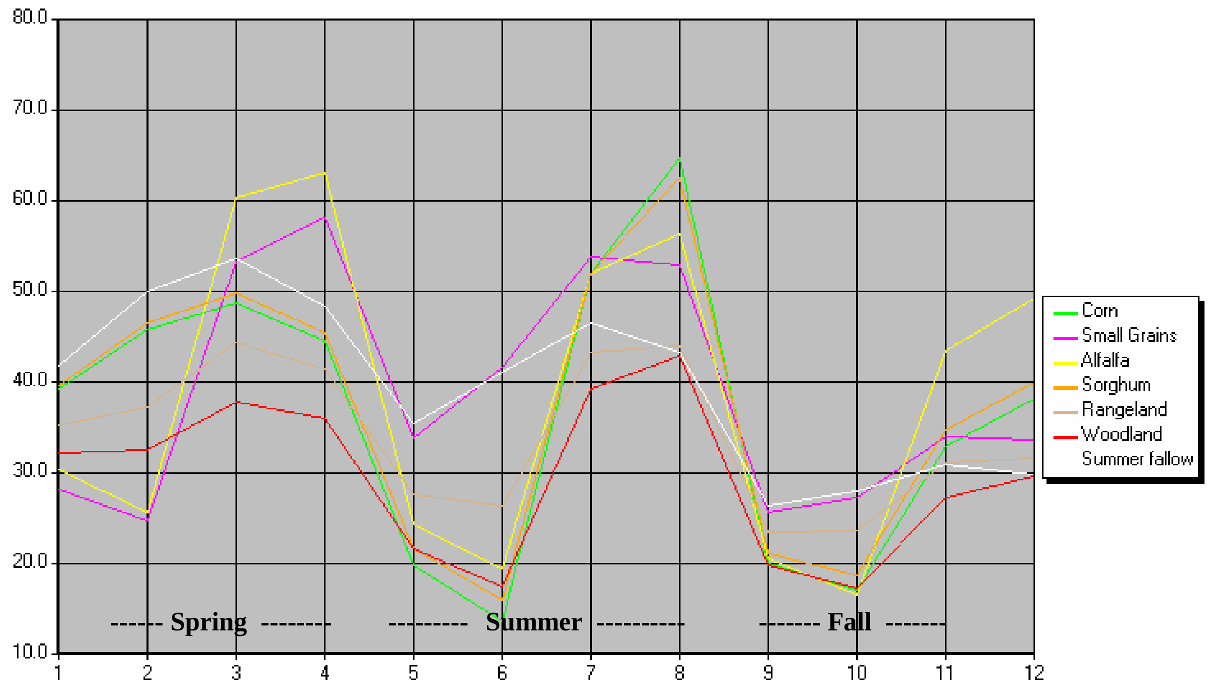


Figure 8. Spectral Reflectance Curves for Crops.

The seasonal dynamics of agricultural crops are evident in the spectral reflectance curves found in Figure 8. Supervised classifications incorporate these differences in crop phonologies 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).

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

Delineation of Water and Wetlands

In addition to the supervised classification method, we also applied the Normalized Difference Water Index (NDWI) (McFeeters, 1996) to delineate water bodies. The NDWI is defined as

$$NDWI = (GREEN - NIR)/(GREEN + NIR)$$

where GREEN and NIR are reflectance of green and near infrared bands, respectively. Because water strongly absorbs light in NIR, the reflectance is lower than the visible green band. As a result, water shows positive NDWI values, while soil and terrestrial vegetation demonstrates zero or negative values. The use of NDWI can enhance the presence of water features while eliminating the presence of soil and terrestrial vegetation features (McFeeters, 1996). In this project, the NDWI was method is mainly used as a supplementary method to delineate perennial rivers. Figure 7 is example of Platte River delineated with the NDWI method from Path 33/Row 31 summer scene. In Figure 7, Graphic A is a Landsat MSS color composite (bands 5, 6 and 8 displayed as blue, green and red) and Graphic B is a Binary image displaying river channels with perennial water.

In the study area, there are four categories of wetlands (Mitsch and Gosselink 1993, LaGrange, 1997): (1) Sandhill wetlands; (2) Riverine wetlands (e.g. Platte River Wetlands); (3) Palya wetlands (e.g., Rainwater Basin, Central Table, Southwest Wetlands); and (4) Saline/Alkaline Wetlands (e.g. Eastern Saline Wetlands). Each of the categories is comprised of subclasses (Cowardin et al. 1979): (1) Aquatic bed; (2) Submergents; (3) Emergents; (4) Rocky-unconsolidated bottom/shore; (5) Scrub-shrub; and (6) Upland forest. For this project, aquatic bed and submergents are classified as "open water"; upland forest and scrub-shrub wetlands are classified as "riparian forest/woodlands”. Therefore, “wetlands” only includes emergent wetlands and rocky-unconsolidated shore.

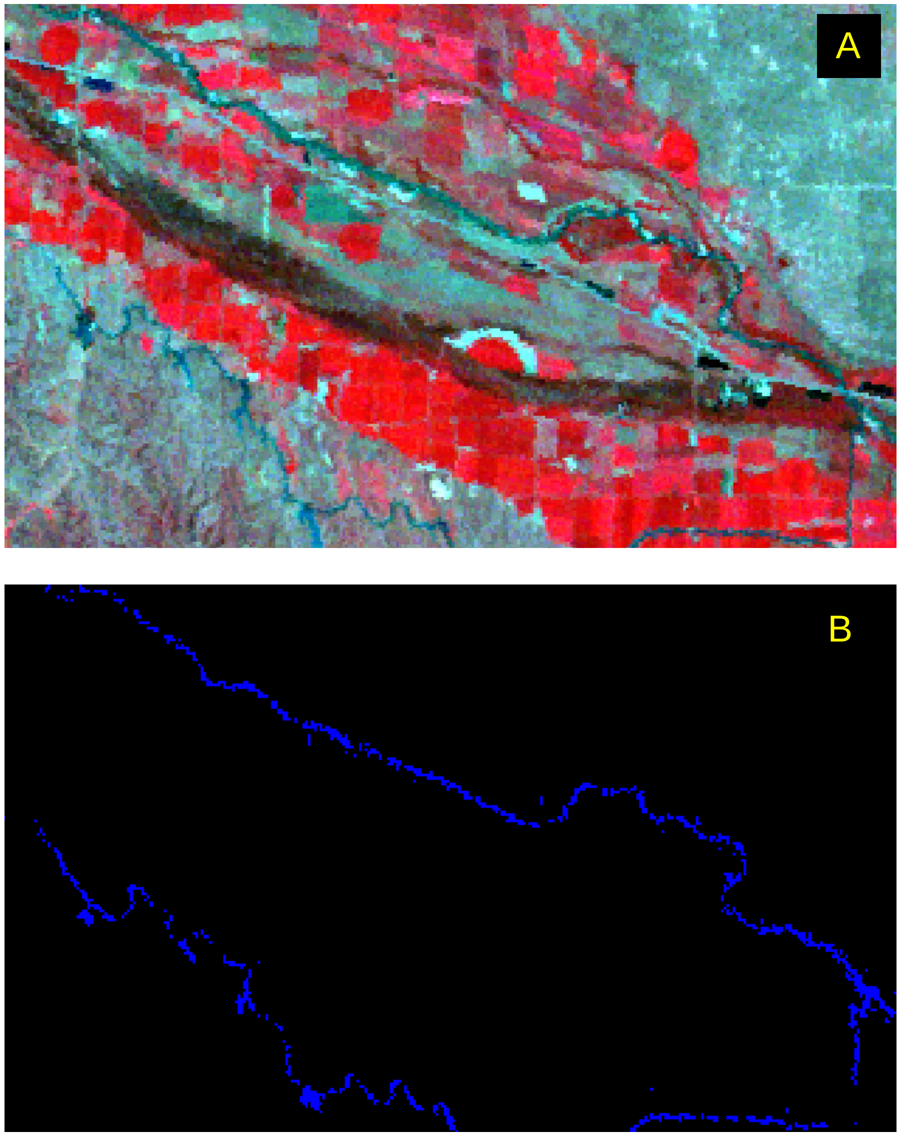


Figure 7. Delineating Water Bodies for Perennial Rivers with NDWI method

The modified NWI polygons were used as the training data in supervised classification for wetlands. Logical analysis was also used to delineate wetlands as a complementary method. The basic concept of logical analysis emergent wetlands is that the cover displays spectral vegetation features in summer, i.e., in the middle of growing season, but displays water features in spring. A logical analysis was performed for the Landsat MSS images:

if $NDWI_{spring} > 0$ AND $NDVI_{summer} > 0.2$,
then pixel = "wetlands",

where $NDWI_{spring}$ is NDWI image of spring date, $NDVI_{summer}$ is NDVI image of summer date.

Rocky-unconsolidated bottom/shore is the landforms such as beaches, bars and flats. The areas are flooded seasonally, especially in the early growing season (spring). This category can be identified using logical analysis:

if $NDWI_{spring} > 0$ AND $NDWI_{summer} \leq 0$,

then pixel = "wetlands",

where $NDVI_{summer}$ is NDWI image of summer date.

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 state, 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, 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 supervised classification based on the maximum likelihood decision rule was chosen for the classification of the 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).

The output of the classification resulted in 13 classes. The classes were as follows: Corn, Sugar Beets, Soybeans, Sorghum, Alfalfa, Small Grains, Range/Pasture/Grass, Barren Land (Blow-out), Open Water, Riparian Forest and Woodlands, Other Agricultural Crops and Wetlands. Irrigated or dryland crops were not distinguished in the supervised classification process. Irrigation information was collected at the field level and was added to the classification at a later stage.

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

After the initial classification, areas of mixed pixels were identified. This was done through visual inspection of the classification as well as in comparing the field data used to identify training sites for crops. Mixed pixels were reclassified using a technique referred to as “cluster busting” (Jensen, 1996). Mixed pixels were identified and masked from the raw MSS 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.

Unsupervised Classification

An unsupervised classification was run on scenes where less than three dates of imagery were available and on scenes with clouded areas. Unsupervised classification does not use training sites as a basis for the classification. Instead, the image is classified using mathematical algorithms that search for natural groupings of the spectral properties of pixels (Jensen, 1996).

Once the data were classified, the resulting clusters were identified based on the surrounding areas of overlap with the supervised classification. Clusters were also identified using ancillary data such as the NRI field data points used to identify training sites. Work was done to improve the classification of these areas and mixed pixels were reclassified using “cluster busting” techniques.

Post Classification Smoothing and Roads Addition

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 & 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.

After the filter was applied to the agricultural classes, a separate roads layer was added to the classification. Due to the large cell size of the MSS satellite data, roads were not able to be classified using the supervised classification. Roads identified in the 1997 COHYST land cover classification were overlaid onto the 1982 classification.

Identifying 1982 Irrigated Areas

1982 Center Pivot Inventory

Due to their unmistakable pattern across the study area, center pivots were visually interpreted using satellite imagery. Center pivot irrigation areas were identified using Landsat 3 MSS satellite imagery from 1982. Multi-date satellite imagery were collected across the study area to capture spring, summer and fall growing conditions. Center pivots were digitized on screen using ESRI software and were collected across the COHYST study area including a one kilometer buffer. Center pivots were checked for accuracy using registered irrigation well data current to 1982, land cover data provided by the Nebraska Natural Resources Conservation Service (NRCS) and the Nebraska Department of Natural Resources (NDNR). 1993 Digital Orthophoto Quarter Quadrangles were also used to help determine field boundaries.

Identifying Other Historic Irrigated Areas

Historic irrigation data were collected from a variety of sources. Maps were obtained from the Nebraska Department of Natural Resources (NDNR) and the Natural Resources Conservation Service (NRCS). The NDNR maps contain a detailed 1980 irrigation inventory for South Central Nebraska. These maps identify irrigated fields for the following counties: Dawson, Gosper, Phelps, Furnas, Harlan, Buffalo, Franklin, and Webster.

Irrigated areas for other counties were determined using data provided by the NRCS. NRCS land cover maps were developed for 27 counties within the COHYST study area. The source dates for these land cover maps range from 1977-1981 and the maps identify irrigated and non-irrigated cropland. Counties included are: Adams, Box Butte, Buffalo, Butler, Chase, Clay, Custer, Dawson, Franklin, Frontier, Furnas, Gosper, Hall, Hamilton, Harlan, Hayes, Hitchcock, Howard, Kearney, Nance, Nuckolls, Phelps, Platte, Polk, Red Willow, Webster, and York. For these counties it will be assumed that areas irrigated between 1977-1981 were also irrigated in 1982.

In some areas the 1997 irrigation layer previously developed by CALMIT was edited using the above mentioned historical sources and including the Pathfinder Irrigation District and other irrigation maps obtained from the Nebraska Department of Natural Resources. These paper maps identifying surface water irrigation rights were digitized using ArcInfo. The canal project maps include; 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. Maps were individually digitized and then merged into one map. Irrigation data was also obtained from the Central Nebraska Public Power and Irrigation District. This layer was checked for accuracy using 1982 NRCS field data and registered irrigation well data current to 1982. 1993 Digital Orthophoto Quarter Quadrangles and multi-date Landsat 3 satellite imagery were also used to help identify field boundaries.

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 mosaiced is shown in Table 7. 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. Urban areas defined using the 1985 Digital Raster Graphic data 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

Table 7. Mosaic Order of Classified Scenes

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

image and the irrigation map were compared and combined into one final map using the DOCELL command in ArcInfo GRID (see Figure 8). 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 dryland.

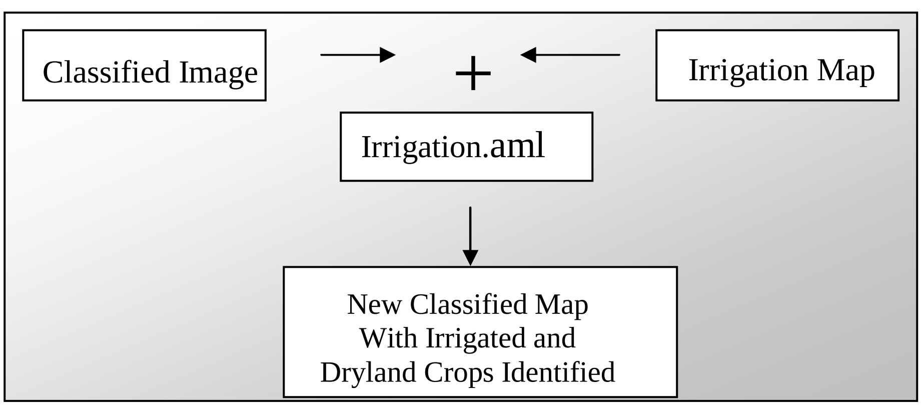


Figure 8. Flowchart of Irrigation Analysis to Create Final Map

This procedure was performed done for all agricultural classes excluding sugar beets. For this study, all sugar beets were considered to be irrigated as these crops rely entirely on irrigation.

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 & 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 & Green, 1999).

Reference data are key in determining the accuracy of the image as they are the benchmark for the comparison of correctly versus incorrectly classified pixels. Reference data were collected from the 1982 NRI field point data set aside for the accuracy assessment. For open water and riparian areas, random points were generated and 1993 DOQQs were used to label points that fell in areas of open water and in riparian woodland and forested areas.

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 & Kiefer, 2000). The error matrix derives overall accuracy by incorporating the major diagonal and excluding the omission and commission errors. The K_{HAT} statistic incorporates the non-diagonal elements of the error matrix as a product of row and column marginal (Jensen, 1996). 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 1982 land cover maps were produced in both digital and paper formats. An example of the final land cover classification is found in Figure 9. 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.

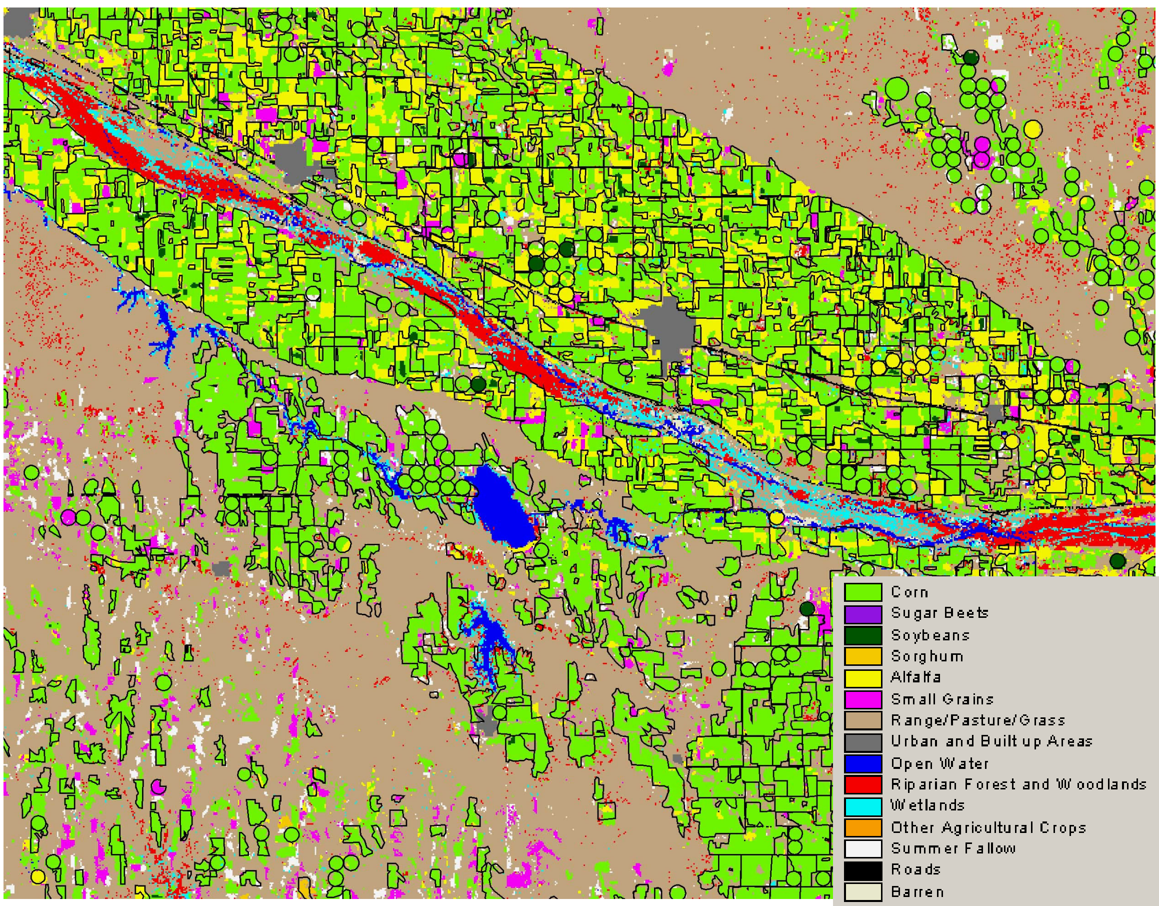


Figure 9. Example of 1982 Land Use Classification

Table 8 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 just over 50% of the study area. Irrigated Corn was the largest agricultural class representing 13.78% of the study area, followed by Dryland Small Grains (9.02%), Summer Fallow (7.89%), and Dryland Corn (6.36%). Crops representing smaller amounts of the project area and other land cover classes can be found in Table 8.

Table 8. 2001 Acreage Totals by Land Cover Class for the COHYST Study Area

Landcover Class	Acres	Percent of Total Study Area
Irrigated Corn	2,581,212.92	13.78%
Irrigated Sugar Beets	57,149.95	0.31%
Irrigated Soybeans	88,762.53	0.47%
Irrigated Sorghum	64,765.83	0.35%
Irrigated Alfalfa	247,198.36	1.32%
Irrigated Small Grains	104,026.58	0.56%
Range/Pasture/Grass	9,407,667.42	50.22%
Urban and Built up Areas	84,612.36	0.45%
Open Water	115,947.30	0.62%
Riparian Forest and Woodlands	503,617.05	2.69%
Wetlands	364,770.18	1.95%
Irr. Other Agricultural Crops	41,115.77	0.22%
Summer Fallow	1,474,482.77	7.87%
Roads	39,191.54	0.21%
Dryland Corn	1,190,702.57	6.36%
Dryland Soybeans	24,957.62	0.13%
Dryland Sorghum	142,280.28	0.76%
Dryland Other Agricultural Crops	10,216.75	0.05%
Dryland Alfalfa	335,362.68	1.79%
Dryland Small Grains	1,690,057.91	9.02%
Barren	164,663.70	0.88%

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

Accuracy Assessment of the Classified Imagery

An error matrix was computed to determine the accuracy of the classified satellite imagery. Table 9 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 74.07% and the overall K_{HAT} statistic was .6804. These accuracy results are considered better than average when taking into account the types of land cover classes identified in the historic classification and working with Landsat MSS data (Batista *et al.*, 1985, Congalton *et al*., 1998).

The land cover class that had the highest accuracy was Open Water (94.82%) followed by Range/Pasture/Grasslands (89.08%), Irrigated Corn (81.69%), Riparian Forest & Woodlands (75.93%), Dryland Small Grains (72.13%), Summer Fallow (71.94%). Classes with less than 60% accuracy included Irrigated Other Agricultural Crops (58.03%), Irrigated Alfalfa (42.67%), Dryland Sorghum (41.94%), Irrigated Soybeans (40.83%), Dryland Soybeans (40%), Irrigated Sugar Beets (35.39%), Irrigated Small Grains (34.17%), Dryland Corn (29.65%), Dryland Alfalfa (18.70%), Irrigated Sorghum (18.06%). Explanations for the lower accuracies are presented in the error matrix in Table 10.

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 cover crops can also be explained by examining the error matrix.

Looking at the Dryland Corn classification, the bulk of the error arose from the Dryland Corn class mixing with Irrigated Corn and Dryland Sorghum. Thirty-five Irrigated Corn, and 22 Dryland Sorghum reference points fell on pixels classified as Dryland Corn.

The errors found in Irrigated and Dryland Alfalfa, Irrigated and Dryland Soybeans, Irrigated Sorghum, Irrigated Sugar Beets, and Irrigated Other Agricultural Crops result from the small number of reference points available for the analysis (See

Table 11). The lack of reference points for these classes hindered the classification and lowered the classification accuracies.

Table 9. Accuracy Totals by Land Use Type

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Overall Accuracy
Irrigated Corn	470	417	361	76.81%	86.57%	81.69%
Irrigated Sugar Beets	10	13	4	40.00%	30.77%	35.39%
Irrigated Soybeans	12	30	7	58.33%	23.33%	40.83%
Irrigated Sorghum	23	13	3	13.04%	23.08%	18.06%
Irrigated Alfalfa	25	15	8	32.00%	53.33%	42.67%
Irrigated Small Grains	21	20	7	33.33%	35.00%	34.17%
Range, Pasture, Grass	528	579	492	93.18%	84.97%	89.08%
Urban Land	0	0	0	---	---	---
Open Water	78	76	73	93.59%	96.05%	94.82%
Riparian Forest & Woodlands	98	76	65	66.33%	85.53%	75.93%
Wetlands	0	30	0	---	---	---
Irrigated Other Agricultural Crops	35	13	11	31.43%	84.62%	58.03%
Summer Fallow	136	131	96	70.59%	73.28%	71.94%
Roads	0	0	0	---	---	---
Dryland Corn	23	96	11	47.83%	11.46%	29.65%
Dryland Soybeans	10	6	3	30.00%	50.00%	40.00%
Dryland Sorghum	65	27	16	24.62%	59.26%	41.94%
Dryland Other Agricultural Crops	0	2	0	---	---	---
Dryland Alfalfa	20	23	4	20.00%	17.39%	18.70%
Dryland Small Grains	185	168	127	68.65%	75.60%	72.13%
Barren	0	4	0	---	---	---
Totals	1739	1739	1288			
Overall Classification Accuracy = 74.07% Overall Kappa Statistics = 0.6804						

Table 10. Error Matrix for the 2001 Land Use Classification

Classified Data									Reference	Data	Data									
	Irr Corn	Irr SB	Irr Soy	Irr Sorgh.	Irr Alf	Irr Sm Grain	Range	Open Water	Riparian& Woodlands	Wetlnds	Irr Other Crops	Summer Fallow	Dry Corn	Dry Soy	Dry Sorgh	Dry Other Crops	Dry Alfa	Dry Sm Grains	Barren	Row Total
Irr Corn	**361**	1	2	10	7	4	3	0	1	0	14	2	4	1	3	0	0	4	0	417
Irr S. Beets	4	**4**	0	0	0	0	1	0	0	0	4	0	0	0	0	0	0	0	0	13
Irr Soybeans	17	0	**7**	1	0	0	1	0	1	0	0	0	0	3	0	0	0	0	0	30
Irr Sorghum	7	0	0	**3**	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	13
Irr Alfalfa	4	0	0	0	**8**	0	0	0	0	0	1	0	0	0	0	0	2	0	0	15
Irr Sm Grains	4	0	0	0	1	**7**	0	0	0	0	1	2	0	0	0	0	0	5	0	20
Range /Pasture	23	0	1	1	0	3	**492**	1	8	0	0	8	4	1	13	0	9	15	0	579
Open Water	0	0	0	0	0	0	0	**73**	3	0	0	0	0	0	0	0	0	0	0	76
Riparian & Wood.	3	0	0	0	0	0	8	0	**65**	0	0	0	0	0	0	0	0	0	0	76
Wetlands	1	0	0	0	1	0	9	4	15	0	0	0	0	0	0	0	0	0	0	30
Irr Other Crops	0	2	0	0	0	0	0	0	0	0	**11**	0	0	0	0	0	0	0	0	13
Sum Fallow	3	2	0	1	0	0	1	0	0	0	1	**96**	1	0	3	0	1	22	0	131
Dry Corn	35	1	2	3	0	0	3	0	3	0	0	7	**11**	1	22	0	2	6	0	96
Dry Soybean	1	0	0	0	1	0	0	0	0	0	0	0	0	**3**	0	0	0	1	0	6
Dry Sorghum	1	0	0	3	0	1	0	0	0	0	0	0	0	1	**16**	0	1	4	0	27
Dry Other Crops	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
Dry Alfalfa	4	0	0	0	6	1	4	0	2	0	0	0	0	0	1	0	**4**	1	0	23
Dry Sm Grains	2	0	0	1	1	5	2	0	0	0	0	21	3	0	5	0	1	**127**	0	168
Barren	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	4
Column Total	470	10	12	23	25	21	528	78	98	0	35	136	23	10	65	0	20	185	0	1739

Table 11. Reference Point Totals for Crops with Lower Accuracies

Class Name	Reference Totals
Irrigated Sugar Beets	10
Irrigated Soybeans	12
Irrigated Sorghum	23
Irrigated Alfalfa	25
Irrigated Small Grains	21
Irrigated Other Agricultural Crops	35
Dryland Corn	23
Dryland Soybeans	10
Dryland Other Agricultural Crops	0
Dryland Alfalfa	20

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 1982 NRCS NRI reference points 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 1,034 randomly collected reference points were used for this analysis. The overall classification accuracy for the irrigation layer was calculated at 87.23% (Table 12). More detail about the accuracy assessment can be found in the error matrix (Table 13).

Table 12. Accuracy Totals For 1982 Irrigation Layer

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Overall Accuracy
Irrigated Pixels	570	488	463	81.23%	94.88%	88.06%
Dryland Pixels	464	546	439	94.61%	80.40%	87.51%
Totals	1034	1034	902			
Overall Classification Accuracy = 87.23%						
Overall Kappa Statistics = 0.7461						

Table 13. Error Matrix for 1982 Irrigation Layer

Classified Data	Irrigated Pixels	Dry Land Pixels	Row Totals
Irrigated Pixels	463	25	488
Dry Land Pixels	107	439	546
Column Totals	570	464	1034

Accuracy Totals for Eastern, Central and Western Sections of the Study Area

Land cover types vary across the study area, this becomes especially apparent when comparing individual land cover acreage totals between counties. In light of these differences, further information can be obtained by performing the accuracy assessment on separate sections of the study area. To do this, the study area was broken into three sections representing western, central and eastern areas. These three areas were selected to represent similar areas designated for the COHYST eastern, central, and western hydrologic modeling units. See Figure 10.

Accuracy totals for the three sections showed the western section with the highest overall accuracy at 80.40%, followed by the central section at 77.96%, while the eastern section had the lowest accuracy at 67.17%. These totals were somewhat surprising, since the western section had proved to be the most difficult to classify. One possible reason for these differences can be found in the number and variety of land cover classes in each section; western section had the lowest number of land cover classes at 11 compared to 13 for the central and 14 for the eastern. Classification in the eastern and central sections were complicated by cloud cover in the summer image dates. This lowered the accuracy for summer crops such as sorghum and alfalfa.

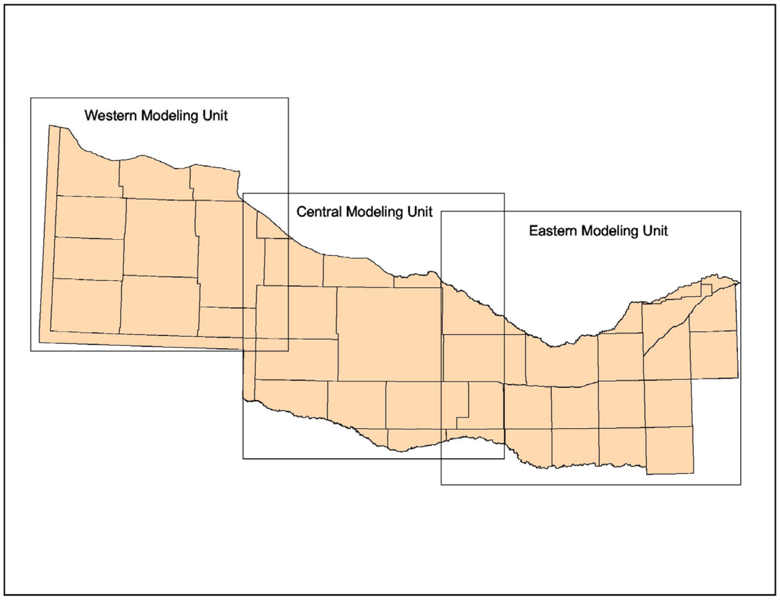


Figure 10. COHYST Study Area and Modeling Units

Table 14. Accuracy Totals for Western Section

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Overall Accuracy
Irrigated Corn	22	33	13	59.09%	39.39%	49.24%
Irrigated Sugar Beets	10	13	4	40.00%	30.77%	35.39%
Irrigated Soybeans	0	0	0	---	---	---
Irrigated Sorghum	0	0	0	---	---	---
Irrigated Alfalfa	6	5	3	50.00%	60.00%	55.00%
Irrigated Small Grains	6	9	3	50.00%	33.33%	41.67%
Range, Pasture, Grass	263	256	244	92.78%	95.31%	94.05%
Urban Land	0	0	0	---	---	---
Open Water	62	59	57	91.94%	96.61%	94.28%
Riparian Forest & Woodlands	28	18	14	50.00%	77.78%	63.89%
Wetlands	0	15	0	---	---	---
Irrigated Other Agricultural Crops	30	12	10	33.33%	83.33%	58.33%
Summer Fallow	87	86	69	79.31%	80.23%	79.77%
Roads	0	0	0	---	---	---
Dryland Corn	0	5	0	---	---	---
Dryland Soybeans	0	0	0	---	---	---
Dryland Sorghum	0	0	0	---	---	---
Dryland Other Agricultural Crops	0	0	0	---	---	---
Dryland Alfalfa	3	6	0	0%	0%	0.00%
Dryland Small Grains	90	85	71	78.89%	83.53%	81.21%
Barren	0	4	0	---	---	---
Totals	607	607	488			
Overall Classification Accuracy =	80.40%					
Overall Kappa Statistics = 0.7425						

Table 15. Accuracy Totals for Central Section

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Overall Accuracy
Irrigated Corn	96	92	80	83.33%	86.96%	85.15%
Irrigated Sugar Beets	1	0	0	---	---	---
Irrigated Soybeans	0	1	0	---	---	---
Irrigated Sorghum	2	1	0	0%	0%	0%
Irrigated Alfalfa	9	7	4	44.44%	57.14%	50.79%
Irrigated Small Grains	6	5	1	16.67%	20.00%	18.34%
Range, Pasture, Grass	194	202	182	93.81%	90.10%	91.96%
Urban Land	0	0	0	---	---	---
Open Water	19	20	19	100.00%	95.00%	97.50%
Riparian Forest & Woodlands	30	25	24	80.00%	96.00%	88.00%
Wetlands	0	5	0	---	---	---
Irrigated Other Agricultural Crops	8	1	1	12.50%	100.00%	56.25%
Summer Fallow	52	49	36	69.23%	73.47%	71.35%
Roads	0	0	0	---	---	---
Dryland Corn	6	24	2	33.33%	8.33%	20.83%
Dryland Soybeans	0	0	0	---	---	---
Dryland Sorghum	7	1	0	0%	0%	0.00%
Dryland Other Agricultural Crops	0	1	0	---	---	---
Dryland Alfalfa	7	6	2	28.57%	33.33%	30.95%
Dryland Small Grains	62	57	38	61.29%	66.67%	63.98%
Barren	0	2	0	---	---	---
Totals	499	499	389			

Overall Classification Accuracy = 77.96%
Overall Kappa Statistics = 0.7163

Table 16. Accuracy Totals for Eastern Section

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Overall Accuracy
Irrigated Corn	378	322	291	76.98%	90.37%	83.68%
Irrigated Sugar Beets	0	0	0	---	---	---
Irrigated Soybeans	12	29	7	58.33%	24.14%	41.24%
Irrigated Sorghum	22	12	3	13.64%	25.00%	19.32%
Irrigated Alfalfa	13	3	1	7.69%	33.33%	20.51%
Irrigated Small Grains	9	8	3	33.33%	37.50%	35.42%
Range, Pasture, Grass	128	184	120	93.75%	65.22%	79.49%
Urban Land	0	0	0	---	---	---
Open Water	10	11	10	100.00%	90.91%	95.46%
Riparian Forest & Woodlands	54	44	38	70.37%	86.36%	78.37%
Wetlands	0	12	0	---	---	---
Irrigated Other Agricultural Crops	0	0	0	---	---	---
Summer Fallow	12	7	1	8.33%	14.29%	11.31%
Roads	0	0	0	---	---	---
Dryland Corn	19	76	10	52.63%	13.16%	32.90%
Dryland Soybeans	10	6	3	30.00%	50.00%	40.00%
Dryland Sorghum	61	27	16	26.23%	59.26%	42.75%
Dryland Other Agricultural Crops	0	0	0	---	---	---
Dryland Alfalfa	14	14	3	21.43%	21.43%	21.43%
Dryland Small Grains	50	37	26	52.00%	70.27%	61.14%
Barren	0	0	0	---	---	---
Totals	792	792	532			

Overall Classification Accuracy = 67.17%
Overall Kappa Statistics = 0.5651

Causes of Lower Accuracies and Sources of Error

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

Although the NRCS NRI field point data were the best available choice for ground truth on crop types, in some cases these records did not provide sufficient information. There were not enough field points to provide an adequate classification and accuracy assessment of the following crops; soybeans, sugar beets, and other agricultural crops (sunflowers, potatoes, dry edible beans). Often the NRI points fell outside of field boundaries and many points had to be eliminated due to problems with their spatial accuracy.

Problems with the Landsat MSS satellite imagery also added to the lower accuracies. Due to its larger cell size, more detailed features could not be classified. The cell size of the MSS data is about double the size of the Landsat Thematic Mapper (TM) used in the 1997 and 2001 COHYST classification. Errors present in the MSS imagery, such as line drops, increased the error since imagery was missing for some areas and had to be interpolated using statistical techniques. The Landsat MSS sensor does not have a robust spectral range when compared to Landsat TM. Since MSS does not have the spectral range within the visible blue, near and mid-infrared spectral bands, vegetation classifications prove more difficult. Once significant problem was that the classification was unable to clearly separate sorghum from corn. This resulted in low accuracy for the sorghum class. Soybeans, in addition, proved difficult to classify.

Although the classification techniques used were based on standard procedures (Jensen, 1996, Lillesand & 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.

1982, 1997 and 2001 Land Cover Comparisons

Overview of Change Detection Techniques

Change detection can be defined as the process of identifying differences in the state of an object or phenomenon by observing it at different times, and involves the ability to quantify temporal effects using multi-temporal data. Change detection techniques aim to detect changes in images over time. They rely upon differences in radiance values or spectral homogeneity. These differences may be due to an actual change in land cover, or differences in illumination, atmospheric conditions, vegetation phenology changes, ground moisture conditions and differences in the registration of the two classified images. (Singh, 1989). Remote sensing change detection techniques can be categorized into two basic approaches, pre-classification and post-classification.

The pre-classification approach incorporates the simultaneous analysis of multi-temporal data sets. There are a variety of methods used in this type of analysis, these including composite analysis, image differencing, principal component analysis, change vector, and spectral analysis methods (Lunetta & Elvidge 1998)

The most commonly used change detection approach is post-classification. This approach incorporates independently produced thematic classifications of imagery from different dates, followed by a comparison of the corresponding pixel (thematic) labels to identify areas where change has occurred. This was the method employed to determine the amount of change between 1982-2001 in the COHYST study area.

While the post-classification approach is the most common, one main disadvantage of this approach is that errors in classifications can have compounding effects (Pilon et al., 1988). One basic assumption in performing a post-classification change detection analysis is that the input classifications were generated using exactly similar methods. Another assumption is that the satellite images used to generate the classifications were not affected by differences in geometric rectification, atmospheric conditions, illumination and viewing angle, changes in precipitation, and soil moisture levels.

Land Cover Comparisons

The post-classification change detection approach was employed to determine the amount of change between 1982 and 2001 in the COHYST study area. The total acreage of each land cover class within each county and for the entire study area was compared using the three separate classified images from 1982, 1997 and 2001. Results for each land cover class are found in Table 17. Potatoes, Sunflowers, and Dry Edible Beets identified in the 2001 classification were merged into the Other Agricultural Crops land cover class. Other agricultural lands and barren areas were merged into the range class.

Table 17. 1982 and 2001 Acreage Change Comparisons

Landcover Class	1982 Acres	1997 Acres	2001 Acres	Acres Change 1982-2001	Change as a % of Study Area
Irrigated Soybeans	88,762.53	431,108.77	869,423.77	780,661.24	4.17%
Range, Pasture, Grass	9,736,994.81	9,066,471.87	10,060,999.07	324,004.26	1.73%
Dryland Soybeans	24,957.62	244,494.77	250,016.50	225,058.88	1.20%
Dryland Other Agricultural Crops	10,216.75	95,257.41	85,666.55	75,449.80	0.40%
Irrigated Other Agricultural Crops	41,115.77	99,059.93	115,150.28	74,034.51	0.40%
Irrigated Small Grains	104,026.58	165,776.67	154,229.08	50,202.50	0.27%
Irrigated Alfalfa	247,198.36	216,370.76	294,194.55	46,996.19	0.25%
Open Water	115,947.30	124,991.50	122,989.43	7,042.14	0.04%
Roads	39,191.54	68,998.85	45,583.11	6,391.57	0.03%
Urban Land	84,612.36	114,376.14	87,914.76	3,302.41	0.02%
Dryland Sorghum	142,280.28	327,852.92	126,737.39	-15,542.89	-0.08%
Irrigated Sugar Beets	57,149.95	62,235.76	39,413.41	-17,736.54	-0.09%
Irrigated Sorghum (Milo, Sudan)	64,765.83	76,963.18	41,085.48	-23,680.35	-0.13%
Irrigated Corn	2,581,212.92	2,805,143.38	2,473,506.80	-107,706.13	-0.57%
Wetlands	364,770.18	379,004.10	255,247.34	-109,522.83	-0.58%
Dryland Alfalfa	335,362.68	325,952.77	214,621.46	-120,741.22	-0.64%
Riparian Forest and Woodlands	503,617.05	413,848.47	321,507.70	-182,109.35	-0.97%
Dryland Corn	1,190,702.57	815,201.69	830,754.81	-359,947.76	-1.92%
Dryland Small Grains	1,690,057.91	1,549,941.19	1,292,138.50	-397,919.41	-2.12%
Summer Fallow	1,474,482.77	1,101,736.83	948,599.85	-525,882.91	-2.81%

The largest increase in crops acreage was found in Irrigated Soybeans (+780,661 acres), Dryland Soybeans (+225,058 acres), Dryland Other Agricultural Crops (+75,449 acres), and Irrigated Other Agricultural Crops (+74,034 acres). The largest decrease in crop acreage was calculated for Dryland Small Grains (-397,919 acres), Dryland Corn (-359,947 acres), and Summer Fallow (525,882 acres).

These changes were also identified by the Nebraska Agricultural Statistics Service (NASS). According to their records, irrigated soybeans increased more than any crop between the years 1982 and 2001 across the state (+1,800,000 acres). The crop that had the greatest decline between the years 1982 and 2001 was irrigated and non-irrigated wheat (-1,150,000 acres).

Other acreage changes, such as open water and wetlands, could be attributed to changes in classification techniques used in the 1982 and 2001 classifications. These acreage differences can also result from the increased cell size of the MSS satellite imagery used to derive the 1982 classification.

Table 18. 1982 and 2001 NASS Acreage Change Comparisons for Nebraska

(Nebraska Agricultural Statistics Service, 1982, 2002)

Crop	1982 Acres	1997 Acres	2001 Acres	Acreage Change 1982-2001
Irrigated Alfalfa	385,000	335,000	440,000	55,000
Irrigated Corn	4,740,000	5,557,000	4,730,000	-10,000
Irrigated Sorghum	210,000	32,000	49,000	-161,000
Irrigated Soybeans	420,000	1,070,000	2,220,000	1,800,000
Non-Irrigated Alfalfa	1,215,000	965,000	1,010,000	-205,000
Non-Irrigated Corn	2,500,000	3,343,000	3,370,000	870,000
Non-Irrigated Sorghum	1,550,000	868,000	501,000	-1,049,000
Non-Irrigated Soybeans	1,830,000	2,530,000	2,730,000	900,000
Oats	460,000	160,000	155,000	-305,000
Sugar Beets	45,400	673,000.00	486,000.00	440,600
Wheat (Irr & non-irr)	2,900,000	2,000,000	1,750,000	-1,150,000

County Land Cover Comparisons

Changes in acreage of agricultural crops at the county level also reflected these trends. Similar to the 1997 and 2001 acreage comparisons, a majority of the counties which had a decrease in irrigated corn acreage saw a corresponding increase in irrigated soybean acreage. The counties that had the highest increases in irrigated soybean acreage between 1982 and 2001 included: Phelps (+93,263 acres), Kearney (+63,988 acres), York

(+58,236 acres), Clay (+57,153 acres), and Hamilton (+56,250 acres). County acreage change totals for all crops are listed by county in Appendix C.

Non-irrigated small grains acreage totals decreased across the study area. The counties with the largest decrease included: Webster (-28,180), Perkins (-56,918 acres), Nuckolls (-49,005 acres), Keith (-34,273 acres), and Banner (-25,966 acres) Counties.

Non-irrigated sorghum acreage totals also decreased across the study area between 1982 and 2001. The counties with the largest decrease included: Franklin (-18,098), Nuckolls (-10,573 acres), and York (-5,896 acres) Counties.

Irrigation Estimates and Comparisons

Between 1982 and 2001 irrigation rates increased across the study area. Overall, the increase was estimated at 755,536 acres, representing over four percent of the total study area. Areas irrigated in 1982 were not always irrigated in 2001, as crop patterns change over time. Table 19 outlines the extent of the change in irrigated acres in the study area within the Nebraska border between the years 1982, 1997, and 2001.

Table 19. 1982, 1997 and 2001 Irrigation Estimate Comparisons

Category	Acres	Percent of Study Area
Irrigated in 1982 Only	328,337.59	1.84%
Irrigated in 1997 Only	240,924.35	1.35%
Irrigated both in 1982 & 1997	195,834.34	1.10%
Irrigated in 2001 Only	324,750.32	1.82%
Irrigated in both 1982 & 2001	210,984.64	1.18%
Irrigated both in 1997& 2001	954,958.12	5.35%
Irrigated in 1982,1997, & 2001	2,419,911.21	13.55%
Total 1982 Irrigated Areas	3,155,067.78	17.66%
Total 1997 Irrigated Areas	3,811,628.02	21.34%
Total 2001 Irrigated Areas	3,910,604.29	21.89%
Irrigation Increase 1982-2001:	755,536.51	4.23%

The county that had the greatest increase in irrigated acres between 1982 and 2001 was York County, (+64,021), followed by Box Butte (+50,928), Polk (+46,576) and

Chase (+40,340) Counties. Only four counties had a decrease in irrigated acres, these were Arthur County (-1,764), Garden County (-1,149), Grant County (-722), and McPherson County (-641). Irrigation comparisons for all counties are listed in Table 20.

Table 20. 1982, 1997, & 2001 County Irrigation Comparisons

County	1982 Irrigated Acres	1997 Irrigated Acres	2001 Irrigated Acres	Acreage Change 1982-2001
Adams	148,648.97	179,591.99	183,149.90	34,500.94
Arthur*	9,680.66	9,516.03	7,915.78	-1,764.88
Banner	15,878.88	23,971.66	22,452.23	6,573.34
Box Butte*	56,745.73	101,968.94	107,674.03	50,928.30
Buffalo*	162,054.50	200,600.98	199,565.64	37,511.14
Chase*	75,318.72	120,389.96	115,659.42	40,340.70
Cheyenne	30,666.79	47,739.20	49,609.91	18,943.12
Clay	152,691.74	184,188.46	178,340.73	25,648.99
Custer*	40,252.72	48,128.22	48,507.37	8,254.64
Dawson	218,833.14	217,367.32	238,361.99	19,528.84
Deuel	17,363.21	19,439.82	18,725.33	1,362.12
Franklin*	64,893.89	79,134.36	84,088.57	19,194.68
Frontier	45,877.77	51,420.37	60,783.36	14,905.60
Furnas*	19,973.03	20,389.78	25,116.30	5,143.27
Garden*	29,710.69	27,666.22	28,561.13	-1,149.55
Gosper	59,394.08	75,596.62	78,661.10	19,267.02
Grant*	780.30	80.24	57.79	-722.51
Hall	172,309.14	193,735.86	187,199.78	14,890.63
Hamilton	213,516.37	227,175.84	223,307.52	9,791.15
Harlan*	50,540.28	49,690.35	61,027.70	10,487.42
Hayes*	23,691.48	39,460.90	50,738.62	27,047.14
Hitchcock*	11,141.71	15,160.73	15,379.60	4,237.89
Howard*	24,240.58	33,236.50	33,329.18	9,088.60
Kearney	167,271.73	197,172.22	195,789.20	28,517.47
Keith	66,362.16	89,256.38	91,279.36	24,917.19
Kimball	18,279.18	24,066.00	27,082.45	8,803.28
Lincoln	168,622.00	195,319.26	205,236.22	36,614.22
Logan*	8,996.69	13,505.12	14,418.69	5,421.99
McPherson*	6,613.26	6,991.18	5,971.69	-641.56
Merrick	133,617.82	159,701.37	155,462.02	21,844.20
Morrill	97,200.75	106,531.34	106,142.99	8,942.24
Nance*	11,431.51	17,094.79	18,015.58	6,584.07
Nuckolls	30,188.34	38,628.75	48,171.33	17,983.00
Perkins	100,102.78	129,514.50	127,669.21	27,566.43
Phelps	207,608.75	231,107.96	227,308.90	19,700.15
Platte*	13,232.94	20,279.84	20,107.32	6,874.38
Polk	90,128.31	128,267.49	136,704.99	46,576.68
Red Willow*	21,418.03	29,047.01	30,168.40	8,750.38
Scotts Bluff	147,790.80	165,640.39	166,006.56	18,215.76
Sheridan*	1,753.26	1,774.38	2,477.91	724.65
Sioux*	23,802.27	28,820.52	28,555.32	4,753.05
Webster*	27,418.77	39,320.93	45,291.02	17,872.26
York	169,396.68	219,851.91	233,418.61	64,021.93

* Partial counties not completely within the COHYST boundary

PROJECT EXPOSURE

WWW Page

The Center for Advanced Land Management Information Technologies (CALMIT) has developed a web site for the COHYST Land Use Mapping project at: **http://www.calmit.unl.edu/cohyst/**. 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 2001, 1997, and 1982 land cover maps and reports can also be downloaded over the Internet. These maps and reports are in Adobe .PDF format. Internet mapping is also available for the COHYST study area. The land cover maps, digital orthphotography, and topographic maps are viewable through any web browser though a link on the above-mentioned web site.

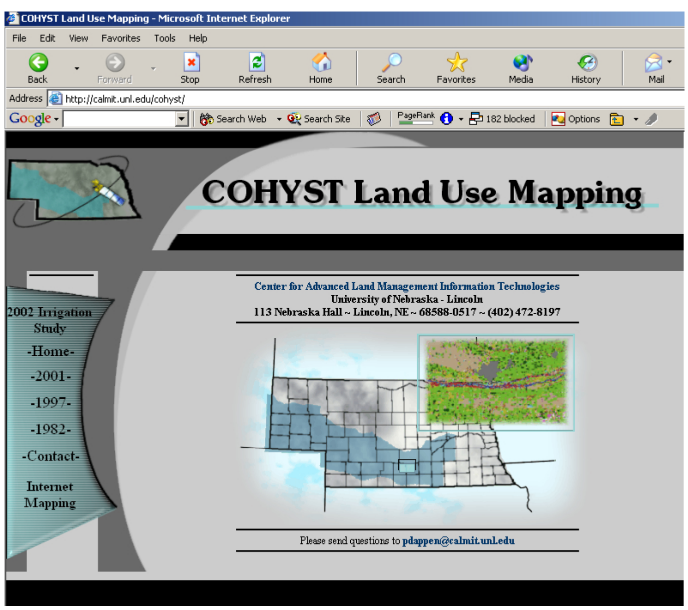


Figure 11. COHYST Land Use Mapping Web Page
(http://www.calmit.unl.edu/cohyst)

REFERENCES

Anuta, P., Bartolucci, L., Dean, M., Lozano, D., Malaret, E., McGillem, C., Valdes, J. and Valenzuela, C. 1984. Landsat 4 MSS and Thematic Mapper data quality and information content analysis. *IEEE Transactions on Geoscience and Remote Sensing,* 3:222-235.

Avery, T. E., and Berlin, G. L., 1992, *Fundamentals of Remote Sensing and Airphoto Interpretation* (5^{th} edition), Upper Saddle River, New Jersey: Prentice Hall.

Batista, G., Hixson, M., and Bauer, M. 1985. Landsat MSS crop classification performance as a function of scene characteristics. *International Journal of Remote Sensing,* 6(9):1521-1533.

Belward, A.S. and A. de Hoyos, 1987. A comparison of supervised maximum likelihood and decision tree classification for crop cover estimation from multitemporal LANDSAT MSS data, *International Journal of Remote Sensing*, 8(2):22-235.

Bobba, A.G., V.P. Singh, L. Bengtsson, 2000. Application of environmental models to different hydrological systems, *Ecological Modelling*, 125(1):15-49.

Brisco, B. and R.J. Brown, 1995. Multidate SAR/TM synergism for crop classification in Western Canada, *Photogrammetric Engineering and Remote Sensing*, 61(8): 1009-1014.

Campbell, James, 1981. Spatial correlation effects upon accuracy of supervised classification of land cover, *Photogrammetric Engineering and Remote Sensing,* 47(3): 355-363.

Chuvieco, E, and Congalton R., 1988. Using cluster analysis to improve the selection of training statistics in classifying remotely sensed data, *Photogrammetric Engineering and Remote Sensing*, 54(9):1275-1281.

Clevers, J.G.P.W., and H.J.C. van Leeuwen, 1996. Combined use of optical and microwave remote sensing data for crop growth monitoring, *Remote Sensing of Environment*, 56:42-51.

Congalton, Russel G., 1991. A review of assessing the accuracy of classifications of remotely sensed data, *Remote Sensing of Environment*, 37:35-46.

Congalton, R., M. Balogh, C. Bell, K. Green, J. Milliken, and R. Ottman, 1998. Mapping and monitoring agricultural crops and other land cover in the lower Colorado River Basin, *Photogrammetric Engineering and Remote Sensing,* 64(11): 1107-1113.

Congalton, Russel and Kass Green, 1999. *Assessing the Accuracy of Remotely Sensed Data: Principles and Practices*, New York, NY: Lewis Publishers.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe, 1979, *Classification of wetlands and deepwater habitats of the United States*, Office of Biological Sciences, Fish and Wildlife Service, U. S. Dept. of the Interior, Washington, DC. FWS/OBS-79/31.

Crist, E. 1984. Effects of cultural and environmental factors on corn and soybean spectral development patterns, *Remote Sensing of Environment*, 14:3-13.

DeGloria, S. 1984. Spectral variability of Landsat-4 Thematic Mapper and Multispectral Scanner data for selected crop and forest cover Types, *IEEE Transactions on Geoscience and Remote Sensing*, 3:303-311

ERDAS Inc., 1999. *ERDAS IMAGINE Field Guide*, 5th edition, Atlanta, GA: ERDAS Inc.

Ehrlich, D., Estes, J., Scepan, J. and McGwire, C., 1994. Crop Area Monitoring within An Advanced Agricultural Information System. *Geocarto International*. 4:31-42.

Gibson, Paul, 2000. *Introductory Remote Sensing: Principles and Concepts*, New York, NY: Routledge.

Great Plains Flora Association, 1986. *Flora of the Great Plains*, Lawrence: University Press of Kansas.

Green, K., 1992. Spatial Imagery and GIS: Integrated data for natural resource management, *Journal of Forestry*, 90(11): 32-36.

Grunblatt, Jess, 1987. An MTF analysis of Landsat classification error at field boundaries, *Photogrammetric Engineering and Remote Sensing,* 53(6): 639-643.

Jenkins, Ph.D., editor, 1993. *The Platte River: An Atlas of the Big Bend Region. Kearney*, University of Nebraska at Kearney.

Jensen, J.R., Ramsey, E.W., Mackey, H.E., Christiansen, E.J., and Sharitz, R.R., 1987. Inland wetland change detection using aircraft MSS data, *Photogrammetric Engineering and Remote Sensing,* 53(5): 521-529.

Jensen, J.R., 1996. *Introductory Digital Image Processing*, Prentice Hall, Upper Saddle River, New Jersey.

LaGrange, T., 1997, *Guide to Nebraska's Wetlands and Their Conservation Needs*. Nebraska Game and Parks Commission.

Lillesand, Thomas and Ralph Kiefer, 2000. *Remote Sensing and Image Interpretation*, Fourth Edition. New York, New York: John Wiley and Sons, Inc.

Littell, R. C., Milliken, G. A., Stroup, W. W., and Wolfinger, R. D., 1996, *SAS System for Mixed Models,* Cary, North Carolina: SAS® Institute Inc.

Lunetta, Ross S., Russell Congalton, Lynn Fenstermaker, John Jensen, Kenneth McGwire, and Larry Tinney, 1991. Remote sensing and geographic information system data integration: error sources and research issues, *Photogrammetric Engineering and Remote Sensing,* 57(6):677-587.

Lunetta, Ross and Christopher Elvidge, 1998. *Remote Sensing Change Detection: Environmental Monitoring Methods and Applications,* Ann Arbor Press, Chelsea, Michigan.

Lo, T.H.C., F.L. Scarpace and T.M. Lillesand, 1986. Use of multitemporal spectral profiles in agricultural land-cover classification, *Photogrammetric Engineering and Remote Sensing*, 52(4):535-544.

Mariotti, Marco, Laura Ercoli, and Alessandro Masoni, 1996. Spectral properties of iron-deficient corn and sunflower leaves, *Remote Sensing of Environment*, 58:282-288.

Maxwell, Susan and Roger Hoffer, 1996. "Mapping agricultural crops with multi-date Landsat data", *Technical Papers,* American Society for Photogrammetry and Remote Sensing, 433-443.

McAdam, J.H., 1997. High and low resolution TM data for the assessment of herbage and sward characteristics in small fields, *International Journal of Remote Sensing*, 18(4):3027-3037.

McFeeters, S. K., 1996, The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. *International Journal of Remote Sensing*, 17:1425-1432.

McGwire, Kenneth, John Estes, and Jeffery Starr, 1996. A comparison of maximum likelihood-based supervised classification strategies, *Geocarto International*, 11(2)3-13.

Mitsch, W. J., and J.G. Gosselink, 1993, *Wetlands*, New York: Van Nostrand Reinhold.

Moulin, S., and A. Bondeau, and R. Delecolle, 1998. Combining agricultural crop models and satellite observations: from field to regional scales, *International Journal of Remote Sensing*, 19(6)1021-1036.

Nebraska Agricultural Statistics Service, 2002. *Nebraska Agricultural Statistics,* *<http://www.nass.usda.gov/ne/2001book/contents.htm#General>*.

National Agricultural Statistics Service, 1997. *Usual planting and harvesting dates for U.S. field crops*. <http://usda.mannlib.cornell.edu/>.

Nebraska Department of Agriculture, 1998. *Agriculture Statistics Division Data Base*. <http://www.nrc.state.ne.us/docs/frame4.html>.

Nebraska Agricultural Statistics Service, 1990. *Nebraska Weather and Crops*, Lincoln, NE: Nebraska Department of Agriculture.

Nebraska Agricultural Statistics Service, 1982. *Nebraska Weather and Crops, 1982* Lincoln, NE: Nebraska Department of Agriculture. http://www.nass.usda.gov/ne/cropwthr/1982.htm/>.

NOAA, 1980, *Climatological Data – Nebraska.* Vol. 85

NOAA, 1981, *Climatological Data – Nebraska.* Vol. 86.

NOAA, 1982, *Climatological Data – Nebraska.* Vol. 87.

Odenweller, J. and Johnson, K., 1984. Crop Identification Using Landsat Temporal-Spectral Profiles, *Remote Sensing of Environment*, 14:39-54.

Oetter, D., Cohen, W., Berterretche, M., Maiersperger, T., and Kennedy, R., 2000. Land cover mapping in an agricultural setting using multiseasonal Thematic Mapper data. *Remote Sensing of Environment,* 76:139-155.

Ortiz, M.J., A.R. Formaggio, and J.C.N. Epiphanio, 1997. Classification of croplands through integration of remote sensing, GIS, and historical database, *International Journal of Remote Sensing,* 18(1)95-105.

Pilon P.G., P.J. Howarth, R.A. Bullock and P.O. Adeniyi, 1988. An enhanced classification approach to change detection in semi-arid environments, *Photogrammetric Engineering and Remote Sensing,* 54 (12)1709-1716.

Richards, John, Xiuping, Jia, 1999. *Remote Sensing Digital Image Analysis: An Introduction, 3rd Edition.* Berlin, Germany: Springer

Sabins, Floyd F., 1987. *Remote Sensing Principles and Interpretation,* New York: W.H. Freeman and Company.

Schwartz, M.D., 1994. Monitoring global change with phenology: the case of the spring green wave, *International Journal of Biometeorology,* 38:18-22.

Serra, P., Pons, X., and Sauri, D. 2003. Post-classification change detection with data from different sensors: some accuracy considerations, *International Journal of Remote Sensing*, 24(16):3311-3340.

Singh A.,1989. Digital change detection techniques using remotely-sensed data. *International Journal of Remote Sensing*, 10(6) 989-1003.

Srinivasan R., T.S. Ramanarayanan, J.G. Arnold, S.T. Bednarz, 1998. Large area hydrologic modeling and assessment part II: Model application, *Journal of the American Water Resources Association*, 34(1):91-101.

Stehman, Stephan V and Raymond L. Czaplewski, 1998. Design and Analysis for thematic map accuracy assessment: fundamental principles, *Remote Sensing of Environment*, 64:331-344.

Swain, P.H., and S. M. Davis, editors, 1978. *Remote sensing The Quantitative Approach*, New York: McGraw-Hill Inc.

Thenkabail, Prasad, Andrew Ward, John Lyon, and Carolyn Merry, 1994. Thematic Mapper vegetation indices for determining soybean and corn growth parameters, *Photogrammetric Engineering and Remote Sensing*, 60(4): 437-442

Tao, Yongyi and M. Duane Nellis, 1999. "Improving Crop Classification Accuracy Using Multi-Seasonal TM Data by Incorporating Change Vector Analysis", *Proceedings*, Bethesda, MD: American Society for Photogrammetry and Remote Sensing.

Tucker, C.J., 1979. Red and photographic infrared linear combinations for monitoring vegetation, *Remote Sensing of Environment*, 8:127-150.

U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and U.S. Geological Survey, 1983. Upper Platte River Study: Summary Report. Washington D.C., U.S. Department of the Interior.

U.S. Fish and Wildlife Service. 1981. The Platte River ecology study special research report. U.S. Fish and Wildlife Service, Jamestown, ND. Jamestown, ND: Northern Prairie Wildlife Research Center Home Page.

http://www.npwrc.usgs.gov/resource/othrdata/platteco/platteco.htm (Version 16JUL97).

Wiegand, C.L., A.J. Richardson, D.E. Escobar, and A.H.Gerbermann, 1991. Vegetation indices in crop assessments, *Remote Sensing of Environment*, 35:105-119.

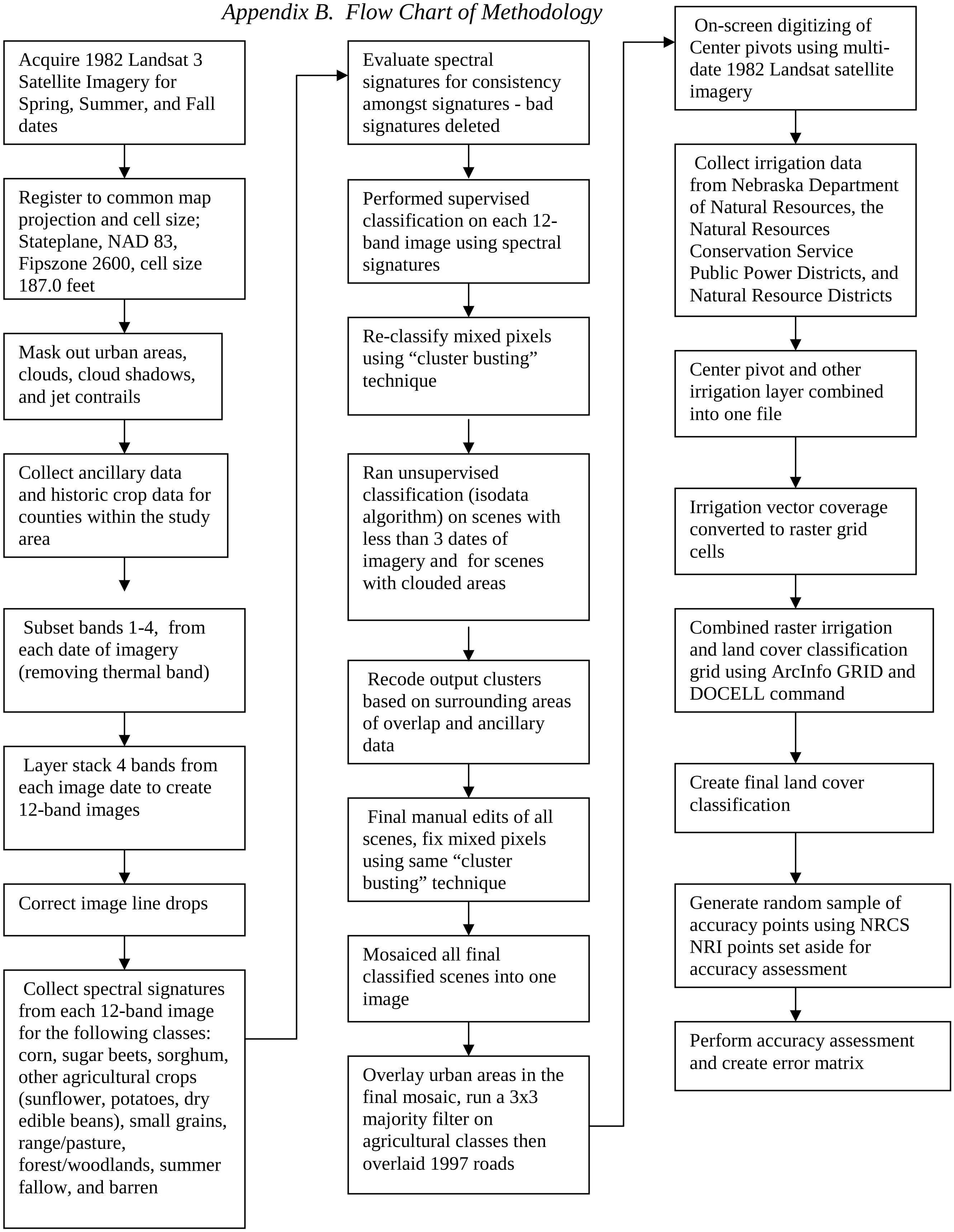
Zheng, P.Q. and B.W. Baetz, 1999. GIS-based analysis of development options from a hydrology perspective, *Journal of Urban Planning and Development*, 125(4):164-180.

APPENDICES

Appendix A. Monthly Temperature and Precipitation of the Study Area

WEATHER STATION	PARAMETER	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
Grand Island WSO AP	Monthly average temperature (F)	1980	21.60	23.66	34.19	51.43	60.92	73.07	80.69	76.84	66.87	51.52	41.65	29.79	51.02
Grand Island WSO AP	Monthly average temperature (F)	1981	28.89	31.39	41.69	58.22	57.00	73.17	75.82	71.79	64.60	50.58	40.98	24.55	51.56
Grand Island WSO AP	Monthly average temperature (F)	1982	12.84	23.77	35.00	46.95	60.74	65.70	76.47	72.39	63.18	52.45	34.93	28.55	47.75
Grand Island WSO AP	Monthly average temperature (F)	1961-90 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.)	1980	0.80	0.65	2.23	1.92	2.06	3.62	0.85	4.42	0.83	1.46	0.12	0.18	19.14
Grand Island WSO AP	Monthly total precipitation (In.)	1981	0.16	0.19	3.14	1.14	4.28	0.60	3.45	4.38	0.93	1.08	3.21	0.63	23.19
Grand Island WSO AP	Monthly total precipitation (In.)	1982	0.65	0.56	2.41	3.15	8.88	4.47	2.65	5.78	2.37	2.06	1.49	1.18	35.65
Grand Island WSO AP	Monthly total precipitation (In.)	1961-90 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
Kearney 4 NE	Monthly average temperature (F)	1980	22.79	24.28	32.81	50.76	60.80	73.15	79.57	75.16	65.59	51.00	40.77	31.21	52.43
Kearney 4 NE	Monthly average temperature (F)	1981	31.23	31.07	43.02	58.47	57.43	74.17	76.60	72.03	64.37	50.56	40.58	27.06	50.22
Kearney 4 NE	Monthly average temperature (F)	1982	16.10	22.78	35.44	45.48	59.66	63.92	75.34	71.77	62.77	51.18	33.70	28.84	47.25
Kearney 4 NE	Monthly average temperature (F)	1961-90 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.)	1980	0.54	0.94	3.61	1.52	2.07	2.24	1.61	2.93	1.54	1.07	0.00	0.00	18.07
Kearney 4 NE	Monthly total precipitation (In.)	1981	0.00	0.29	1.43	2.15	3.62	1.27	5.42	3.30	1.43	0.52	1.82	1.22	22.47
Kearney 4 NE	Monthly total precipitation (In.)	1982	0.35	0.52	2.14	1.76	6.13	2.86	3.09	2.95	1.66	3.58	1.26	1.30	27.60
Kearney 4 NE	Monthly total precipitation (In.)	1961-90 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
North Platte WSO ARPT	Monthly average temperature (F)	1980	25.08	26.72	35.45	50.45	60.24	72.48	77.98	73.94	63.63	48.89	38.43	31.90	50.43
North Platte WSO ARPT	Monthly average temperature (F)	1981	29.66	29.05	40.16	55.72	54.77	68.57	73.74	70.03	62.98	48.97	39.82	26.68	50.01
North Platte WSO ARPT	Monthly average temperature (F)	1982	17.10	28.04	36.26	44.73	57.31	63.38	74.95	73.06	61.68	49.18	33.28	28.08	47.25
North Platte WSO ARPT	Monthly average temperature (F)	1961-90 normal	#REF!	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.)	1980	0.52	0.82	2.56	0.77	2.59	1.89	0.64	3.04	0.34	1.00	0.13	0.02	14.32
North Platte WSO ARPT	Monthly total precipitation (In.)	1981	0.07	0.05	2.72	2.47	5.37	2.32	5.09	2.48	0.25	0.60	1.94	0.43	23.79
North Platte WSO ARPT	Monthly total precipitation (In.)	1982	0.20	0.15	0.99	1.42	6.32	2.35	1.78	1.18	1.26	2.44	0.73	1.08	19.90
North Platte WSO ARPT	Monthly total precipitation (In.)	1961-90 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
Scottsbluff WSO AP	Monthly average temperature (F)	1980	23.03	29.62	36.05	49.35	58.55	72.32	78.19	73.13	66.23	51.55	40.78	37.02	51.32
Scottsbluff WSO AP	Monthly average temperature (F)	1981	32.45	32.73	42.66	56.38	57.34	71.25	76.15	72.77	66.90	50.85	42.65	31.15	52.77
Scottsbluff WSO AP	Monthly average temperature (F)	1982	22.53	27.64	37.60	43.83	55.55	62.77	72.77	74.18	62.12	48.50	34.17	27.94	47.47
Scottsbluff WSO AP	Monthly average temperature (F)	1961-90 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.)	1980	1.21	0.99	2.16	0.57	2.82	0.79	1.07	0.47	0.47	0.76	0.57	0.15	12.03
Scottsbluff WSO AP	Monthly total precipitation (In.)	1981	0.69	0.14	0.59	1.47	2.75	2.54	3.54	1.10	0.39	0.34	0.26	0.19	14.00
Scottsbluff WSO AP	Monthly total precipitation (In.)	1982	0.32	0.20	0.46	0.50	2.93	6.63	4.78	1.66	1.78	1.22	0.80	0.57	21.85
Scottsbluff WSO AP	Monthly total precipitation (In.)	1961-90 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

Appendix B. Flow Chart of Methodology



Appendix C. Crop Acreage Change By County 1982 - 2001

(Counties not completely within the COHYST boundary are listed as 'partial')

Adams County

Adams					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	59,780.52	25,968.53	6,264.05	53,516.47	14.83%
Dryland Soybeans	19,150.42	14,199.47	851.74	18,298.68	5.07%
Irrigated Alfalfa	4,666.14	2,848.48	2,093.64	2,572.50	0.71%
Irrigated Other Agricultural Crops	20.86	0.60	0.00	20.86	0.01%
Irrigated Small Grains	720.98	1,746.18	1,752.46	-1,031.47	-0.29%
Dryland Alfalfa	4,033.42	9,976.72	7,518.79	-3,485.37	-0.97%
Summer Fallow	1,735.86	4,416.64	5,866.68	-4,130.82	-1.14%
Irrigated Sorghum	2,352.33	2,918.13	8,219.61	-5,867.28	-1.63%
Dryland Sorghum	3,560.39	15,833.45	13,438.45	-9,878.06	-2.74%
Irrigated Corn	115,609.07	146,110.05	130,319.22	-14,710.15	-4.08%
Dryland Small Grains	5,819.83	13,889.97	26,662.55	-20,842.72	-5.77%
Dryland Corn	38,511.68	36,085.55	60,705.01	-22,193.33	-6.15%

Arthur County (partial)

Arthur					
Class	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Alfalfa	5,392.34	2,621.94	3,496.89	1,895.45	0.46%
Irrigated Sorghum	1,019.09	1.00	114.80	904.29	0.22%
Summer Fallow	560.70	898.72	211.13	349.57	0.08%
Irrigated Small Grains	365.91	1,057.00	32.91	332.99	0.08%
Dryland Sorghum	152.86	1.81	20.87	131.99	0.03%
Irrigated Soybeans	46.14	432.31	0.00	46.14	0.01%
Dryland Soybeans	1.00	215.85	0.00	1.00	0.00%
Irrigated Other Agricultural Crops	0.00	268.21	0.00	0.00	0.00%
Dryland Other Agricultural Crops	0.00	175.73	5.62	-5.62	0.00%
Dryland Small Grains	30.89	978.36	58.60	-27.71	-0.01%
Irrigated Sugar Beets	0	197.40	126.84	-126.84	-0.03%
Dryland Alfalfa	516.16	804.64	2,051.89	-1,535.73	-0.37%
Dryland Corn	76.83	1,319.80	1,684.22	-1,607.39	-0.39%
Irrigated Corn	1,092.31	4,946.59	5,909.22	-4,816.91	-1.16%

Banner County

Banner					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Dryland Other Agricultural Crops	5,102.66	1,323.49	285.79	4,816.87	1.01%
Irrigated Other Agricultural Crops	4,313.07	2,844.47	923.99	3,389.07	0.71%
Irrigated Small Grains	5,613.21	7,264.32	2,560.85	3,052.36	0.64%
Irrigated Corn	7,255.18	4,592.06	5,674.81	1,580.37	0.33%
Dryland Soybeans	94.89	626.22	0.00	94.89	0.02%
Irrigated Soybeans	43.33	2,079.96	0.00	43.33	0.01%
Irrigated Sugar Beets	983.18	1,627.76	1,532.50	-549.32	-0.12%
Irrigated Alfalfa	4,244.26	5,563.09	5,186.73	-942.47	-0.20%
Dryland Corn	2,354.13	1,245.01	3,357.20	-1,003.07	-0.21%
Dryland Alfalfa	859.00	3,508.82	5,568.85	-4,709.84	-0.99%
Dryland Small Grains	59,499.07	70,349.05	85,465.79	-25,966.72	-5.44%
Summer Fallow	50,422.37	50,342.02	81,532.20	-31,109.83	-6.52%

Box Butte County (partial)

Box Butte County					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Small Grains	29,398.27	21,553.70	15,105.81	14,292.46	3.26%
Irrigated Other Agricultural Crops	16,352.75	11,388.30	2,700.53	13,652.21	3.12%
Irrigated Sugar Beets	16,284.14	20,268.61	3,228.76	13,055.38	2.98%
Irrigated Corn	36,788.06	33,536.41	27,983.12	8,804.94	2.01%
Dryland Other Agricultural Crops	6,926.99	1,947.50	464.81	6,462.18	1.48%
Irrigated Sorghum	574.14	0.00	0.00	574.14	0.13%
Irrigated Alfalfa	8,276.68	8,290.72	7,727.51	549.17	0.13%
Dryland Sorghum	474.84	0.00	0.00	474.84	0.11%
Dryland Soybeans	0.00	1,750.30	0.00	0.00	0.00%
Irrigated Soybeans	0.00	10,064.09	0.00	0.00	0.00%
Dryland Alfalfa	784.18	2,831.78	6,313.02	-5,528.84	-1.26%
Dryland Corn	6,029.87	5,696.26	15,777.73	-9,747.86	-2.23%
Dryland Small Grains	46,023.64	50,465.90	72,431.14	-26,407.50	-6.03%
Summer Fallow	35,126.22	39,002.77	64,188.25	-29,062.03	-6.63%

Buffalo County (partial)

Buffalo					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	50,700.61	29,545.92	7,687.37	43,013.24	7.84%
Dryland Soybeans	13,108.11	6,623.47	1,571.03	11,537.08	2.10%
Irrigated Alfalfa	12,417.62	12,682.43	9,865.30	2,552.33	0.47%
Irrigated Small Grains	2,047.80	1,468.85	1,498.78	549.02	0.10%
Irrigated Other Agricultural Crops	444.55	3.01	0.00	444.55	0.08%
Summer Fallow	2,127.25	2,166.36	3,886.23	-1,758.99	-0.32%
Irrigated Corn	133,872.81	150,414.32	136,713.32	-2,840.51	-0.52%
Dryland Sorghum	371.93	14,951.50	4,656.90	-4,284.97	-0.78%
Dryland Alfalfa	19,500.68	26,592.57	23,797.45	-4,296.77	-0.78%
Dryland Small Grains	7,640.75	7,843.16	12,481.54	-4,840.79	-0.88%
Irrigated Sorghum	82.25	6,487.05	6,289.74	-6,207.49	-1.13%
Dryland Corn	36,182.22	23,009.71	51,165.64	-14,983.42	-2.73%

Chase County (partial)

Chase County					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Corn	88,103.74	94,723.59	64,622.55	23,481.18	6.01%
Irrigated Soybeans	5,593.15	1,831.55	0.00	5,593.15	1.43%
Irrigated Other Agricultural Crops	4,726.12	6,461.78	775.48	3,950.64	1.01%
Irrigated Small Grains	9,104.99	8,604.47	6,116.34	2,988.65	0.76%
Irrigated Sugar Beets	2,126.84	1,242.56	0.00	2,126.84	0.54%
Irrigated Alfalfa	5,240.88	4,303.84	3,804.35	1,436.53	0.37%
Dryland Other Agricultural Crops	1,954.92	2,916.03	522.61	1,432.32	0.37%
Dryland Sorghum	1,394.42	5,380.90	0.00	1,394.42	0.36%
Irrigated Sorghum	763.71	3,227.78	0.00	763.71	0.20%
Dryland Soybeans	372.33	1,404.25	0.00	372.33	0.10%
Dryland Alfalfa	1,518.40	3,158.77	2,621.06	-1,102.66	-0.28%
Dryland Small Grains	33,364.69	32,750.43	40,644.48	-7,279.79	-1.86%
Dryland Corn	17,215.16	13,048.73	27,199.61	-9,984.45	-2.55%
Summer Fallow	27,277.44	37,939.35	48,493.20	-21,215.76	-5.43%

Cheyenne County

Cheyenne					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Dryland Other Agricultural Crops	16,997.70	16,830.18	85.90	16,911.80	2.21%
Irrigated Small Grains	17,944.37	17,971.22	4,659.30	13,285.06	1.74%
Irrigated Other Agricultural Crops	8,408.88	3,247.50	1,010.69	7,398.18	0.97%
Dryland Sorghum	2,537.89	7.63	0.00	2,537.89	0.33%
Dryland Small Grains	237,136.07	271,866.05	234,919.14	2,216.93	0.29%
Irrigated Soybeans	488.68	5,665.06	0.00	488.68	0.06%
Dryland Corn	9,619.34	6,896.82	9,278.47	340.88	0.04%
Irrigated Sorghum	173.73	88.31	0.00	173.73	0.02%
Dryland Soybeans	84.05	1,659.47	0.00	84.05	0.01%
Irrigated Corn	17,263.71	14,560.95	17,446.70	-182.99	-0.02%
Irrigated Sugar Beets	333.81	2,662.43	689.58	-355.77	-0.05%
Irrigated Alfalfa	4,996.74	3,543.75	6,860.51	-1,863.77	-0.24%
Dryland Alfalfa	1,599.85	1,606.89	13,151.05	-11,551.21	-1.51%
Summer Fallow	172,757.82	176,532.35	240,137.98	-67,380.16	-8.81%

Clay County

Clay					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	63,891.78	36,950.41	6,738.49	57,153.29	15.57%
Dryland Soybeans	15,900.17	22,230.90	590.04	15,310.13	4.17%
Irrigated Other Agricultural Crops	68.41	0.00	0.00	68.41	0.02%
Irrigated Sugar Beets	6.22	0	0	6.22	0.00%
Dryland Other Agricultural Crops	3.61	0.00	0.00	3.61	0.00%
Irrigated Sorghum	4,648.68	7,608.74	5,962.21	-1,313.52	-0.36%
Dryland Alfalfa	5,718.12	7,432.91	7,110.17	-1,392.05	-0.38%
Summer Fallow	225.68	405.44	1,771.72	-1,546.04	-0.42%
Irrigated Small Grains	732.22	1,797.16	2,338.48	-1,606.26	-0.44%
Irrigated Alfalfa	5,356.83	2,161.45	9,656.58	-4,299.75	-1.17%
Dryland Sorghum	8,669.87	24,993.28	15,457.42	-6,787.56	-1.85%
Irrigated Corn	109,732.47	135,670.70	127,995.99	-18,263.52	-4.98%
Dryland Small Grains	4,150.58	12,937.80	22,769.10	-18,618.52	-5.07%
Dryland Corn	31,878.59	32,550.84	57,803.78	-25,925.20	-7.06%

Custer County (partial)

Custer					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Dryland Soybeans	7,879.67	4,965.85	453.57	7,426.11	1.86%
Dryland Other Agricultural Crops	6,705.72	905.94	0	6,705.72	1.68%
Irrigated Soybeans	6,890.68	2,359.95	3,664.67	3,226.01	0.81%
Irrigated Alfalfa	4,458.31	4,993.13	1,678.60	2,779.71	0.70%
Irrigated Corn	36,475.91	39,240.09	34,199.80	2,276.11	0.57%
Dryland Sorghum	1,258.81	8,835.37	0.00	1,258.81	0.32%
Irrigated Sorghum	258.98	1,263.63	0.00	258.98	0.06%
Dryland Corn	25,966.87	27,188.98	25,930.42	36.45	0.01%
Irrigated Other Agricultural Crops	14.44	129.19	0	14.44	0.00%
Irrigated Sugar Beets	0.00	3.61	0.00	0.00	0.00%
Irrigated Small Grains	409.04	139.42	709.65	-300.61	-0.08%
Dryland Alfalfa	3,438.22	13,029.88	6,308.20	-2,869.99	-0.72%
Summer Fallow	3,699.01	4,632.44	9,572.28	-5,873.28	-1.47%
Dryland Small Grains	72.22	6,508.92	17,102.31	-17,030.09	-4.26%

Dawson County

Dawson					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	38,043.46	17,454.19	3,027.26	35,016.20	5.37%
Dryland Soybeans	9,257.25	4,038.70	529.83	8,727.42	1.34%
Irrigated Other Agricultural Crops	214.85	0.00	0.00	214.85	0.03%
Dryland Sorghum	258.98	10,099.15	118.01	140.98	0.02%
Dryland Small Grains	6,480.23	5,888.25	6,447.08	33.15	0.01%
Dryland Other Agricultural Crops	0.00	0.20	0.00	0.00	0.00%
Irrigated Small Grains	3,019.35	938.12	3,651.02	-631.67	-0.10%
Irrigated Sorghum	77.03	5,129.96	800.37	-723.33	-0.11%
Summer Fallow	2,765.38	2,500.05	8,259.75	-5,494.37	-0.84%
Irrigated Alfalfa	30,640.84	22,433.02	36,568.79	-5,927.96	-0.91%
Irrigated Corn	166,366.45	171,412.03	174,785.70	-8,419.25	-1.29%
Dryland Corn	28,525.23	32,457.71	42,618.50	-14,093.27	-2.16%
Dryland Alfalfa	22,130.85	48,217.50	36,586.45	-14,455.60	-2.22%

Deuel County

Deuel					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Dryland Other Agricultural Crops	13,977.15	21,407.79	455.17	13,521.97	4.80%
Dryland Corn	9,471.50	3,342.43	4,718.71	4,752.79	1.69%
Irrigated Small Grains	3,414.34	3,428.14	1,674.59	1,739.76	0.62%
Irrigated Other Agricultural Crops	1,111.17	1,732.93	427.88	683.29	0.24%
Dryland Sorghum	662.61	0.40	2.41	660.20	0.23%
Irrigated Corn	12,831.28	11,525.60	12,223.05	608.23	0.22%
Irrigated Soybeans	189.37	865.87	0.00	189.37	0.07%
Dryland Soybeans	41.53	224.60	0.00	41.53	0.01%
Irrigated Sorghum	17.45	1.00	34.52	-17.07	-0.01%
Irrigated Sugar Beets		514.42	533.85	-533.85	-0.19%
Irrigated Alfalfa	1,161.72	1,371.86	2,469.33	-1,307.61	-0.46%
Dryland Alfalfa	236.12	321.34	2,324.03	-2,087.92	-0.74%
Summer Fallow	77,313.24	71,088.06	89,742.97	-12,429.73	-4.41%
Dryland Small Grains	72,399.96	90,007.84	91,380.63	-18,980.68	-6.73%

Franklin County (partial)

Franklin					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	31,820.41	11,679.19	1,352.68	20,141.22	6.93%
Dryland Soybeans	12,558.85	4,297.02	557.13	8,261.83	2.84%
Dryland Corn	27,988.60	23,056.26	44,524.29	4,932.34	1.70%
Irrigated Alfalfa	4,239.44	3,156.96	1,496.37	1,082.48	0.37%
Irrigated Small Grains	1,264.23	852.98	1,825.51	411.25	0.14%
Irrigated Other Agricultural Crops	226.49	3.81	0.00	222.68	0.08%
Dryland Alfalfa	5,965.67	6,352.65	5,408.29	-386.97	-0.13%
Dryland Small Grains	13,218.45	15,179.59	18,114.61	-1,961.14	-0.67%
Irrigated Sorghum	94.49	2,499.77	2,637.11	-2,405.29	-0.83%
Summer Fallow	4,880.39	7,900.74	5,499.01	-3,020.35	-1.04%
Irrigated Corn	46,443.51	60,944.05	57,582.22	-14,500.53	-4.99%
Dryland Sorghum	1,104.15	19,202.38	4,687.40	-18,098.23	-6.23%

Frontier County

Frontier					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	11,214.18	3,651.13	31.31	11,182.87	1.78%
Dryland Small Grains	55,480.29	63,296.08	48,127.14	7,353.15	1.17%
Dryland Alfalfa	10,779.86	10,847.00	3,667.88	7,111.98	1.13%
Dryland Soybeans	5,514.91	4,916.61	53.79	5,461.12	0.87%
Irrigated Alfalfa	4,992.73	3,710.74	789.93	4,202.80	0.67%
Summer Fallow	40,031.89	46,388.02	37,029.58	3,002.30	0.48%
Dryland Sorghum	7,727.81	32,190.56	5,417.93	2,309.89	0.37%
Irrigated Small Grains	3,589.68	2,271.84	1,620.80	1,968.87	0.31%
Irrigated Sorghum	1,612.08	5,956.89	313.08	1,299.00	0.21%
Irrigated Other Agricultural Crops	415.06	143.51	0.00	415.06	0.07%
Dryland Other Agricultural Crops	325.99	899.79	0	325.99	0.05%
Irrigated Sugar Beets	10.43	4.42	0.00	10.43	0.00%
Irrigated Corn	38,949.21	35,684.73	43,122.64	-4,173.43	-0.67%
Dryland Corn	38,150.19	37,400.81	57,123.03	-18,972.84	-3.03%

Furnas County (partial)

Furnas					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2	% of County Change
Irrigated Soybeans	9,529.67	5,913.32	106.77	9,422.90	9.40%
Dryland Small Grains	12,170.67	13,639.52	8,181.08	3,989.60	3.98%
Dryland Soybeans	2,078.90	1,640.97	23.28	2,055.62	2.05%
Dryland Alfalfa	4,152.58	3,800.92	2,544.80	1,607.79	1.60%
Irrigated Alfalfa	2,294.95	1,099.53	1,069.30	1,225.66	1.22%
Dryland Sorghum	785.18	5,229.04	523.41	261.77	0.26%
Irrigated Sorghum	34.50	755.89	429.48	-394.98	-0.39%
Irrigated Small Grains	648.36	547.06	1,248.31	-599.95	-0.60%
Dryland Corn	10,125.48	9,954.96	11,576.81	-1,451.33	-1.45%
Summer Fallow	5,508.89	7,545.26	7,227.38	-1,718.49	-1.71%
Irrigated Corn	12,608.80	12,073.98	17,119.17	-4,510.37	-4.50%

Garden County (partial)

Garden					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Dryland Other Agricultural Crops	6,184.54	12,899.08	74.66	6,109.88	0.56%
Irrigated Small Grains	4,216.78	4,161.41	1,579.86	2,636.92	0.24%
Dryland Corn	8,717.41	8,433.15	7,268.32	1,449.09	0.13%
Irrigated Other Agricultural Crops	871.04	756.49	0.00	871.04	0.08%
Irrigated Soybeans	578.35	1,334.84	0	578.35	0.05%
Dryland Sorghum	574.14	10.43	0.00	574.14	0.05%
Irrigated Sorghum	307.13	30.69	26.49	280.64	0.03%
Dryland Soybeans	121.97	629.11	0.00	121.97	0.01%
Irrigated Alfalfa	9,114.82	5,969.49	9,413.33	-298.52	-0.03%
Irrigated Sugar Beets	0.00	631.31	816.42	-816.42	-0.07%
Dryland Alfalfa	2,833.59	3,478.34	6,870.95	-4,037.36	-0.37%
Dryland Small Grains	50,830.41	58,741.37	54,933.06	-4,102.66	-0.37%
Irrigated Corn	13,473.02	14,781.99	17,696.36	-4,223.34	-0.39%
Summer Fallow	44,968.24	47,115.95	55,208.41	-10,240.17	-0.93%

Gosper County

Gosper					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	27,422.28	7,595.09	322.72	27,099.57	9.15%
Dryland Small Grains	17,042.23	21,908.56	10,756.38	6,285.86	2.12%
Dryland Soybeans	5,016.40	1,221.93	51.38	4,965.02	1.68%
Irrigated Alfalfa	3,812.15	2,647.37	2,025.40	1,786.75	0.60%
Irrigated Small Grains	2,294.95	1,599.86	1,165.63	1,129.32	0.38%
Dryland Alfalfa	3,640.23	3,602.96	2,963.04	677.19	0.23%
Irrigated Other Agricultural Crops	160.89	0.20	0.00	160.89	0.05%
Dryland Sorghum	1,561.13	15,230.92	1,691.45	-130.32	-0.04%
Irrigated Sorghum	213.45	3,968.65	399.78	-186.34	-0.06%
Summer Fallow	9,755.56	12,652.59	12,565.83	-2,810.27	-0.95%
Dryland Corn	19,640.11	12,641.95	26,115.86	-6,475.76	-2.19%
Irrigated Corn	44,910.27	59,785.45	55,480.55	-10,570.29	-3.57%

Grant County (partial)

Grant					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Dryland Sorghum	0.00	2.41	0.00	0.00	0.00%
Dryland Soybeans	0.00	35.11	0.00	0.00	0.00%
Irrigated Small Grains	0.00	33.50	0.00	0.00	0.00%
Irrigated Soybeans	0.00	1.00	0.00	0.00	0.00%
Irrigated Other Agricultural Crops	0.00	0.40	0.80	-0.80	0.00%
Dryland Other Agricultural Crops	0.00	19.46	3.21	-3.21	0.00%
Dryland Small Grains	0.00	103.51	3.21	-3.21	0.00%
Summer Fallow	0.00	208.83	20.87	-20.87	-0.02%
Dryland Corn	0.80	239.33	66.63	-65.83	-0.08%
Dryland Alfalfa	136.21	283.06	369.28	-233.06	-0.28%
Irrigated Alfalfa	57.78	18.66	354.02	-296.25	-0.35%
Irrigated Corn	0.00	26.68	425.47	-425.47	-0.51%

Hall County

Hall					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	39,197.76	16,627.66	4,276.38	34,921.38	9.89%
Dryland Soybeans	4,676.37	4,516.99	325.12	4,351.24	1.23%
Irrigated Small Grains	615.26	1,395.34	175.00	440.26	0.12%
Irrigated Other Agricultural Crops	316.16	0.60	0.00	316.16	0.09%
Dryland Other Agricultural Crops	24.47	0.00	0.00	24.47	0.01%
Summer Fallow	795.01	316.72	817.22	-22.22	-0.01%
Irrigated Sorghum	1,138.05	3,036.55	1,295.68	-157.63	-0.04%
Dryland Sorghum	779.56	5,458.12	1,154.39	-374.83	-0.11%
Dryland Small Grains	1,597.84	2,895.25	2,100.86	-503.02	-0.14%
Irrigated Alfalfa	4,955.21	4,014.21	5,823.33	-868.11	-0.25%
Dryland Corn	20,012.03	17,345.61	22,596.50	-2,584.47	-0.73%
Dryland Alfalfa	6,987.77	15,126.95	12,993.71	-6,005.94	-1.70%
Irrigated Corn	140,977.33	168,661.49	160,738.75	-19,761.42	-5.60%

Hamilton County

Hamilton					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	68,454.20	28,323.67	12,203.78	56,250.42	16.07%
Dryland Soybeans	9,299.78	13,077.10	864.59	8,435.19	2.41%
Irrigated Other Agricultural Crops	120.97	0.00	0.00	120.97	0.03%
Irrigated Sugar Beets	12.64	0.00	0.00	12.64	0.00%
Dryland Other Agricultural Crops	0.20	0.00	0.00	0.20	0.00%
Irrigated Sorghum	1,958.94	2,923.15	2,278.27	-319.34	-0.09%
Irrigated Small Grains	890.50	1,974.39	1,466.67	-576.17	-0.16%
Summer Fallow	83.85	19.87	769.86	-686.01	-0.20%
Dryland Sorghum	1,430.53	5,131.37	2,519.91	-1,089.38	-0.31%
Irrigated Alfalfa	3,781.46	1,595.25	4,956.33	-1,174.87	-0.34%
Dryland Small Grains	1,753.91	3,680.83	4,000.23	-2,246.31	-0.64%
Dryland Alfalfa	2,520.44	4,815.85	6,357.97	-3,837.54	-1.10%
Dryland Corn	26,634.50	35,732.50	42,213.90	-15,579.41	-4.45%
Irrigated Corn	148,084.46	192,359.38	192,611.31	-44,526.85	-12.72%

Harlan County (partial)

Harlan					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	25,294.44	8,699.16	1,604.75	23,689.69	9.52%
Dryland Soybeans	9,089.94	4,132.12	419.85	8,670.09	3.49%
Dryland Small Grains	20,978.16	23,463.89	15,202.14	5,776.02	2.32%
Summer Fallow	12,976.11	12,870.60	9,882.16	3,093.96	1.24%
Irrigated Alfalfa	2,932.28	2,069.27	2,094.44	837.85	0.34%
Irrigated Other Agricultural Crops	0.00	1.00	0.00	0.00	0.00%
Irrigated Small Grains	858.80	634.12	1,703.49	-844.69	-0.34%
Dryland Sorghum	1,283.69	18,931.76	3,276.93	-1,993.24	-0.80%
Irrigated Sorghum	38.52	1,466.44	2,810.51	-2,772.00	-1.11%
Dryland Alfalfa	5,253.32	7,033.31	8,116.85	-2,863.54	-1.15%
Dryland Corn	29,421.94	29,314.22	36,731.75	-7,309.81	-2.94%
Irrigated Corn	31,903.66	36,820.36	42,327.09	-10,423.43	-4.19%

Hayes County (partial)

Hayes					
Class	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Corn	37,241.44	30,302.28	18,945.48	18295.96	0.83%
Dryland Sorghum	9,554.83	10,398.01	3,077.04	6477.79	0.29%
Irrigated Alfalfa	4,724.53	1,800.57	985.81	3738.72	0.17%
Dryland Alfalfa	5,302.17	5,521.15	2,377.02	2925.16	0.13%
Irrigated Soybeans	2,763.98	1,381.69	15.25	2748.73	0.13%
Irrigated Sorghum (Milo, Sudan)	2,891.64	1,696.41	594.05	2297.58	0.10%
Irrigated Other Agricultural Crops	1,511.35	602.73	229.59	1281.76	0.06%
Dryland Other Agricultural Crops	1,040.08	1,701.82	120.42	919.67	0.04%
Dryland Soybeans	293.24	3,774.16	14.45	278.79	0.01%
Irrigated Sugar Beets	4.62	1.40	0.00	4.62	0.00%
Irrigated Small Grains	1,601.07	3,675.81	2,921.30	-1320.23	-0.06%
Dryland Corn	14,771.89	26,263.58	19,442.40	-4670.50	-0.21%
Summer Fallow	33,740.25	47,606.94	48,575.89	-14835.64	-0.68%
Dryland Small Grains	43,604.37	47,734.39	62,526.51	-18922.14	-0.86%

Hitchcock County (partial)

Hitchcock					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Dryland Sorghum (Milo, Sudan)	2,049.01	1,587.41	538.66	1,510.35	2.38%
Irrigated Soybeans	1,441.77	1,256.61	5.62	1,436.15	2.27%
Irrigated Sorghum (Milo, Sudan)	1,248.18	626.10	101.15	1,147.03	1.81%
Summer Fallow	6,673.42	8,175.37	5,562.43	1,110.99	1.75%
Irrigated Alfalfa	1,175.56	853.39	233.61	941.95	1.49%
Dryland Alfalfa	1,258.41	956.50	455.98	802.44	1.27%
Irrigated Small Grains	1,051.99	1,137.05	574.79	477.20	0.75%
Dryland Small Grains	10,154.57	9,167.17	9,817.13	337.44	0.53%
Dryland Soybeans	151.86	871.04	4.82	147.04	0.23%
Irrigated Other Agricultural Crops	136.21	163.09	0	136.21	0.21%
Dryland Other Agricultural Crops	114.55	375.34	0	114.55	0.18%
Irrigated Corn	10,292.99	11,124.50	10,226.55	66.44	0.10%
Irrigated Sugar Beets	32.90	0.00	0.00	32.90	0.05%
Dryland Corn	2,486.53	4,589.71	5,539.14	-3,052.61	-4.82%

Howard County (partial)

Howard					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	3,966.82	6,559.07	148.51	3,818.31	3.44%
Irrigated Alfalfa	4,550.39	3,754.58	1,619.20	2,931.19	2.64%
Irrigated Corn	23,591.88	22,662.06	22,198.32	1,393.56	1.26%
Irrigated Sorghum (Milo, Sudan)	1,174.36	206.02	203.10	971.26	0.88%
Dryland Soybeans	773.54	3,040.01	24.08	749.46	0.68%
Summer Fallow	908.75	0.40	237.62	671.13	0.61%
Dryland Sorghum (Milo, Sudan)	705.34	368.72	62.62	642.72	0.58%
Irrigated Small Grains	45.74	54.77	71.45	-25.71	-0.02%
Dryland Small Grains	109.13	164.50	147.71	-38.58	-0.03%
Dryland Alfalfa	1,957.33	4,935.15	3,706.41	-1,749.08	-1.58%
Dryland Corn	4,837.06	4,717.49	12,032.79	-7,195.73	-6.49%

Kearney County

Kearney					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	68,208.26	20,159.17	4,220.19	63,988.07	19.29%
Dryland Soybeans	15,200.86	5,774.64	1,129.50	14,071.35	4.24%
Irrigated Other Agricultural Crops	1,610.28	600.33	0.00	1,610.28	0.49%
Irrigated Alfalfa	4,379.27	4,084.46	3,888.64	490.63	0.15%
Summer Fallow	4,087.18	6,136.12	5,183.52	-1,096.33	-0.33%
Irrigated Small Grains	846.97	1,630.57	2,565.67	-1,718.70	-0.52%
Dryland Sorghum	505.73	12,386.05	5,113.67	-4,607.94	-1.39%
Dryland Small Grains	6,769.51	10,471.07	12,125.91	-5,356.40	-1.61%
Irrigated Sorghum	92.48	3,827.35	6,009.57	-5,917.09	-1.78%
Dryland Alfalfa	4,455.50	7,189.45	11,928.43	-7,472.93	-2.25%
Dryland Corn	36,602.90	25,584.17	56,485.63	-19,882.73	-5.99%
Irrigated Corn	120,651.95	166,870.35	150,587.67	-29,935.72	-9.03%

Keith County

Keith					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Corn	64,517.07	60,892.17	46,384.32	18,132.76	2.56%
Dryland Corn	29,054.43	22,718.43	16,949.78	12,104.65	1.71%
Irrigated Soybeans	6,812.64	2,656.20	0.00	6,812.64	0.96%
Dryland Other Agricultural Crops	3,846.65	5,331.68	520.20	3,326.46	0.47%
Irrigated Other Agricultural Crops	2,609.91	6,102.80	423.06	2,186.85	0.31%
Dryland Sorghum	2,312.81	4,089.08	226.38	2,086.42	0.29%
Dryland Soybeans	1,474.67	2,788.47	0.00	1,474.67	0.21%
Irrigated Alfalfa	8,896.96	7,829.32	7,903.32	993.64	0.14%
Irrigated Sorghum	1,145.27	2,071.53	1,204.96	-59.69	-0.01%
Irrigated Small Grains	6,079.42	8,689.56	6,667.04	-587.62	-0.08%
Irrigated Sugar Beets	1,218.09	1,014.79	3,779.46	-2,561.37	-0.36%
Dryland Alfalfa	3,312.84	7,215.95	6,671.86	-3,359.02	-0.47%
Summer Fallow	36,817.35	50,912.64	61,693.23	-24,875.88	-3.51%
Dryland Small Grains	44,599.13	56,703.14	78,872.60	-34,273.48	-4.83%

Kimball County

Kimbal					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Corn	11,175.86	5,822.41	3,938.41	7,237.45	1.19%
Dryland Other Agricultural Crops	3,927.10	3,652.73	161.36	3,765.74	0.62%
Irrigated Small Grains	6,201.19	8,377.86	3,919.15	2,282.04	0.37%
Dryland Small Grains	148,595.21	144,552.94	146,570.58	2,024.63	0.33%
Irrigated Other Agricultural Crops	2,432.17	1,557.92	734.54	1,697.63	0.28%
Dryland Sorghum	227.69	2.01	0.00	227.69	0.04%
Irrigated Sorghum	11.23	8.03	0.00	11.23	0.00%
Irrigated Soybeans	2.01	1,706.04	0.00	2.01	0.00%
Dryland Soybeans	0.00	1,515.36	0.00	0.00	0.00%
Dryland Corn	2,534.08	3,933.32	2,610.62	-76.55	-0.01%
Irrigated Sugar Beets	1,341.06	1,840.52	1,880.90	-539.84	-0.09%
Irrigated Alfalfa	5,918.93	4,753.23	7,806.18	-1,887.25	-0.31%
Dryland Alfalfa	911.76	3,526.28	3,754.58	-2,842.81	-0.47%
Summer Fallow	97,946.96	126,460.29	206,719.27	-108,772.32	-17.86%

Lincoln County

Lincoln					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	23,755.17	10,295.25	2,877.14	20,878.03	1.27%
Irrigated Corn	148,258.79	155,852.95	139,621.77	8,637.02	0.52%
Dryland Sorghum	8,296.14	12,522.33	325.93	7,970.21	0.48%
Dryland Soybeans	5,810.60	11,263.27	490.50	5,320.11	0.32%
Irrigated Alfalfa	23,882.76	17,648.48	21,456.56	2,426.20	0.15%
Irrigated Sorghum	3,349.35	5,501.48	1,042.80	2,306.54	0.14%
Irrigated Small Grains	4,788.11	4,347.59	3,484.04	1,304.07	0.08%
Irrigated Other Agricultural Crops	1,173.76	1,655.66	20.87	1,152.88	0.07%
Dryland Other Agricultural Crops	1,259.42	4,205.89	124.43	1,134.99	0.07%
Irrigated Sugar Beets	28.29	17.86	118.81	-90.52	-0.01%
Dryland Alfalfa	31,760.83	40,256.92	40,856.41	-9,095.58	-0.55%
Dryland Corn	40,865.61	63,448.42	56,254.43	-15,388.82	-0.93%
Summer Fallow	22,050.21	28,793.13	41,168.69	-19,118.48	-1.16%
Dryland Small Grains	26,517.34	35,466.56	55,678.84	-29,161.50	-1.77%

Logan County (partial)

Logan					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Corn	10,654.48	11,375.26	6,434.24	4,220.24	4.28%
Dryland Soybeans	3,037.60	2,081.11	272.14	2,765.46	2.80%
Dryland Corn	7,371.33	10,101.20	4,896.93	2,474.41	2.51%
Irrigated Alfalfa	1,616.70	1,049.98	985.81	630.89	0.64%
Irrigated Soybeans	1,642.78	785.38	1,063.68	579.10	0.59%
Dryland Sorghum	420.07	38.32	0.00	420.07	0.43%
Irrigated Sorghum (Milo, Suda	353.67	66.40	0.00	353.67	0.36%
Dryland Other Agricultural Crops	152.46	892.70	0	152.46	0.15%
Dryland Alfalfa	1,788.62	3,570.42	1,675.39	113.23	0.11%
Irrigated Other Agricultural Crops	5.82	196.60	0	5.82	0.01%
Irrigated Sugar Beets	0.40	5.02	0.00	0.40	0.00%
Irrigated Small Grains	144.84	31.50	512.97	-368.13	-0.37%
Summer Fallow	2,657.65	2,778.02	7,320.50	-4,662.85	-4.72%
Dryland Small Grains	1,686.91	2,799.28	9,500.03	-7,813.12	-7.92%

Merrick County

Merrick					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	42,029.74	27,094.52	3,630.15	38,399.59	12.30%
Dryland Soybeans	5,393.14	9,107.04	226.38	5,166.76	1.66%
Irrigated Alfalfa	6,249.94	2,777.63	5,329.62	920.32	0.29%
Irrigated Sorghum	2,447.42	238.24	1,819.89	627.53	0.20%
Dryland Sorghum	773.94	274.17	295.42	478.52	0.15%
Irrigated Small Grains	679.46	112.00	346.00	333.46	0.11%
Summer Fallow	637.93	1.40	408.61	229.32	0.07%
Dryland Small Grains	448.56	187.06	887.87	-439.31	-0.14%
Dryland Alfalfa	2,095.35	6,688.28	5,108.86	-3,013.51	-0.97%
Dryland Corn	16,037.59	16,850.85	22,492.14	-6,454.55	-2.07%
Irrigated Corn	104,055.47	129,478.98	122,492.16	-18,436.70	-5.91%

McPherson County (partial)

McPherson					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Alfalfa	2,124.24	1,569.15	1,477.91	646.33	0.21%
Irrigated Sorghum (Milo, Sudan)	419.47	0.00	0.00	419.47	0.14%
Irrigated Soybeans	104.92	228.09	0.00	104.92	0.03%
Dryland Soybeans	58.98	322.18	0.00	58.98	0.02%
Dryland Sorghum (Milo, Sudan)	40.32	0.40	0.00	40.32	0.01%
Dryland Other Agricultural Crops	13.64	143.43	4.82	8.82	0.00%
Irrigated Sugar Beets	0.00	21.87	1.61	-1.61	0.00%
Irrigated Other Agricultural Crops	0.60	77.84	15.25	-14.65	0.00%
Irrigated Small Grains	141.03	213.05	158.15	-17.12	-0.01%
Summer Fallow	451.97	368.12	846.93	-394.96	-0.13%
Dryland Small Grains	28.69	708.15	503.34	-474.65	-0.16%
Dryland Alfalfa	134.01	962.92	712.86	-578.86	-0.19%
Irrigated Corn	3,181.44	4,881.19	4,960.34	-1,778.91	-0.58%
Dryland Corn	177.14	1,946.30	2,834.60	-2,657.46	-0.87%

Morrill County

Morrill					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Other Agricultural Crops	16,057.05	13,765.53	7,920.17	8,136.88	0.89%
Irrigated Alfalfa	23,759.19	16,396.04	17,396.93	6,362.26	0.70%
Irrigated Small Grains	7,919.80	12,770.41	1,854.41	6,065.39	0.66%
Dryland Other Agricultural Crops	6840.93	2509.28	1,115.05	5,725.87	0.63%
Dryland Sorghum	1,049.58	3.81	0.00	1,049.58	0.11%
Irrigated Sorghum	400.41	24.69	0.00	400.41	0.04%
Irrigated Soybeans	258.78	11,904.74	0.80	257.98	0.03%
Dryland Soybeans	78.24	1,549.69	0.00	78.24	0.01%
Irrigated Corn	57,286.77	46,911.88	63,189.60	-5,902.83	-0.65%
Dryland Small Grains	26,835.91	48,118.55	33,052.64	-6,216.73	-0.68%
Irrigated Sugar Beets	461.00	4,758.04	6,838.84	-6,377.84	-0.70%
Dryland Alfalfa	5,021.01	3,849.23	14,308.65	-9,287.64	-1.02%
Dryland Corn	9,619.34	5,990.41	19,157.41	-9,538.07	-1.04%
Summer Fallow	18,530.14	32,207.02	34,085.81	-15,555.67	-1.70%

Nance County (partial)

Nance					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	5,084.00	4,150.78	211.93	4,872.07	6.95%
Dryland Soybeans	3,139.91	6,729.19	142.09	2,997.82	4.28%
Irrigated Corn	11,282.18	12,563.87	10,155.90	1,126.28	1.61%
Irrigated Alfalfa	1,381.59	379.55	509.76	871.82	1.24%
Summer Fallow	147.25	0.00	57.00	90.25	0.13%
Irrigated Sorghum (Milo, Suda	205.22	0.00	145.30	59.92	0.09%
Irrigated Sugar Beets	1.20	0.00	0.00	1.20	0.00%
Irrigated Other Agricultural Crops	0.80	0.00	0.00	0.80	0.00%
Irrigated Small Grains	60.58	0.60	408.61	-348.03	-0.50%
Dryland Sorghum	262.80	0.00	713.67	-450.87	-0.64%
Dryland Alfalfa	1,071.05	2,306.39	1,770.12	-699.07	-1.00%
Dryland Small Grains	504.73	2.81	1,420.91	-916.18	-1.31%
Dryland Corn	7,644.96	8,401.25	14,149.70	-6,504.74	-9.29%

Nuckolls County (partial)

Nuckolls					
Class	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Dryland Soybeans	27,123.62	23,294.27	647.04	26,476.59	7.08%
Irrigated Soybeans	17,501.36	10,002.41	789.13	16,712.23	4.47%
Dryland Corn	36,623.85	33,862.88	27,043.07	9,580.79	2.56%
Irrigated Corn	26,489.58	25,901.50	24,577.75	1,911.83	0.51%
Dryland Alfalfa	8,386.09	8,067.76	7,166.37	1,219.72	0.33%
Irrigated Sorghum (Milo, Sudan)	1,874.03	1,547.28	1,296.48	577.55	0.15%
Irrigated Small Grains	584.47	886.14	1,096.59	-512.12	-0.14%
Irrigated Alfalfa	1,721.90	291.43	2,428.39	-706.50	-0.19%
Summer Fallow	2,799.31	1,907.35	7,895.29	-5,095.98	-1.36%
Dryland Sorghum	40,066.64	47,734.99	50,639.82	-10,573.18	-2.83%
Dryland Small Grains	27,578.23	66,800.69	76,583.89	-49,005.66	-13.10%

Perkins County

Perkins					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Dryland Corn	57,697.81	34,766.68	28,959.29	28,738.52	5.08%
Irrigated Corn	98,331.12	97,668.36	78,569.96	19,761.16	3.49%
Irrigated Soybeans	11,296.43	3,536.92	0.00	11,296.43	2.00%
Dryland Sorghum	5,809.80	11,999.88	115.60	5,694.20	1.01%
Dryland Other Agricultural Crops	6696.49	7460.41	1,019.52	5,676.97	1.00%
Dryland Soybeans	2,574.20	4,501.13	0.00	2,574.20	0.45%
Dryland Alfalfa	4,945.18	2,895.45	2,381.03	2,564.15	0.45%
Irrigated Other Agricultural Crops	2,746.52	6,227.04	647.04	2,099.49	0.37%
Irrigated Sorghum	2,132.46	4,281.76	1,339.03	793.43	0.14%
Irrigated Alfalfa	5,075.98	3,401.64	5,686.05	-610.07	-0.11%
Irrigated Sugar Beets	775.35	996.93	2,656.38	-1,881.03	-0.33%
Irrigated Small Grains	7,311.35	13,401.84	11,204.32	-3,892.97	-0.69%
Summer Fallow	89,643.40	117,698.27	137,686.28	-48,042.88	-8.49%
Dryland Small Grains	109,101.55	119,794.89	166,020.21	-56,918.65	-10.06%

Phelps County

Phelps					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	103,497.98	15,245.37	10,234.57	93,263.40	26.96%
Dryland Soybeans	13,776.34	3,467.88	1,780.55	11,995.79	3.47%
Irrigated Other Agricultural Crops	187.37	670.77	0.00	187.37	0.05%
Summer Fallow	3,075.52	1,916.59	3,333.92	-258.40	-0.07%
Irrigated Small Grains	628.30	1,216.51	1,779.75	-1,151.45	-0.33%
Dryland Sorghum	290.48	8,689.96	1,827.92	-1,537.44	-0.44%
Irrigated Alfalfa	5,599.16	7,000.38	7,566.15	-1,966.99	-0.57%
Dryland Alfalfa	4,324.10	8,170.73	7,578.99	-3,254.89	-0.94%
Dryland Small Grains	2,790.45	4,756.84	8,218.00	-5,427.55	-1.57%
Irrigated Sorghum	49.15	4,516.59	10,754.77	-10,705.62	-3.09%
Dryland Corn	19,372.09	17,610.74	37,731.21	-18,359.12	-5.31%
Irrigated Corn	117,346.94	202,458.34	177,273.50	-59,926.57	-17.32%

Platte County (partial)

Platte					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Corn	14,522.20	16,064.07	11,030.12	3,492.08	6.26%
Irrigated Soybeans	3,645.85	3,834.22	633.39	3,012.46	5.40%
Irrigated Alfalfa	1,595.43	381.15	740.16	855.28	1.53%
Summer Fallow	290.68	0.00	0.00	290.68	0.52%
Dryland Soybeans	336.62	1,794.64	134.06	202.56	0.36%
Dryland Small Grains	132.00	0.00	122.82	9.18	0.02%
Irrigated Small Grains	115.95	0.40	163.77	-47.81	-0.09%
Dryland Alfalfa	352.87	694.50	519.40	-166.53	-0.30%
Dryland Sorghum	40.92	0.00	413.43	-372.50	-0.67%
Irrigated Sorghum (Milo, Suda	227.89	0.00	665.50	-437.61	-0.78%
Dryland Corn	1,863.04	2,885.14	5,082.37	-3,219.32	-5.77%

Polk County

Polk					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	48,081.88	32,190.16	6,310.61	41,771.27	14.83%
Dryland Soybeans	22,063.65	30,769.33	7,612.71	14,450.94	5.13%
Irrigated Corn	84,485.97	95,220.10	77,576.12	6,909.85	2.45%
Irrigated Alfalfa	3,971.03	848.20	2,248.57	1,722.46	0.61%
Irrigated Sorghum	0.00	0.00	1,206.57	-1,206.57	-0.43%
Dryland Alfalfa	3,264.49	4,751.62	5,204.39	-1,939.90	-0.69%
Dryland Sorghum	0.00	0.00	2,454.88	-2,454.88	-0.87%
Irrigated Small Grains	166.10	9.03	2,786.43	-2,620.33	-0.93%
Dryland Small Grains	435.72	67.64	9,258.40	-8,822.68	-3.13%
Dryland Corn	46,434.89	46,912.48	97,659.13	-51,224.25	-18.18%

Red Willow County (partial)

Red Willow					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	5,286.02	3,545.54	81.08	5,204.94	2.99%
Dryland Small Grains	27,401.82	25,939.19	24,167.53	3,234.29	1.86%
Irrigated Alfalfa	3,290.57	2,263.86	626.97	2,663.60	1.53%
Dryland Alfalfa	3,177.03	5,454.73	1,508.41	1,668.61	0.96%
Dryland Soybeans	1,216.29	2,053.02	25.69	1,190.60	0.68%
Irrigated Corn	18,546.19	20,476.44	18,092.93	453.26	0.26%
Irrigated Small Grains	2,352.73	1,226.32	2,166.69	186.04	0.11%
Irrigated Sorghum (Milo, Suda	635.32	1,501.75	450.36	184.97	0.11%
Irrigated Other Agricultural Crops	52.76	33.10	0.00	52.76	0.03%
Dryland Other Agricultural Crops	34.91	107.12	0.00	34.91	0.02%
Irrigated Sugar Beets	4.81	0.00	0.00	4.81	0.00%
Summer Fallow	18,273.16	16,485.15	18,380.33	-107.16	-0.06%
Dryland Sorghum	1,706.17	8,051.59	2,044.67	-338.50	-0.19%
Dryland Corn	14,844.38	16,217.94	18,381.13	-3,536.75	-2.03%

Scotts Bluff County

Scottsbluff					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Other Agricultural Crops	39,316.12	34,344.99	22,543.52	16,772.60	3.52%
Irrigated Small Grains	12,928.37	9,801.50	2,954.21	9,974.16	2.09%
Irrigated Corn	78,598.34	66,458.88	72,059.46	6,538.88	1.37%
Irrigated Alfalfa	27,340.03	26,641.11	22,557.97	4,782.07	1.00%
Dryland Other Agricultural Crops	5,160.44	2,371.60	2,816.94	2,343.50	0.49%
Irrigated Sorghum	66.40	11,255.45	0.00	66.40	0.01%
Dryland Sorghum	11.84	1,111.74	0.00	11.84	0.00%
Dryland Corn	7,607.25	5,605.64	11,291.83	-3,684.58	-0.77%
Dryland Alfalfa	3,677.54	7,725.95	7,496.31	-3,818.77	-0.80%
Dryland Small Grains	14,648.98	16,253.14	19,698.48	-5,049.50	-1.06%
Irrigated Sugar Beets	7,757.30	17,138.47	27,674.85	-19,917.55	-4.18%
Summer Fallow	7,934.04	12,050.06	35,550.07	-27,616.03	-5.79%

Sheridan County (partial)

Sheridan					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Alfalfa	1,708.38	848.97	960.12	748.26	0.29%
Irrigated Small Grains	235.71	464.41	4.01	231.70	0.09%
Irrigated Other Agricultural Crops	137.56	72.16	0.00	137.56	0.05%
Dryland Other Agricultural Crops	26.28	8.83	0.00	26.28	0.01%
Summer Fallow	93.88	1,448.39	70.64	23.24	0.01%
Dryland Sorghum (Milo, Sudan)	2.01	0.00	0.00	2.01	0.00%
Irrigated Sorghum (Milo, Sudan)	2.01	0.00	0.00	2.01	0.00%
Dryland Soybeans	0.00	146.84	0.00	0.00	0.00%
Irrigated Soybeans	0.00	9.63	0.00	0.00	0.00%
Dryland Small Grains	129.39	1,533.85	154.94	-25.54	-0.01%
Dryland Corn	75.43	186.97	101.95	-26.52	-0.01%
Irrigated Sugar Beets	0.40	17.05	168.58	-168.18	-0.06%
Irrigated Corn	411.45	333.81	620.54	-209.10	-0.08%
Dryland Alfalfa	427.29	677.05	1,770.12	-1,342.82	-0.52%

Sioux County (partial)

Sioux					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Alfalfa	8,104.35	6,930.00	4,992.46	3,111.90	0.62%
Irrigated Small Grains	2,387.43	3,003.70	496.11	1,891.32	0.38%
Irrigated Other Agricultural Crops	3,234.40	3,954.78	1,648.10	1,586.30	0.32%
Irrigated Corn	13,493.28	12,025.84	12,646.91	846.37	0.17%
Dryland Other Agricultural Crops	392.59	294.09	241.64	150.95	0.03%
Dryland Sorghum (Milo, Sudan)	10.43	0.00	0.00	10.43	0.00%
Irrigated Sorghum (Milo, Sudan)	6.62	0.00	0.00	6.62	0.00%
Dryland Soybeans	0.00	140.22	0.00	0.00	0.00%
Irrigated Soybeans	0.00	1,211.27	0.00	0.00	0.00%
Dryland Alfalfa	957.90	1,055.00	1,468.27	-510.37	-0.10%
Dryland Corn	1,471.66	728.61	2,513.49	-1,041.83	-0.21%
Dryland Small Grains	877.46	3,014.13	3,461.56	-2,584.11	-0.51%
Irrigated Sugar Beets	1,329.23	1,694.94	4,018.69	-2,689.46	-0.53%
Summer Fallow	945.67	3,865.31	6,177.35	-5,231.69	-1.04%

Webster County (partial)

Webster					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	15,042.78	7,099.91	402.19	14,640.59	4.94%
Dryland Soybeans	10,818.98	9,345.31	909.54	9,909.44	3.34%
Irrigated Corn	24,659.71	28,729.64	21,638.79	3,020.92	1.02%
Irrigated Alfalfa	2,886.55	1,470.25	1,611.17	1,275.38	0.43%
Irrigated Other Agricultural Crops	375.34	0.40	0.00	375.34	0.13%
Dryland Sorghum	14,500.13	21,855.62	15,068.88	-568.75	-0.19%
Irrigated Sorghum (Milo, Suda	1,347.88	826.91	2,019.78	-671.90	-0.23%
Irrigated Small Grains	978.77	1,193.82	1,746.84	-768.07	-0.26%
Summer Fallow	6,719.56	9,889.76	8,784.76	-2,065.20	-0.70%
Dryland Alfalfa	6,592.77	9,290.75	11,223.59	-4,630.82	-1.56%
Dryland Corn	31,192.51	26,511.12	41,309.17	-10,116.67	-3.41%
Dryland Small Grains	21,433.54	41,325.01	49,613.88	-28,180.34	-9.51%

York County

York					
CLASS	2001 Acres	1997 Acres	1982 Acres	Acres Change (1982-2001)	% of County Change
Irrigated Soybeans	69,113.60	35,800.34	10,877.60	58,236.00	15.82%
Dryland Soybeans	22,030.75	22,425.39	5,237.30	16,793.45	4.56%
Irrigated Corn	154,340.02	179,870.17	147,936.10	6,403.91	1.74%
Dryland Alfalfa	9,136.28	4,428.48	6,355.57	2,780.71	0.76%
Irrigated Alfalfa	5,001.95	893.76	4,469.85	532.11	0.14%
Irrigated Sorghum (Milo, Suda	4,394.31	2,599.20	4,055.62	338.70	0.09%
Summer Fallow	280.85	3.61	614.12	-333.27	-0.09%
Irrigated Small Grains	568.72	688.44	2,057.51	-1,488.79	-0.40%
Dryland Sorghum	2,266.47	6,129.90	6,289.74	-4,023.27	-1.09%
Dryland Small Grains	1,109.96	3,937.94	7,006.62	-5,896.65	-1.60%
Dryland Corn	42,847.42	52,586.57	99,109.75	-56,262.33	-15.28%