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

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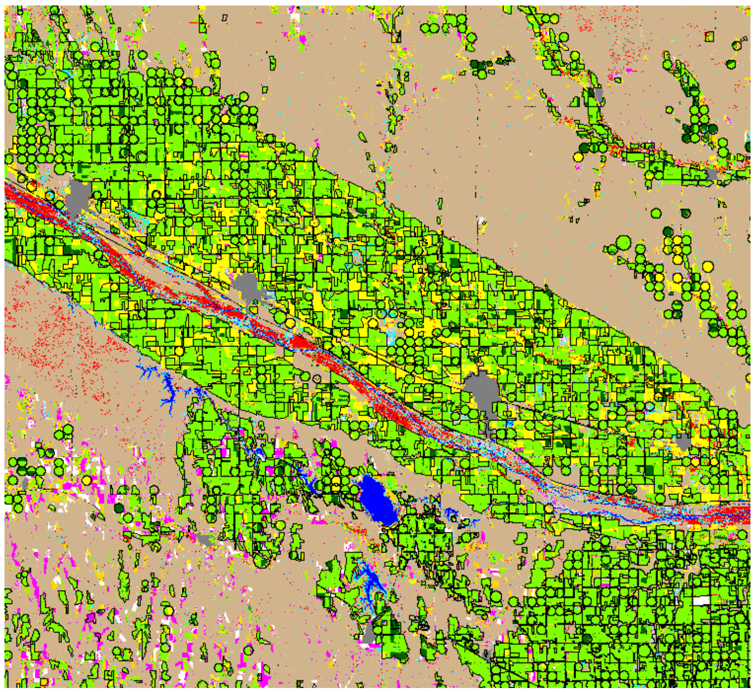

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INTRODUCTION

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 sand hill cranes and the several million other waterfowl that migrate annually through the valley. Nine endangered species use the central Platte River 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. Habitat loss has caused concern for the welfare of the millions of migratory birds that stop along the Platte on their way to breeding grounds on the Northern Plains, Taiga, and Arctic.

The Platte River Cooperative Hydrology Study (COHYST) seeks to improve the understanding of the hydrological and geological conditions of the Platte River Basin upstream of Columbus, Nebraska. The study will 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

Process based hydrologic models utilize inputs based on quantifiable variables. Land cover has been identified as one key variable in hydrologic modeling (Bobba *et al*., 2000, Srinvasan *et al*., 1998), and is an important factor in determining consumptive use of water (Zheng and Baetz, 1999). Land cover patterns for the COHYST study area were delineated through analysis of Landsat Thematic Mapper (TM) 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 land use and land cover map of the Platte River Basin in Nebraska.

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.

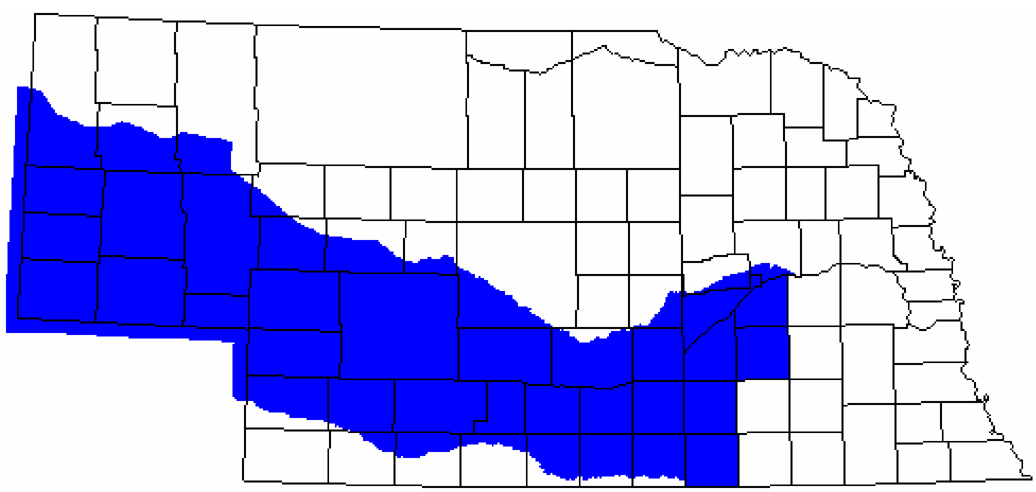


Figure 1. COHYST Study Area.

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, sandhills 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 generally summers are hot, and winters severe. Temperature and precipitation vary widely among 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. Mean monthly temperatures and total monthly precipitation for the years 1995-1997 are summarized in Table 1. Normal mean values are averages computed for the years 1961-90. During 1997, precipitation during the months of August, September, and October was greater than averages.

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 is used for grazing cattle.

Table 1. Mean monthly temperature and precipitation of the study area.

(Mean values from Grand Island, Kearney, North Platte, and Scottsbluff). Climatological data are from the National Oceanic and Atmospheric Administration 1995-1997.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Temperature (C)												
1995	-3.82	1.28	3.33	6.72	11.47	19.36	23.51	24.88	16.38	9.60	2.97	-2.42
1996	-6.75	-0.96	-0.32	8.74	13.88	21.13	22.25	21.43	15.93	10.08	-0.46	-4.00
1997	-5.04	-1.44	4.42	5.75	13.21	21.00	23.64	21.68	18.11	10.72	1.61	-1.38
Normal*	-5.18	-2.18	2.68	9.31	15.32	20.72	23.99	22.53	17.07	10.29	2.53	-3.68
Precipitation (cm)												
1995	1.24	0.82	3.91	6.67	14.89	7.35	5.18	3.80	4.03	2.81	0.83	0.59
1996	2.57	0.01	1.52	2.57	16.90	9.29	10.33	7.64	9.13	0.72	4.70	0.22
1997	0.36	1.92	0.51	5.16	8.17	7.27	4.89	11.16	7.82	7.25	0.90	0.76
Normal*	1.11	1.44	3.84	5.29	8.84	8.78	7.10	5.37	5.14	3.00	2.04	1.55

*Mean values from 1961-1990

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), *Liatris punctata* (dotted gayfeather) (Great Plains Flora Association, 1986). Lowland prairies are a combination of marshes, sedge meadows, and well-drained prairies. Many of the lowland prairies have been drained and cultivated. Dominate grasses include *Andropogon gerardii* (big bluestem), *Sorghastrum nutans*

(Indian grass), *Spartina pectinata* (prairie cordgrass), *Sporobolus asper* (tall dropseed), *Panicum virgatum* (switchgrass), and 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 deltoids* (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 deltoids* (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. In 1997 of the total harvested acres in the study area approximately 54% represented corn, 19% represented wheat, 13% represented hay (including alfalfa), 8% represented soybeans, 3% represented sorghum, and 3% represented ‘other crops’ (oats, sugar beets, and dry beans) (Nebraska Dept. of Agriculture, 1998). 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 any other non-agricultural lands.

Land Cover Classes and Their Characteristics

Land cover classes used in the study included (Table 2): irrigated & non-irrigated corn, irrigated sugar beets, irrigated & non-irrigated soybeans, irrigated & non-irrigated sorghum, irrigated dry edible beans, irrigated potatoes, irrigated & non-irrigated alfalfa, irrigated & non-irrigated small grains, irrigated and non-irrigated sunflower, summer fallow, range/grass/pasture, urban land, open water, riparian forest & woodlands, wetlands, other agricultural lands, and roads. Each class is further detailed and described in Table 2.

Table 2. Land Cover Classes and Characteristics

(Descriptions from Nebraska Agricultural Statistics Service, 1990; National Agricultural Statistics Service, 1997; 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	Planted in April. Full cover in August and harvested in October
Irrigated & Non-Irrigated Soybeans	Planted in May. Full cover by July and harvested in 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 Dry Edible Beans	Includes great northern beans, pinto beans, white beans, and others. Planted in May to early June. Cutting starts mid-August when plants are windrowed to dry. Harvested late August to late September.
Irrigated Potatoes	Planted in late April to early May, harvested September/October.
Irrigated & Non-Irrigated Alfalfa	Green-up 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 are barely are generally planted late March or early April, and harvested in July.

Irrigated & Non-Irrigated Sunflower	Planted in May and harvested in October.
Summer Fallow	Cropland that is purposely kept out of production during a cropping season mainly to conserve moisture for the next season. It is common for wheat producers to rotate half their cropland to summer fallow each year.
Range/Grass/Pasture	Mostly range grasses and pasture with some cultivated grass and hay. Includes brome grass and land in the Conservation Reserve Program. Green-up in spring and early summer. Grazing occurs at irregular intervals.
Urban Land	Areas defined as towns or cities with a population greater than 300 people.
Open Water	Lakes, streams, ponds, reservoirs. Water level varies due to irrigation draw down and evaporation.
Riparian Forest and Woodlands	Forested areas including areas next to streams, lakes and wetlands
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.
Other Agricultural Lands	Includes developed areas associated with farming such as farmsteads, feedlots, etc.
Roads	Interstate, highway, and county roads.

LITERATURE REVIEW

Remote Sensing of Land Cover

Remote sensing is the art and science of obtaining information about an object, area, or phenomenon through the analysis of data acquired by an instrument not in contact with the object, area, or phenomenon of interest (Lillesand & Kiefer, 1994). 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 1970's, it was determined that general vegetation and land cover types could be mapped from satellite imagery faster and at a lower cost than 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 Landsat Thematic Mapper (TM) data using more powerful computer hardware and software (Congalton *et al.*, 1998; McGwire *et al.*, 1996). Landsat TM data are well suited for vegetation/land-cover mapping due to the frequency of satellite coverage. For this satellite, imagery is collected every 16 days for the same ground area.

Remote sensing of land cover is based on principles of interaction between matter and electromagnetic energy. For any type of material, the amount of incoming solar radiation that is reflected, absorbed, and transmitted will vary with wavelength (Sabins, 1987). This basic principle allows for 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 2), in reality they should appear more like "ribbons" since spectral reflectances vary somewhat within a given material type. The spectral response 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 response patterns that emerge for different types of materials.

In healthy vegetation, chlorophyll strongly absorbs energy in the wavelength bands centered at about 0.45 and 0.67 μm (Tucker, 1979). Our eyes see healthy vegetation as green 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 the 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 leafs typically reflects 40%-50% of the energy incident upon it (Lillesand and Kiefer, 1994).

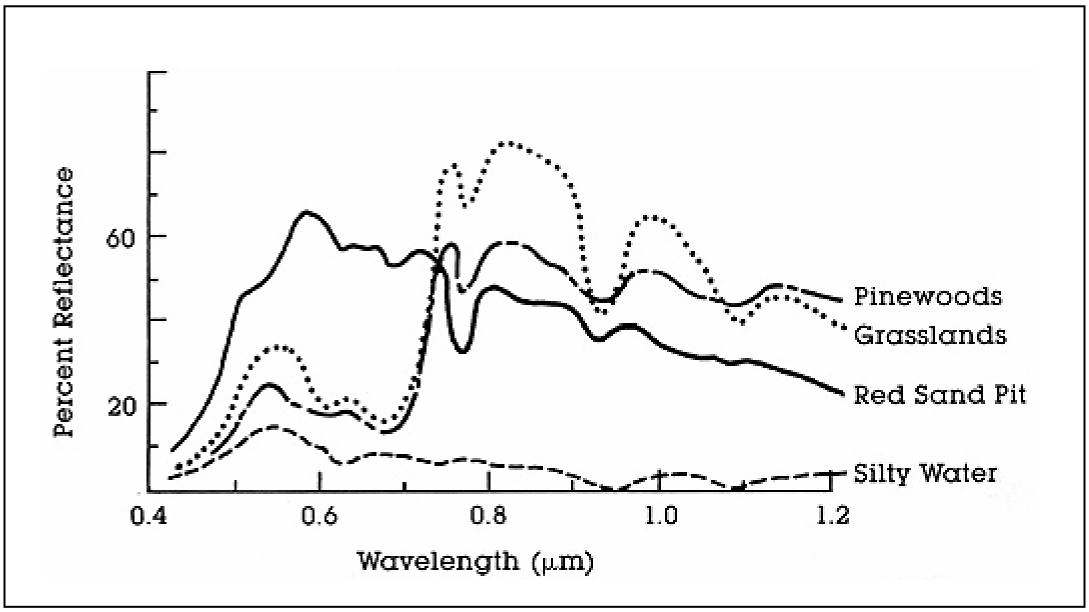


Figure 2. Spectral reflectance curves

(Adapted from Swain, P.H., and S. M. Davis, 1978).

These high reflectance values results 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. Differences and 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, 1994). 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 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 ouput 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. In this case, ancillary data is important in helping to decide which clusters belong to each land cover class.

Remote Sensing of Agriculture

Satellite remote sensing data has been used extensively for agricultural applications. Agricultural applications include using satellite data to estimate crop yield, monitoring of crop conditions, and canopy activity. For over a decade, the United States conducted the Large Area Crop Inventory Experiment (LACIE), which aimed at estimating wheat production over the world using Landsat MSS and TM data (Moulin *et al*, 1998). These estimates were important for agricultural planning and policy making. While LACIE aimed at generating crop acreage and yield estimates, numerous other field experiments and studies have shown that remotely sensed measurements in different wavelengths can provide information on crop conditions (Clevers and van Leeuwen, 1996, Mariotti *et al*., 1996, McAdam, 1997, Wiegand *et al*., 1991).

Data from satellite imagery can, for example, aid in monitoring crop development. Thenkabail *et al.* (1994) used Landsat TM imagery to evaluate soybean and corn crop characteristics. This study tested the ability of satellite derived vegetation indices to estimate crop yield, leaf area, wet and dry biomass. Specific to their tests on corn and soybeans, the mid-infrared bands of Landsat 5 TM provided the most information in regards to crop growth and yield variables. This is in comparison to the more commonly used near-infrared and red based indices.

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

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

Remote sensing and spatial data were also integrated in an agricultural and land cover classification of the Lower Colorado River Basin covering sections of California, Arizona, and Nevada. Congalton *et al*. (1998) achieved very high accuracies using detailed ground observations and a supervised classification of multidate Landsat TM imagery. Prior to the classification, field boundaries were digitized on-screen using SPOT 10-m panchromatic imagery. Fields were selected to represent the variety of crops types across the study area and a random number were chosen to be field checked. Sites were visited at four different times to coincide with the different crops planted throughout the year (March, May, August, and December). One third of the ground visited fields were set aside to be used in the accuracy assessment, the other two thirds were used as training sites for the supervised classification. Four dates of imagery were used to represent the entire growing season. Spectral signatures were evaluated and bad signatures were eliminated to increase classification accuracy. The methodology resulted in an overall accuracy of 93% for the crop classification (Congalton et al.1998).

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

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 significant spectral disparity of the same crop. The same crop may have a large variation in spectral response. Spectral response is also compounded by changes in soil moisture levels at different landscape location, slope, and elevation. 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.

Knowledge of the crop growth cycle is very important in selecting the dates of imagery used in the classification. The agroclimatic calendar for crops in Nebraska span from April to October (Figure3). 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 1997 for the land cover classification (see Table 3).

Maxwell and Hoffer (1996) studied which dates of imagery were most important in mapping agricultural crops for their study area near Ft. Collins, Colorado. Eleven different crops or cover types were evaluated for 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 and later summer maturing crops. 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.

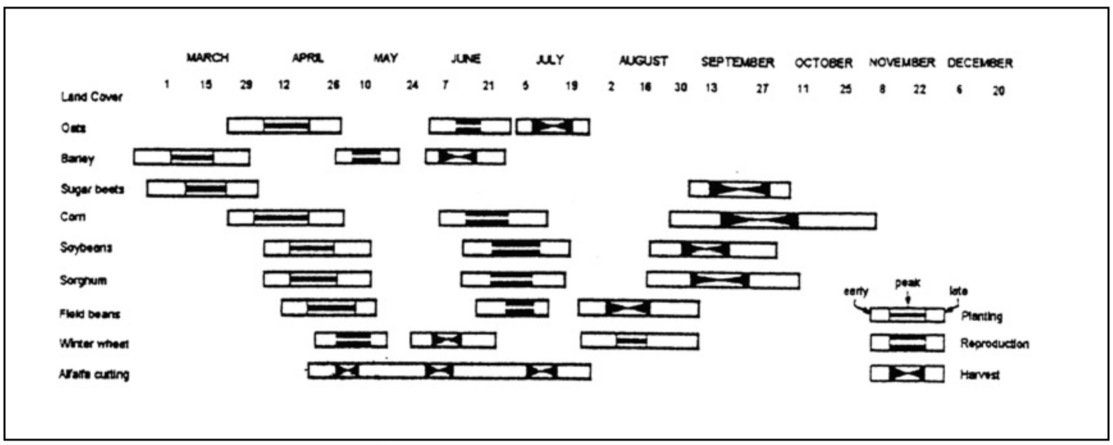


Figure 3. Agroclimatic Calendar for Nebraska.

(Adapted from Nebraska Agricultural Statistics Service, 1990)

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.

METHODS

Data Collection and Initial Processing

Satellite Data Acquisition and Image Preprocessing

To cover the entire study area, ten Landsat Thematic Mapper (TM) scenes were needed (see Figure 4). 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.

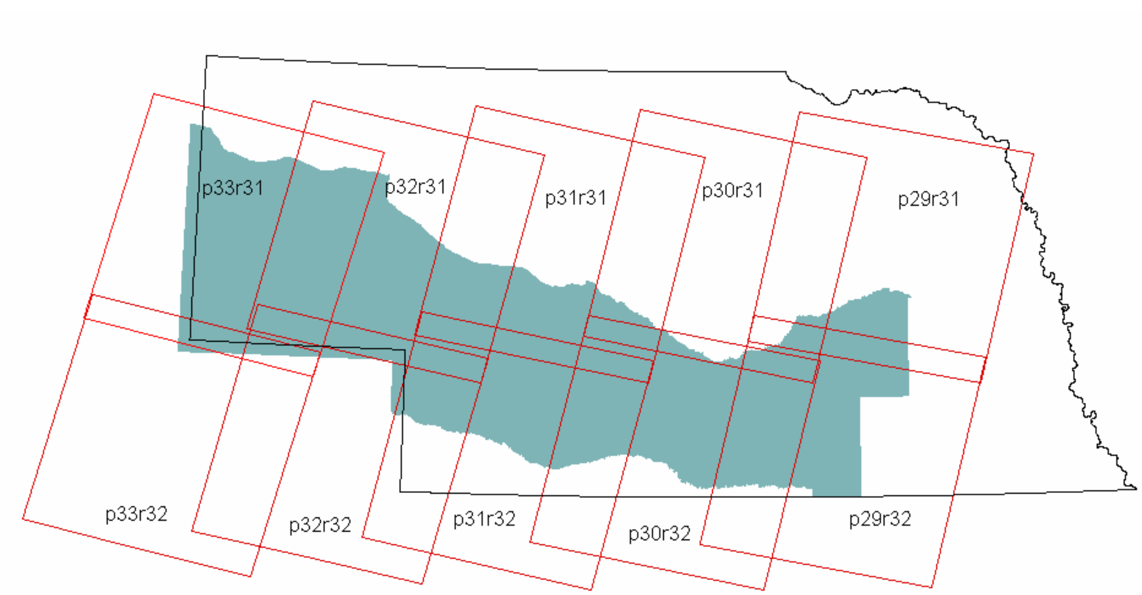


Figure 4. Landsat TM Imagery Coverage of the Study Area by Path/Row.

A total of 24 Landsat 5 TM satellite images were purchased from the U.S. Geological Survey EROS Data Center in a geocoded and terrain-corrected format. Additional atmospheric or radiometric corrections were not applied to these data sets. The selection of imagery was limited due to difficulties in finding relatively cloud free dates. All data were processed using TM Bands 2,3,4,5, and 7 as bands 1 and 6 were removed from each scene.

Table 3. Landsat 5 TM Data used in Classification

No.	Path/Row	Date of Image Acquisition	Scene ID	Percent Cloud Cover
1	29/31	4/27/97	LT5029031009711710	2%
	29/31	7/16/97	LT5029031009719710	0
	29/31	10/4/97	LT5029031009727110	0
2	29/32	5/13/97	LT5029032009713310	6%
	29/32	7/16/97	LT5029032009719710	0
	29/32	10/4/97	LT5029032009727710	0
3	30/31	8/8/97	LT5030031009722010	0
4	30/32	5/4/97	LT5030032009712410	0
	30/32	8/8/97	LT5030032009722010	0
	30/32	9/25/97	LT5030032009726810	0
5	31/31	6/28/97	LT5031031009717910	10%
	31/31	8/15/97	LT5031031009722710	0
	31/31	10/2/97	LT5031031009727510	0
6	31/32	6/28/97	LT5031032009717910	1%
	31/32	8/15/97	LT5031032009722710	0
	31/32	10/2/97	LT5031032009727510	0
7	32/31	3/31/97	LT5032031009709010	0
	32/31	9/9/97	LT5032031009725010	12%
	32/31	10/9/97	LT5032031009728210	0
8	32/32	7/5/97	LT5032032009718610	1%
9	33/31	5/9/97	LT5033031009712910	0
	33/31	8/13/97	LT5033031009722510	3%
	33/31	9/30/97	LT5033031009727310	0
10	33/32	7/12/97	LT5033032009719310	3%

Spectral band 1 was not included due to data redundancy issues. Band 6 was removed as it measures the amount of infrared radiant flux emitted from surfaces (Jensen, 1996). While other bands provide a measure of reflected energy, band 6 measures transmitted energy (see Table 4). The remaining 5 bands from each scene were layer stacked to create a 15 band image for each Path/Row with three dates of imagery.

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

Table 4. Characteristics of Landsat 5

Spectral Band	Spectral Range (μm)	Nominal Spectral Location	Ground Resolution (m)
1	0.45- 0.52	Visible Blue	30
2	0.52 – 0.60	Visible Green	30
3	0.63 – 0.69	Visible Red	30
4	0.76 – 0.90	Near infrared	30
5	1.55 – 1.75	Mid-infrared	30
6	10.4 – 12.5	Thermal infrared	120
7	2.08 – 2.35	Mid-infrared	30

Urban areas were subset using 1992 TIGER (Topologically Integrated Geographic Encoding and Referencing system) line data from the U.S. Census Bureau. TIGER is a digital database of geographic features, such as roads, railroads, rivers, lakes, political boundaries, and census statistical boundaries developed at the Census Bureau to support its mapping needs for the Census and other Bureau programs. These data were downloaded from the Nebraska Department of Natural Resources (http://www.nrc.state.ne.us/databank/spat2.html) by county and reprojected into a common map projection of Universal Transverse Mercator (UTM), zone 14, NAD 27. Urban areas were determined by road density and were on-screen digitized and masked from the imagery.

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, 1994). 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. Spectral signatures were collected using three dates of imagery as one 15-band image for each scene.

Farm Service Agency (FSA) Data

USDA Farm Service Agency (FSA) reporting records from 1997 were the main source of crop information used to determine training areas for agricultural classes. FSA reporting records provide detailed information in regards to crop type, irrigated and dryland fields, and field boundaries. An example of a partial FSA reporting record is found in Figure 5.

Approximately 1500 sections across the entire study area were randomly selected to collect FSA data. FSA aerial photography was labeled with 1997 crop types from each county. FSA photos by county were randomly split into two groups. One group was used to determine training sites for specific crops. The second group was scanned and rectified for use during accuracy assessment.

FSA data were used to locate training areas for the following classes: Corn, Sugar Beets, Soybeans, Sorghum, Dry Edible Beans, Potatoes, Alfalfa, Small Grains, Range/Pasture, Open Water, Sunflower, and Summer Fallow. For each crop type, special attention was given to collecting signatures from homogenous areas. Spectral signatures were taken in the center of fields and not close to field boundaries where spectrally mixed pixels occur. At the boundary between different land cover types there is a loss of accurate pixel values. These pixels are not reflective of a particular cover type but are rather a description of a mixture of adjacent cover types (Grunblatt, 1987). As FSA data are organized by Township/Range/Section, exact field locations were identified on the imagery. Spectral and tonal variations in the imagery were also used in determining field boundaries.

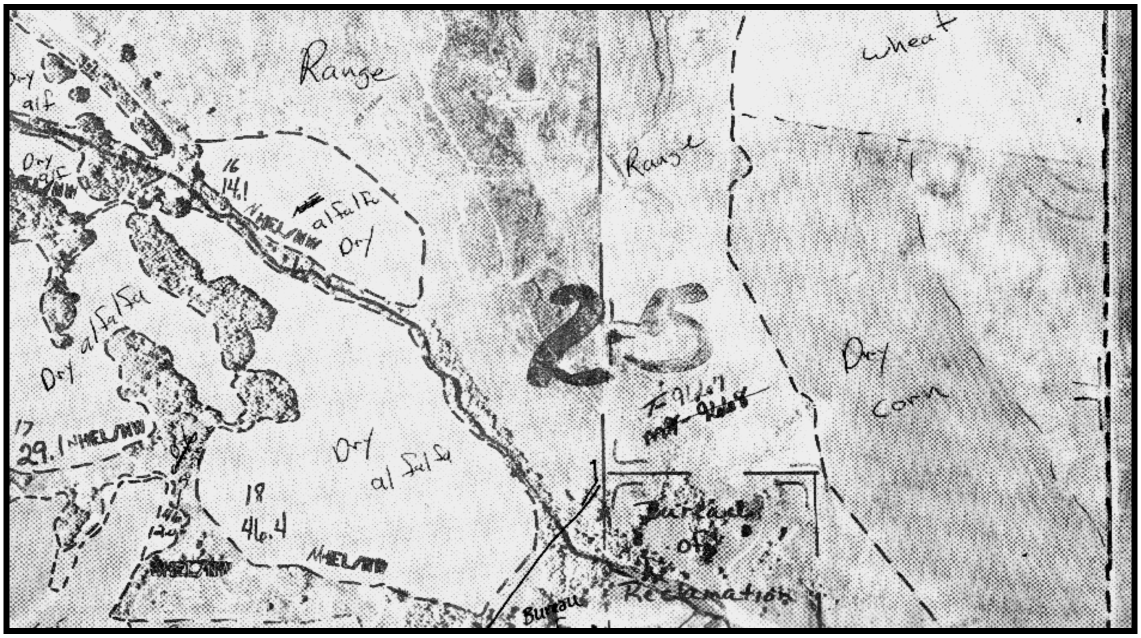


Figure 5. Example of a Farm Service Agency reporting record from 1997

<u>*Digital Orthophoto Quarter Quadrangles*</u>

Another source of land cover data was digital orthophoto quarter quadrangles (DOQQ's). A digital ortho-photograph is a digital image of an aerial photograph with image distortion removed, and corrected for aircraft pitch, yaw and altitude, landscape relief, and camera lens (optic correction) orientation. The DOQQ's used were developed from 1993 National Aerial Photography Program (NAPP) aerial photos mapped to 1:12,000 scale accuracy specifications. DOQQ's have the positional accuracy of a map while providing the spatial detail of a photograph. Because of these features, DOQQ's were used to locate training sites for open water, roads, wooded areas, and other agricultural lands such as homesteads and feeding lots. DOQQ's were randomly selected throughout the study area and downloaded from the Nebraska Department of Natural Resources (http://www.nrc.state.ne.us/databank/spat2.html). The files were then uncompressed and reprojected to UTM, zone 14, NAD 27. Since the DOQQ's were rectified with a high degree of positional accuracy they could be overlaid on the satellite imagery to determine exact locations for the training areas.

National Wetlands Inventory

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

The National Wetlands Inventory (NWI) files used in this project were downloaded from the Conservation and Survey Division at the University of Nebraska (http://csd.unl.edu/csd/gisdata.html). Banner, Scotts Bluff, Morrill, Hayes, Frontier, Lincoln, Red Willow, and Hitchcock counties all had incomplete NWI coverage as the statewide dataset is not finished. The NWI files available were joined together to form one coverage and then reprojected to UTM, zone 14, NAD 27. In determining training areas, polygons were selected that fell into any combination of the following wetland types and water regimes based on judgment from the COHYST group (see Table 5).

These wetland areas were then sorted. Wetlands were deleted if smaller than 3x3 pixels or 90 meters square. This was done to make sure that the training areas represented homogenous wetland areas and to avoid any problems associated by shifts in the NWI. The spatial extent of wetlands may have changed since the NWI were delimited from aerial photography taken between 1972-1986.

Table 5. Wetland types used in selecting training areas

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

Spectral Signatures by Scene and Land Cover Type

As mentioned previously, spectral signatures were collected using three dates of imagery (Landsat TM bands 2, 3, 4, 5, and 7) combined into one 15-band image per scene. Spectral signatures were collected for the following land cover classes; corn, sugar beets, soybeans, sorghum, dry edible beans, potatoes, alfalfa, small grains, range/pasture, open water, riparian forest/woodlands, wetlands, other agricultural lands, sunflower, summer fallow, and roads. An example of spectral signatures collected for corn, soybeans, alfalfa, and small grains is found in Figure 6. The x-axis represents the 15-band image (or three dates of imagery: May, August, and September). The y-axis represents spectral reflectance values.

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 correspond with bands 3 & 4, bands 8 & 9, and bands 13 & 14 found in Figure 6.

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

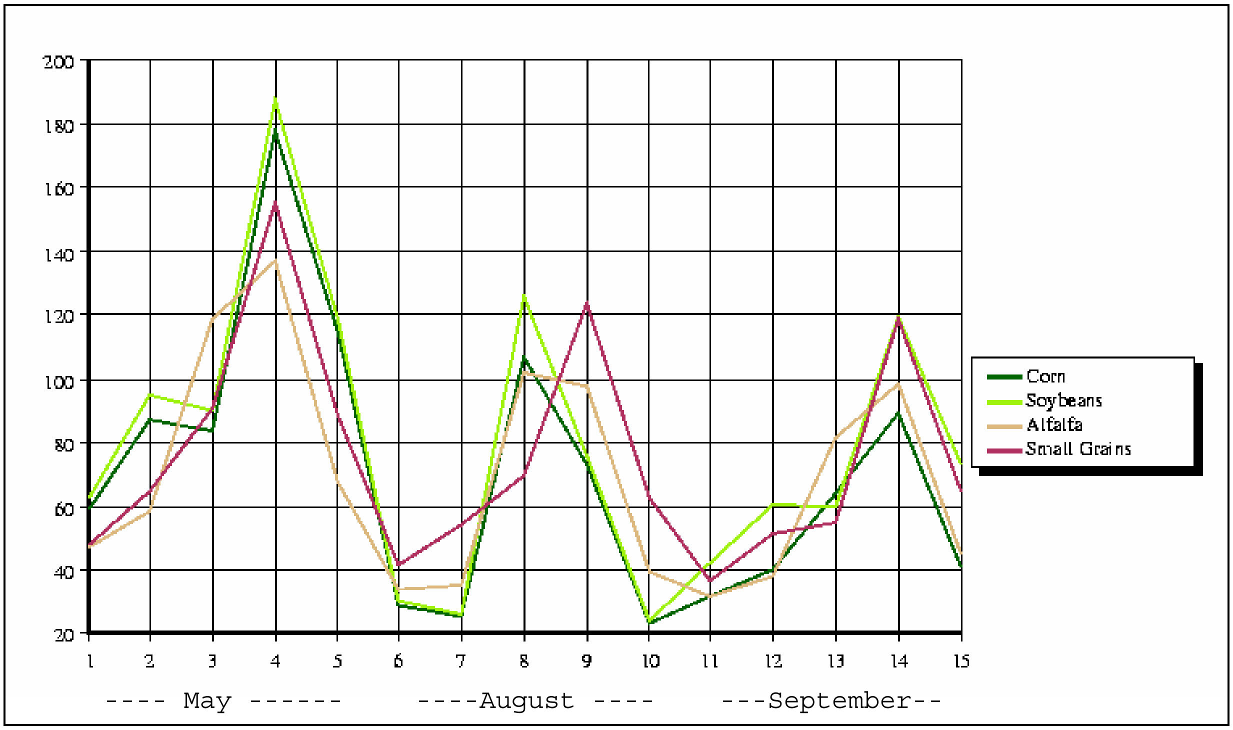


Figure 6. Reflectance Curves for Corn, Soybeans, Alfalfa, and Small Grains.

number of original signatures that were collected for each class and scene are listed in Table 6. The numbers reflect the size of the scene, the diversity and acreage of crops in that scene, and the available ground data obtained by FSA reports. For example, sunflower and sugar beet signatures were only collected in three Landsat scenes found in the western half of the study area reflecting the different agricultural practices found throughout the study area.

On a scene by scene basis, all signatures for each class were merged and averaged into one signature which was the basis for the supervised classification. Instead of having 101 individual signatures to classify small grains in scene 30/32, all 101 signatures were merged into one statistically averaged signature. This step increased computer efficiency and aided post-classification sorting.

Table 6. Spectral Signatures for each Land Cover Class by Scene

Scene Class Name	29/31	29/32	30/32	31/31	31/32	32/31	33/31
Corn	43	132	343	70	201	75	130
Sugar Beets					3	7	33
Soybeans	21	46	80	3	14	9	64
Sorghum		29	54	5	2	2	2
Dry Edible Beans					9	4	7
Potatoes			3		1		1
Alfalfa	12	14	55	31	45	6	38
Small Grains	1	38	101	21	220	188	230
Range/pasture	25	55	130	99	239	150	128
Open Water	6	3	35	63	112	230	31
Forest/woodlands	8	18	19	89	121	72	20
Wetlands	86	163	90	217	118	127	107
Other Ag. lands	6	11	17	13	5	2	28
Sunflower					2	3	2
Summer fallow		8	46	16	209	136	161
Roads	3	4	5	19	7	5	2

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. 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.

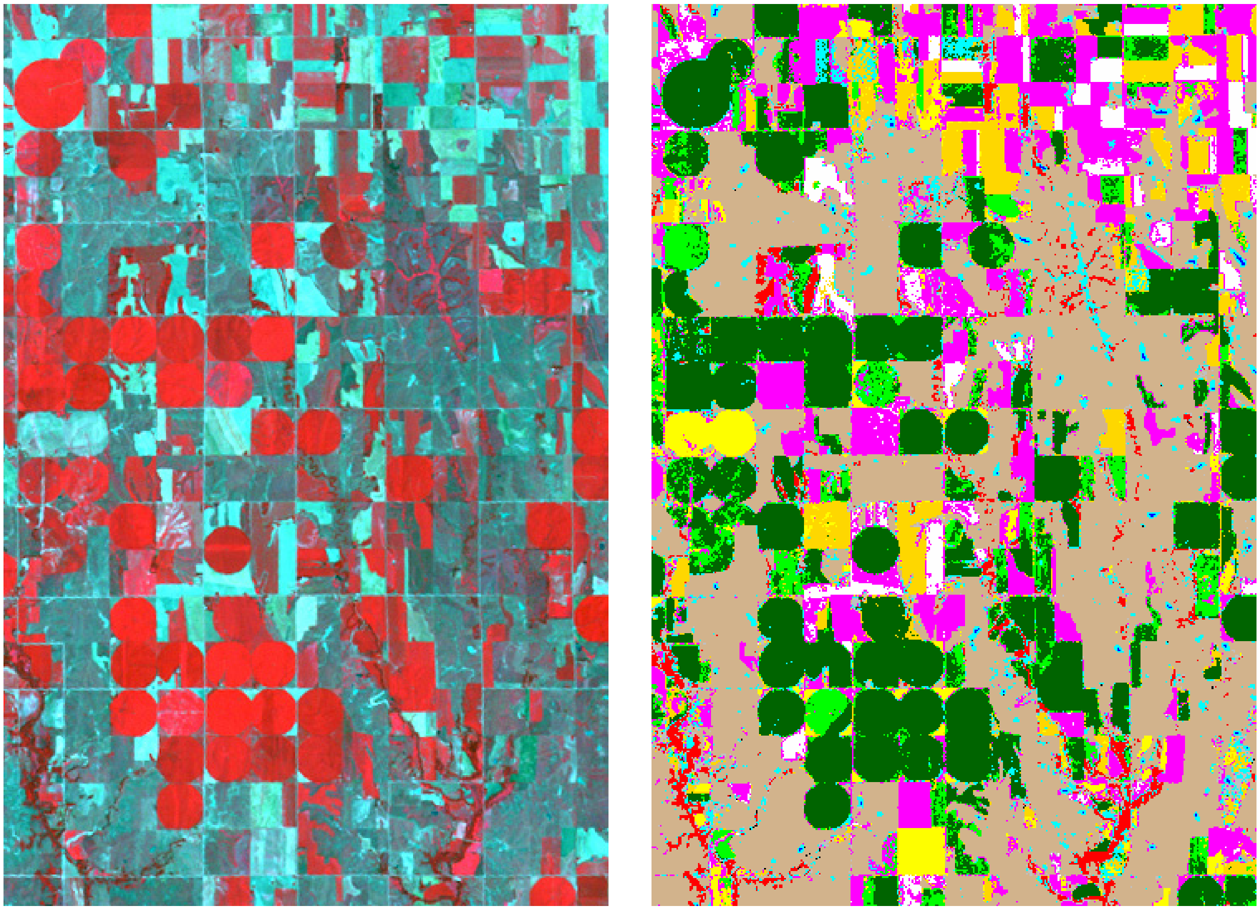
The maximum likelihood decision rule assumes that the probabilities of class membership are equal for all classes and also takes into account the variance of each of the signatures (ERDAS, 1999). This variance is important when comparing a pixel to a signature. For example, a range, pasture, or grass 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 17 classes. The classes were as follows: Corn, Sugar Beets, Soybeans, Sorghum (Milo, Sudan), Dry Edible Beans, Potatoes, Alfalfa, Small Grains, Range/Pasture/Grass, Open Water, Riparian Forest and Woodlands, Wetlands, Other Ag. Land, Sunflower, Summer Fallow, and Roads. An example of the resulting imagery is found in Figure 7. 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.

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 FSA reporting records used to identify training sites for crops. Mixed pixels were reclassified using a technique referred to as “cluster busting” (Jensen et al., 1987). Mixed pixels were identified and masked from the raw TM data. The raw data was then re-classified using an unsupervised classification approach. The resulting output clusters were re-assigned to the output land cover classes they most closely resembled. This method was useful in clearing up much of the confusion in the classification although there were areas where mixed pixels could not be completely resolved due to the spectral similarities of certain crop types.



Original Imagery
(TM Bands 4,3,2)

Classified Image

Figure 7. Example of Supervised Classification

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 digital orthophoto quarter quadrangles and the FSA reporting records used to identify training sites. Work was done to improve the classification of these areas and mixed pixels were reclassified using “cluster busting” techniques.

Delineation of Irrigated Areas

Due to above normal precipitation levels in August, September, and October of 1997 (see Table 1), irrigated and non-irrigated fields were not easily distinguished using satellite imagery. To resolve this issue, center pivots were manually interpreted using the satellite imagery, and other irrigation data were collected from a variety of sources.

Center pivot irrigation areas were identified and on-screen digitized using satellite imagery collected during the summer of 1997. A summer date was selected so that the majority of crops would be at full canopy, allowing for easier identification of center pivots. When questions arose, spring and fall dates of imagery were also displayed.

Digital maps of irrigated acres were also obtained from the Pathfinder Irrigation District. The Pathfinder Irrigation District keeps DXF files of all of their irrigated acres. The original section sized Pathfinder Irrigation District DXF files were brought into ArcInfo, edited, attributed, and appended to create one larger area map.

Maps were also obtained from the Nebraska Department of Natural Resources. These paper maps identifying surface water irrigation rights were digitized using ArcInfo. The 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. These maps were individually digitized and then merged into one map.

Additional irrigation data were obtained from the Central Nebraska Public Power and Irrigation District. The original section-sized DXF files were imported into ArcInfo, edited, attributed, and appended to create one larger area map. All of the above mentioned sources were appended into one file and printed on maps divided by Natural Resource Districts. These maps were sent out to each Natural Resource District within the study area and checked for accuracy. Maps were checked using existing knowledge of 1997 irrigated areas and Farm Service Agency reporting records from 1997. When these maps were returned, the original vector files were edited and all files were merged into one final vector irrigation map.

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 in turn the classifications were more accurate than scenes with single or double dates.

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

When all of the classified scenes were mosaiced, urban polygon areas were laid back into the imagery. Until then, urban areas appeared to have no data. Urban areas defined using the 1992 TIGER 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 to create the final map. Using ArcInfo, the irrigation coverage was converted to a GRID file and the classified image was converted from an ERDAS Imagine file to a GRID file. An irrigation mask was created so that all irrigated areas would have a cell value of 1 and all non-irrigated areas would have a cell value of 0.

The classified image and the irrigation map were compared and combined 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 the final map would be created.

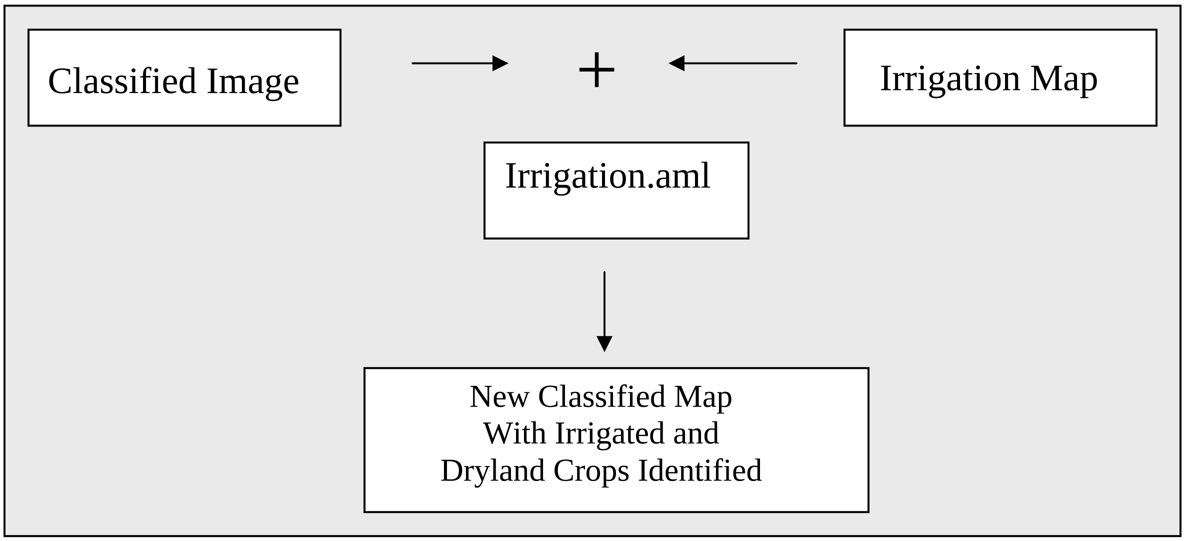


Figure 8. Flowchart of Irrigation Analysis to Create Final Map

Irrigation.aml:

```
DOCELL
   if (landcover == 1 & irrigation == 0) finalmap = 31
      else if (landcover == 2 & irrigation == 0) finalmap = 39
      else if (landcover == 3 & irrigation == 0) finalmap = 32
      else if (landcover == 4 & irrigation == 0) finalmap = 33
      else if (landcover == 5 & irrigation == 0) finalmap = 34
      else if (landcover == 6 & irrigation == 0) finalmap = 42
      else if (landcover == 7 & irrigation == 0) finalmap = 35
      else if (landcover == 8 & irrigation == 0) finalmap = 36
      else if (landcover == 16 & irrigation == 0) finalmap = 37
```

else finalmap = landcover
end

The Irrigation.aml (Arc Macro Language) was run from the GRID module of ArcInfo. For the file names listed, landcover represents the landcover classification grid,

irrigation represents the irrigation grid mask, and finalmap is the new grid resulting from the output of this AML. Looking at the first conditional statement it reads if the landcover map grid cell equals 1 (corn) and the irrigation grid cell over the same area equals 0 (no-irrigation) then the output grid cell for the new map is 31 (dryland corn). Irrigated corn will then be associated with the value 1. This analysis was done for all of the crop classes the values above representing 2 (sugar beets), 3 (soybeans), 4 (sorghum), 5 (dry edible beans), 6 (potatoes), 7 (alfalfa), 8 (small grains), 16 (sunflower). The second to last line of the AML it reads 'else finalmap = landcover', meaning that all other values not changed by the AML will remain the same as the input landcover grid.
The final map was then recoded to have sequential values ranging from 1-26 to eliminate no-data classes.

After all final maps were created they were reprojected to the state plane coordinate system, fipszone 2600, with a horizontal datum of NAD 83.

Accuracy Assessment

An error matrix, also known as a contingency table or confusion matrix, was used to determine the accuracy of the classified satellite imagery. Considered a standard format for evaluating classifications (Congalton, 1991, Congalton & Green, 1994), 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). If the total number of correct pixels in a category is divided by the total number of pixels that were classified in that category you derive the user's accuracy. This indicates the reliability that the pixel classified on the image actually reflects that category on the ground and is 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 Farm Service Agency (FSA) reporting records set aside for the accuracy assessment. Random points were produced using a stratified random sampling design. Five million random points were generated across the study area. Digital section boundaries were used to clip out the random points that fell into those sections for which we had reference data. Reference FSA photos were scanned and rectified. Points that were 2 pixels (60 meters) away from field boundaries were discarded due to inexact rectification of FSA photos. Initially 50 points were labeled for each class (irrigation not included) in each scene, although some classes did not have 50 points available. The labeled reference points from the FSA photos were compared to the classification of each scene to determine errors. For classes that had poor results, more work was done on the classification.

New random points were generated for the final accuracy assessment and 100 reference points were used for each selected land cover class. 1900 points were randomly selected throughout the study and used in the final accuracy assessment.

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, 1994). 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 land cover maps were provided in digital and paper formats. An example of the land cover classification is found in Figure 9. The area shown in Figure 9 is of the Platte River including the cities of Gothenburg, Cozad, and Lexington. In this map irrigation appears as a separate vector layer while in fact the digital land cover map specifies irrigated and dryland crops for each associated grid cell.

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

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

CLASS	PIXEL COUNT	SQUARE METERS	ACRES
Range/Pasture/Grass	45,234,304.00	36,741,563,424.00	9,079,001.98
Irrigated Corn	13,950,906.00	11,331,623,398.50	2,800,094.00
Dryland Small Grains	7,738,710.00	6,285,767,197.50	1,553,240.73
Summer Fallow	5,499,648.00	4,467,089,088.00	1,103,837.37
Dryland Corn	4,090,091.00	3,322,176,414.75	820,924.41
Irrigated Soybeans	2,145,935.00	1,743,035,703.75	430,711.79
Riparian Forest and Woodlands	2,063,610.00	1,676,167,222.50	414,188.30
Wetlands	1,891,167.00	1,536,100,395.75	379,577.17
Dryland Alfalfa	1,636,988.00	1,329,643,503.00	328,560.76
Dryland Sorghum (Milo, Sudan)	1,633,101.00	1,326,486,287.25	327,780.60
Other Agricultural Lands	1,244,057.00	1,010,485,298.25	249,695.36
Dryland Soybeans	1,220,746.00	991,550,938.50	245,016.60
Irrigated Alfalfa	1,067,073.00	866,730,044.25	214,172.81
Irrigated Small Grains	824,334.00	669,565,291.50	165,452.53
Open Water	623,400.00	506,356,650.00	125,122.96
Urban Land	570,180.00	463,128,705.00	114,441.14
Irrigated Dry Edible Beans	410,453.00	333,390,449.25	82,382.25
Irrigated Sorghum (Milo, Sudan)	383,437.00	311,446,703.25	76,959.85
Dryland Sunflower	346,484.00	281,431,629.00	69,542.99
Roads	343,788.00	279,241,803.00	69,001.88
Irrigated Sugar Beets	265,631.00	215,758,779.75	53,314.94
Dryland Dry Edible Beans	134,043.00	108,876,426.75	26,903.84
Irrigated Sunflower	69,723.00	56,632,506.75	13,994.14
Dryland Sugar Beets	45,336.00	36,824,166.00	9,099.41
Irrigated Potatoes	9,643.00	7,832,526.75	1,935.45
Dryland Potatoes	541.00	439,427.25	108.58

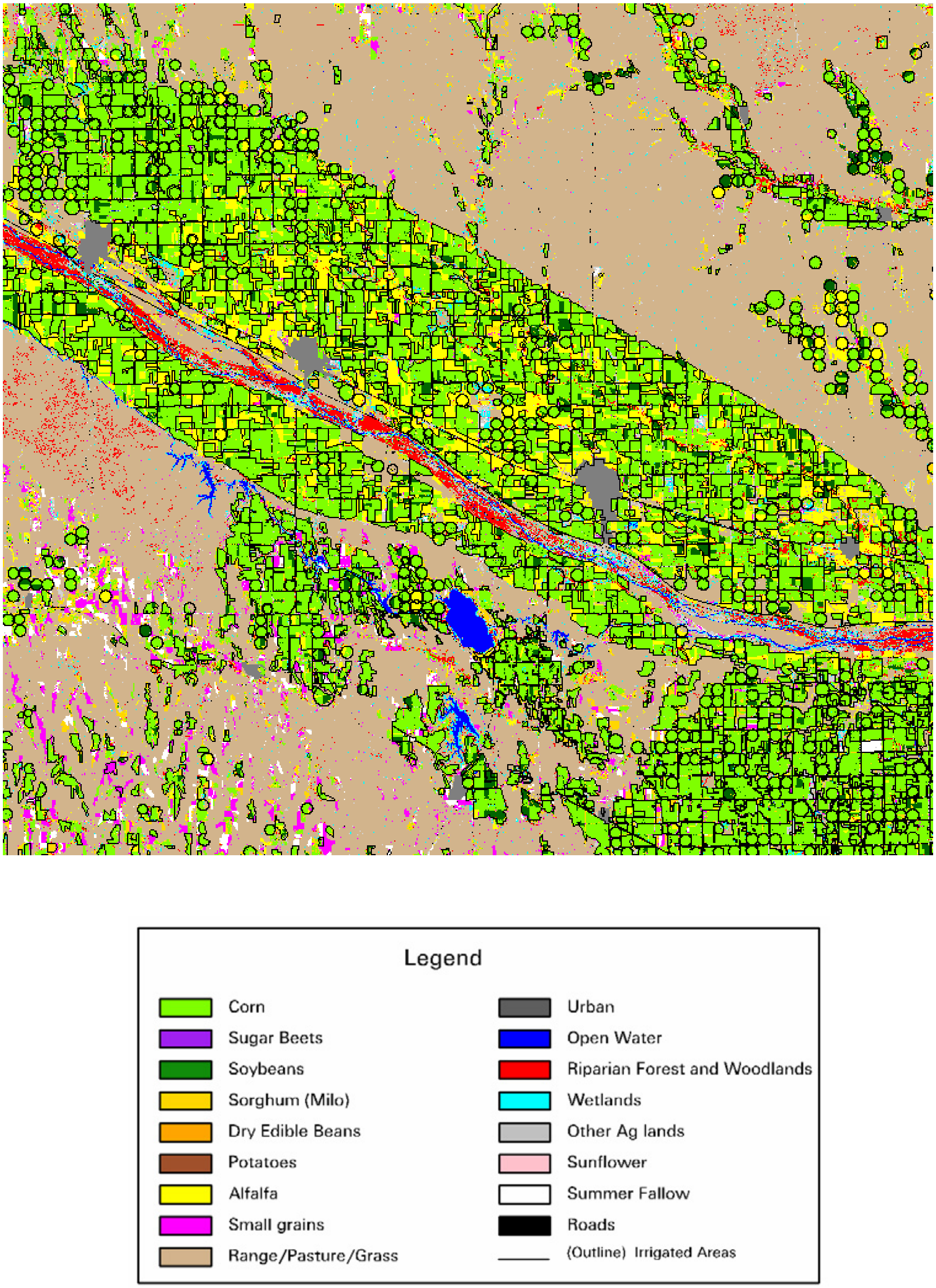


Figure 9. Example of 1997 Land Cover Classification

9 million acres, and irrigated corn was the largest crop at approximately 2.8 million acres. The second largest crop was dryland small grains (approximately 1.5 million acres), followed by summer fallow (approximately 1.1 million acres), dryland corn (820,924 acres), and irrigated soybeans (430,711). The smaller crops in terms of total acreage were irrigated sugar beets (53,314 acres), dryland dry edible beans (26,903 acres), irrigated sunflower (13,994), dryland sugar beets (9,099 acres), irrigated potatoes (1,935 acres), and dryland potatoes (108 acres). Acreage totals for land cover classes are listed by county in Appendix B.

The digital land cover maps were distributed to the COHYST group in ERDAS Imagine and ArcInfo GRID formats. The digital land cover maps were converted into a tabular data format to be used for COHYST modeling efforts. The vector irrigation data were also distributed as separate coverages. All metadata for these datasets are found in Appendix C.

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 more information is contained in the error matrix found in Table 10. The overall classification accuracy for the entire image was 78.53%, and the overall K_{HAT} statistic was .7736. These accuracy results are considered better than average when taking into account the types of land cover classes identified in the classification (Congalton *et al.*, 1998; Maxwell and Hoffer, 1996).

The error matrix details accuracy listed in rows and columns. Looking at the first row, irrigated corn, provides a good example. Where the row irrigated corn meets the column irrigated corn, 90 reference points were classified correctly. Viewing the rest of the row across, these numbers indicate points that were classified as irrigated corn when the reference data labeled that point something else. One point classified as irrigated corn should have been classified as irrigated sugar beets, five should have been irrigated soybeans, two irrigated sorghum, one irrigated dry edible beans, two irrigated alfalfa, 11 dryland corn, one dryland sorghum, and one dryland alfalfa. The row total of 114

Table 9. Accuracy Totals by Land Cover Type

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Overall Accuracy
	----------	----------	-------	---------	-------	----------
Irrigated Corn	100	114	90	90.00%	78.95%	84.48%
Irrigated Sugar Beets	100	80	77	77.00%	96.25%	86.63%
Irrigated Soybeans	100	115	91	91.00%	79.13%	85.07%
Irrigated Sorghum (Milo, Sudan)	100	36	26	26.00%	72.22%	49.11%
Irrigated Dry Edible Beans	100	118	83	83.00%	70.34%	76.67%
Irrigated Potatoes	100	75	73	73.00%	97.33%	85.17%
Irrigated Alfalfa	100	95	76	76.00%	80.00%	78.00%
Irrigated Small Grains	100	91	80	80.00%	87.91%	83.96%
Range, Pasture, Grass	100	119	94	94.00%	78.99%	86.50%
Open Water	100	100	93	93.00%	93.00%	93.00%
Riparian Forest and Woodlands	100	81	74	74.00%	91.36%	82.68%
Wetlands	0	4	0	---	---	---
Other Ag. Lands	0	1	0	---	---	---
Irrigated Sunflower	100	97	87	87.00%	89.69%	88.35%
Summer Fallow	100	139	90	90.00%	64.75%	77.38%
Dryland Corn	100	117	74	74.00%	63.25%	68.63%
Dryland Soybeans	100	67	63	63.00%	94.03%	78.52%
Dryland Sorghum (Milo, Sudan)	100	166	91	91.00%	54.82%	72.91%
Dryland Dry Edible Beans	0	7	0	---	---	
Dryland Alfalfa	100	85	69	69.00%	81.18%	75.09%
Dryland Small Grains	100	117	88	88.00%	75.21%	81.61%
Dryland Sunflower	100	75	73	73.00%	97.33%	85.17%
Dryland Sugar Beets	0	1	0	---	---	---
Totals	1900	1900	1492			

Overall Classification Accuracy = 78.53%

K_{HAT} Statistic = .7736

Table 10. Error Matrix for the 1997 Land Use Classification

CLASSES	Reference Points	Irr. Corn	Irr. S.Beets	Irr. Soybean	Irr. Sorghum	Irr. Dry Ed. Beans	Irr. Potatoes	Irr. Alfalfa	Irr. Sm Grains	Range	Open Water	Riparian Forests	Wetlands	Irr. Sunflower	Summer Fallow	Dry Corn	Dry Soybean	Dry Sorghum	Dry Ed. Beans	Dry Alfalfa	Dry Sm. Grains	Dry Sunflower	Row Totals
Irr. Corn	100	**90**	1	5	2	1	0	2	0	0	0	0	0	0	0	11	0	1	0	1	0	0	114
Irr. Sugar Beets	100	0	**77**	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80
Irr. Soybeans	100	2	1	**91**	0	6	4	0	0	0	0	0	0	0	0	1	10	0	0	0	0	0	115
Irr. Sorghum	100	0	0	0	**26**	4	0	0	0	0	0	0	0	0	0	0	0	4	0	2	0	0	36
Irr. Dry Ed. Beans	100	1	3	0	8	**83**	19	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	118
Irr. Potatoes	100	0	0	0	0	0	**73**	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75
Irr Alfalfa	100	0	0	1	0	0	0	**76**	0	0	0	0	0	0	0	0	0	0	0	18	0	0	95
Irr Sm. Grains	100	0	4	0	0	0	0	2	**80**	0	0	0	0	3	0	0	0	0	0	0	2	0	91
Range	100	0	0	0	0	1	0	4	0	**94**	1	12	0	0	1	1	0	0	0	3	2	0	119
Open Water	100	0	0	0	0	0	0	0	0	0	**93**	7	0	0	0	0	0	0	0	0	0	0	100
Riparian	100	0	0	0	0	0	0	0	0	3	4	**74**	0	0	0	0	0	0	0	0	0	0	81
Wetlands	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0	0	0	0	0	4
Other Ag. Lands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Irr Sunflower	100	0	0	0	6	3	0	0	0	0	0	0	0	**87**	0	0	0	1	0	0	0	15	112
Summer Fallow	100	0	13	0	0	0	3	0	9	0	0	0	0	7	**90**	0	0	0	0	0	2	0	124
Dryland Corn	100	7	0	0	1	0	0	0	0	0	0	5	0	0	0	**74**	25	2	0	1	2	0	117
Dryland Soybeans	100	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	**63**	1	0	0	0	0	67
Dryland Sorghum	100	0	0	0	57	0	1	0	0	0	0	0	0	0	2	12	1	**91**	0	2	0	0	166
Dryland Dry Ed Beans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	7
Dryland Alfalfa	100	0	0	0	0	0	0	13	0	1	0	1	0	0	0	0	0	0	0	**69**	0	1	85
Dryland Small Grains	100	0	0	0	0	0	0	0	11	1	0	0	0	0	7	0	1	0	0	4	**88**	5	117
Dryland Sunflower	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	**73**	75
Dryland Sugar Beets	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Column Totals	1900	100	100	100	100	100	100	100	100	100	100	100	0	100	100	100	100	100	0	100	100	100	1900

indicates that irrigated corn was over classified in the image. Dividing the number of correctly classified points (90) with the row total of 114, gives the users accuracy of 78.95%. Dividing the number of correctly classified points (90) with the number of reference points (100) provides the producers accuracy of 90%. Overall accuracy for irrigated corn is found by averaging the users and producers accuracy.

Viewing the column for irrigated corn, two points were classified as irrigated soybeans when they should have been classified as irrigated corn, one as irrigated dry edible beans, and seven as dryland corn. From looking at the error matrix the majority of the error in the irrigated corn class is found in confusion between irrigated and dryland corn. The next highest error was found in pixels classified as irrigated corn when they should have been irrigated soybeans.

Dryland corn had an overall accuracy of 68.63%. 74 of 100 reference points were correctly classified as dryland corn while 25 points were incorrectly classified as dryland soybeans and 7 classified as irrigated corn. There was also confusion between dryland corn and dryland sorghum with 12 points being incorrectly classified as dryland sorghum. Both irrigated and dryland corn classes mixed with the soybean class. This indicates the spectral similarities found between corn and soybeans. The spectral mixing of the two classes was also evident in the image classification.

Irrigated sugar beets had an overall accuracy of 86.63%. The largest source of error was found in 13 points classified as summer fallow when the reference points identified those areas as irrigated sugar beets. Other sources of error include spectral confusion with irrigated small grains and irrigated dry edible beans. No accuracy assessment was done for dryland sugar beets as there were not enough reference points found for this class.

85.07% was the overall accuracy for irrigated soybeans. 91 out of 100 reference points were correctly classified. Five points were incorrectly classified as irrigated corn and three as dryland soybeans. Other problems were found with irrigated soybeans spectrally confused with irrigated dry edible bean and irrigated sunflower. A total of 115 points were classified as irrigated soybeans signifying that this class was somewhat over represented in the classification.

Dryland soybeans had an overall accuracy of 78.52%. 63 of 100 reference points were correctly classified. The largest source of error was found in 25 points incorrectly classified as dryland corn. The second largest source of error was in confusion between dryland and irrigated soybeans. While irrigated soybeans were somewhat over represented, dryland soybeans were under represented in the classification.

Irrigated sorghum had the lowest overall accuracy of 49.11%. 26 of 100 reference points were correctly classified while 57 were incorrectly classified as dryland sorghum. Irrigated sorghum also mixed with irrigated dry edible beans and dryland alfalfa. Dryland sorghum had an overall accuracy of 72.91%. This was also due to discrepancies between irrigated and non-irrigated areas. Only 36 points were classified as irrigated sorghum while 166 were classified as dryland sorghum indicating that dryland sorghum was over represented in the classification. Without considering irrigated vs. dryland sorghum, the accuracy for this crop increases to 88.56% as noted in Table 11.

Table 11. Accuracy Totals for Crops Without Irrigation Layer

Classes	Producers Accuracy	Users Accuracy	Overall Accuracy
Corn	91.00%	80.53%	85.77%
Sugar Beets	78.00%	96.30%	87.15%
Soybeans	83.50%	91.76%	87.63%
Sorghum (Milo, Sudan)	89.00%	88.12%	88.56%
Dry Edible Bean	83.00%	66.40%	74.70%
Potatoes	73.00%	97.33%	85.17%
Alfalfa	88.00%	98.32%	93.16%
Small grains	90.50%	86.60%	88.55%
Sunflower	80.50%	93.06%	86.78%

Irrigated dry edible beans had an overall accuracy of 76.67%. This crop was more difficult to classify as FSA reporting records did not provide many fields to use as training sites. 19 points were incorrectly classified as irrigated potatoes and eight points classified as irrigated sorghum. No accuracy assessment was done for dryland dry edible beans as there were not enough reference points found for this class.

Irrigated potatoes had an overall accuracy of 85.17%, with the main source of error resulting from misclassification with irrigated dry edible beans. Dryland potatoes were not found in the FSA reporting records we had available so no accuracy assessment was done.

78.00% was the overall accuracy for irrigated alfalfa. 76 of 100 reference points were correctly classified with 13 points misclassified as dryland alfalfa. Smaller sources of error occurred with points misclassified as range, irrigated corn, and irrigated small grains. Dryland alfalfa had an overall accuracy of 75.09%. 69 of 100 reference points were correctly classified although 18 points were misclassified as irrigated alfalfa. Dryland alfalfa also had points misclassified as range, dryland small grains, and dryland sorghum. Looking at the accuracy for alfalfa without distinctions between irrigated and dryland, the overall accuracy increases to 93.16%.

Irrigated small grains had an overall accuracy of 83.96%. 80 of the 100 reference points were correctly classified with 11 points misclassified as dryland small grains and nine points misclassified as summer fallow. Dryland small grains had an overall accuracy of 81.61%. Sources of error for dryland small grains also include misclassification of irrigated small grains and summer fallow.

The range/pasture/grass class had an overall accuracy of 86.50%. 94 of 100 reference points were correctly classified. The largest source of error for this class was in confusion with the riparian forest and woodlands class. A total of 119 points were classified as range, indicating that this land cover class was somewhat over represented in the classification.

Open water had an overall accuracy of 93.00%. 93 of 100 reference points were correctly classified, with error resulting from misclassification with the wetlands class and the riparian forest and woodlands class.

82.68% was the overall accuracy for the riparian forest and woodlands class. 74 out of 100 reference points were correctly classified. The largest source of error was found in confusion with the range/pasture/grass class. The second largest source of error was in misclassification with the open water class.

Irrigated sunflower had an overall accuracy of 88.35%. The main source of error for this class was in misclassification with dryland sunflower. The second largest source of error was found in misclassification with irrigated sorghum. Dryland sunflower had an overall accuracy of 85.17%, with the largest source of error found in confusion with irrigated sunflower. Dryland sunflower also mixed with the dry small grains class. From the imagery it was evident that the sunflower class was mixing with the summer fallow class.

77.38% was the overall accuracy for summer fallow. Summer Fallow mixed with the following classes; irrigated sugar beets, irrigated and dryland small grains, and irrigated sunflowers. A total of 124 points were classified as summer fallow suggesting that this land cover class was over classified in the imagery. Accuracy assessments were not done for the wetlands class and other agricultural lands.

Weighted Kappa

Using the Kappa analysis to derive the K_{HAT} statistic is suitable when all the error in the matrix can be considered of equal importance. For the COHYST study, all of the land cover classes may not have the same influence.   For example, a class like irrigated corn, which represents a larger percentage of the total acreage of the study area, should have more weight than a smaller class such as irrigated potatoes.   Assigning weights for the weighted kappa were based on acreage totals by land cover class. These totals were listed previously in Table 9. Relative weights were then assigned to each cell in the matrix and then applied to the following equation to find KAPPA:

$$P_c = \frac{\sum_{i=1}^{k} (n(+,i) * n(i,+))}{n^2}$$

Where n(i,j) represents the error matrix count in the ith row and jth column, n(i,+) represents the sum of the ith row, n(+,j) represents the sum of the jth column, and n represents the total count in all cells of the error matrix (Congalton and Green, 1999).

Weights were restricted to values greater than zero but less than one with the maximum agreement equal to 1. The weighted kappa formula was entered into an EXCEL spreadsheet and than computed for the error matrix. The weighted kappa for the classified imagery was .794. This increased from the original K_{HAT} statistic of .7736.

Causes of Lower Accuracies and Sources of Error

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

Although Farm Service Agency reporting records were the best available choice for ground truth on crop types, inaccuracies still existed in the data to select signatures and determine accuracy. Field boundaries were not always defined correctly as the aerial photography on which the FSA records was based were sometimes out of date.

Due to the random selection of sections, not all crops may have been represented or there may have been minimal number of signatures available. This was the case for crops such as potatoes, dry edible beans, and sugar beets.

Another major problem was that not all counties labeled crops as irrigated or non-irrigated on the FSA reporting records. Since the FSA data a formed the basis for the accuracy assessment, mislabeling errors were most likely encountered.

Error was also introduced in determining irrigated areas for the study. Irrigation maps were sent out to the Natural Resource Districts (NRD's) to check for accuracy. The maps were sent back with revisions done at various levels of accuracy by different NRD's. Irrigation records were not always available for 1997, and some counties only had records of irrigation if the acres were certified for crop insurance.

The classification techniques used were based on standard procedures (Jensen, 1996, Lillesand & Kiefer, 1994), yet error also becomes a factor. The accuracy estimate is only as good as the ground or sampling information used comparing known land cover types to the results of the classification. Classification systems 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.

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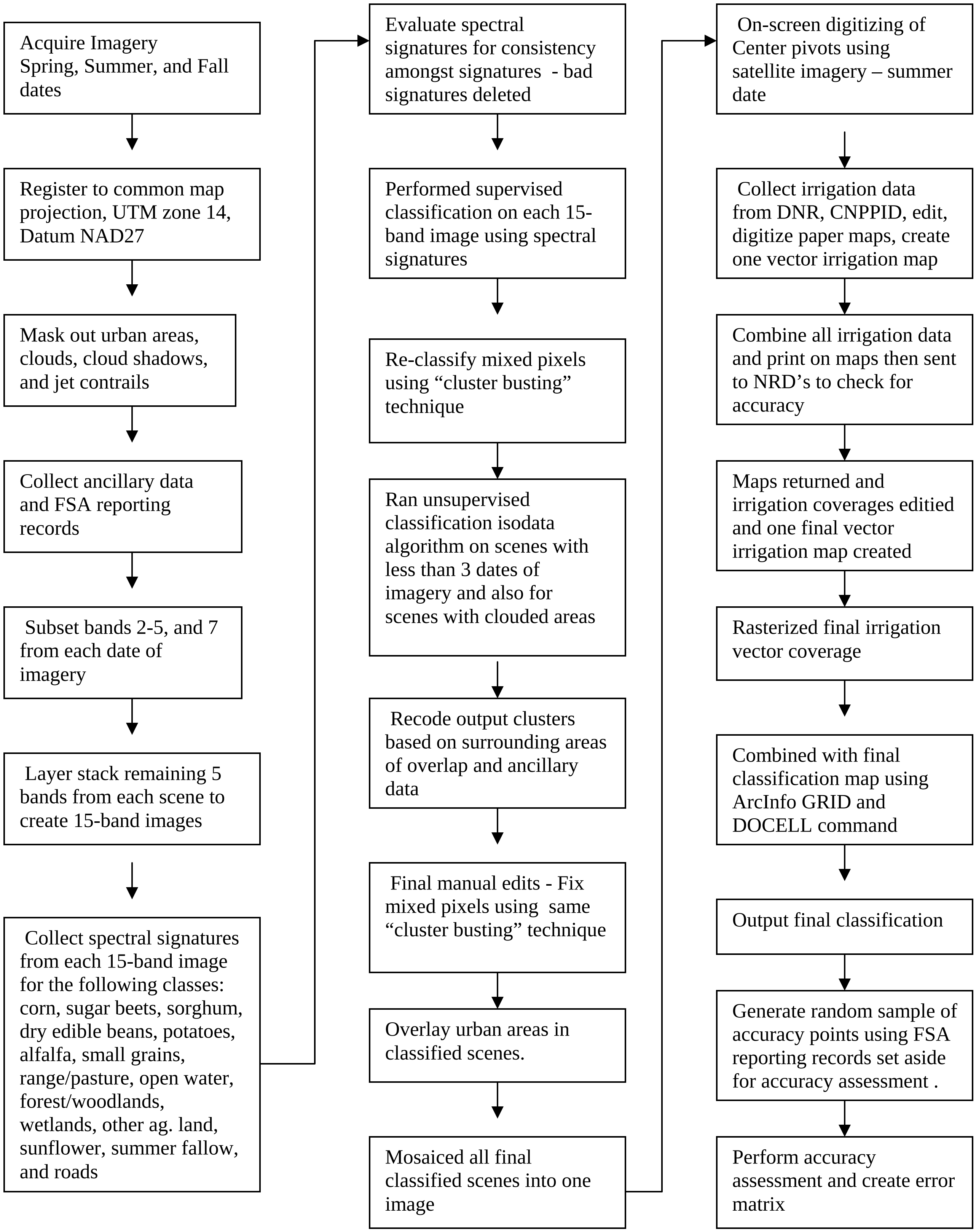
APPENDICES

Appendix A. Flow Chart of Methodology



Appendix B. Landcover Acreage Totals By County
(For Counties Entirely Within the COHYST Boundary)

Adams County

Adams County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	727964	591288759	146110.054
Irrigated Soybeans	3	129383	105091341.8	25968.53295
Irrigated Sorghum	4	14539	11809302.75	2918.13067
Irrigated Potatoes	6	3	2436.75	0.602131647
Irrigated Alfalfa	7	14192	11527452	2848.48411
Irrigated Small Grains	8	8700	7066575	1746.181775
Range/Pasture/Grass	9	230015	186829683.8	46166.43691
Urban Land	10	43063	34977921.75	8643.198367
Open Water	11	1289	1046990.25	258.7158975
Riparian Forest and Woodlands	12	40139	32602902.75	8056.320722
Wetlands	13	23727	19272255.75	4762.259194
Other Agricultural Lands	14	77236	62734941	15502.07995
Summer Fallow	16	22005	17873561.25	4416.635629
Roads	17	17113	13900034.25	3434.759623
Dryland Corn	18	179789	146033615.3	36085.54888
Dryland Soybeans	19	70746	57463438.5	14199.46849
Dryland Sorghum	20	78887	64075965.75	15833.45307
Dryland Alfalfa	22	49707	40374510.75	9976.719254
Dryland Small Grains	23	69204	56210949	13889.97283
Dryland Potatoes	26	3	2436.75	0.602131647

Banner County

Banner County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	22879	18583467.75	4592.06
Irrigated Sugar Beets	2	8110	6587347.50	1627.76
Irrigated Soybeans	3	10363	8417346.75	2079.96
Irrigated Dry Edible Beans	5	8346	6779038.50	1675.13
Irrigated Potatoes	6	105	85286.25	21.07
Irrigated Alfalfa	7	27717	22513133.25	5563.09
Irrigated Small Grains	8	36193	29397764.25	7264.32
Range/Pasture/Grass	9	1524458	1238241010.50	305974.80
Urban Land	10	703	571011.75	141.10
Open Water	11	450	365512.50	90.32
Riparian Forest and Woodlands	12	80027	65001930.75	16062.26
Wetlands	13	26022	21136369.50	5222.89
Other Agricultural Lands	14	31	25179.75	6.22
Irrigated Sunflower	15	5721	4646882.25	1148.27
Summer Fallow	16	250819	203727732.75	50342.02
Roads	17	138	112090.50	27.70
Dryland Corn	18	6203	5038386.75	1245.01
Dryland Soybeans	19	3120	2534220.00	626.22
Dryland Dry Edible Beans	21	1966	1596883.50	394.60
Dryland Alfalfa	22	17482	14199754.50	3508.82
Dryland Small Grains	23	350500	284693625.00	70349.05
Dryland Sunflower	24	4628	3759093.00	928.89
Dryland Sugar Beets	25	507	411810.75	101.76
Dryland Potatoes	26	6	4873.50	1.20

Cheyenne County

Cheyenne County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	72547	58926300.75	14560.95
Irrigated Sugar Beets	2	11440	9292140.00	2296.13
Irrigated Soybeans	3	28225	22925756.25	5665.06
Irrigated Sorghum (Milo, Sudan)	4	440	357390.00	88.31
Irrigated Dry Edible Beans	5	7994	6493126.50	1604.48
Irrigated Alfalfa	7	17656	14341086.00	3543.75
Irrigated Small Grains	8	89538	72727240.50	17971.22
Range/Pasture/Grass	9	1119855	909602223.75	224766.71
Urban Land	10	15427	12530580.75	3096.36
Open Water	11	170	138082.50	34.12
Riparian Forest and Woodlands	12	59588	48400353.00	11959.94
Wetlands	13	11880	9649530.00	2384.44
Other Agricultural Lands	14	3839	3118227.75	770.53
Irrigated Sunflower	15	8186	6649078.50	1643.02
Summer Fallow	16	879537	714403928.25	176532.35
Roads	17	3073	2496044.25	616.78
Dryland Corn	18	34362	27910534.50	6896.82
Dryland Soybeans	19	8268	6715683.00	1659.47
Dryland Sorghum (Milo, Sudan)	20	38	30865.50	7.63
Dryland Dry Edible Beans	21	5188	4213953.00	1041.29
Dryland Alfalfa	22	8006	6502873.50	1606.89
Dryland Small Grains	23	1354518	1100207245.50	271866.05
Dryland Sunflower	24	78665	63895646.25	15788.90
Dryland Sugar Beets	25	1825	1482356.25	366.30

Clay County

Clay County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	675952	549042012.00	135670.70
Irrigated Soybeans	3	184098	149533600.50	36950.41
Irrigated Sorghum	4	37909	30791585.25	7608.74
Irrigated Alfalfa	7	10769	8747120.25	2161.45
Irrigated Small Grains	8	8954	7272886.50	1797.16
Range/Pasture/Grass	9	252954	205461886.50	50770.54
Urban Land	10	16912	13736772.00	3394.42
Open Water	11	3107	2523660.75	623.61
Riparian Forest and Woodlands	12	26768	21742308.00	5372.62
Wetlands	13	45644	37074339.00	9161.23
Other Agricultural Lands	14	61649	50074400.25	12373.60
Summer Fallow	16	2020	1640745.00	405.44
Roads	17	2165	1758521.25	434.54
Dryland Corn	18	162178	131729080.50	32550.84
Dryland Soybeans	19	110761	89965622.25	22230.90
Dryland Sorghum	20	124524	101144619.00	24993.28
Dryland Alfalfa	22	37033	30080054.25	7432.91
Dryland Small Grains	23	64460	52357635.00	12937.80

Dawson County

Dawson County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	854026	693682618.50	171412.03
Irrigated Soybeans	3	86962	70634884.50	17454.19
Irrigated Sorghum	4	25559	20760297.75	5129.96
Irrigated Alfalfa	7	111768	90783558.00	22433.02
Irrigated Small Grains	8	4674	3796456.50	938.12
Range/Pasture/Grass	9	1329625	1079987906.25	266869.76
Urban Land	10	31085	25248791.25	6239.09
Open Water	11	22528	18298368.00	4521.61
Riparian Forest and Woodlands	12	98305	79848236.25	19730.85
Wetlands	13	46233	37552754.25	9279.45
Other Agricultural Lands	14	85384	69353154.00	17137.47
Summer Fallow	16	12456	10117386.00	2500.05
Roads	17	38746	31471438.50	7776.73
Dryland Corn	18	161714	131352196.50	32457.71
Dryland Soybeans	19	20122	16344094.50	4038.70
Dryland Sorghum	20	50317	40869983.25	10099.15
Dryland Dry Edible Beans	21	1	812.25	0.20
Dryland Alfalfa	22	240234	195130066.50	48217.50
Dryland Small Grains	23	29337	23828978.25	5888.25
Dryland Sunflower	24	1	812.25	0.20
Dryland Potatoes	26	3	2436.75	0.60

Deuel County

Deuel County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	57424	46642644.00	11525.60
Irrigated Sugar Beets	2	2563	2081796.75	514.42
Irrigated Soybeans	3	4314	3504046.50	865.87
Irrigated Sorghum (Milo, Sudan)	4	5	4061.25	1.00
Irrigated Dry Edible Beans	5	2880	2339280.00	578.05
Irrigated Alfalfa	7	6835	5551728.75	1371.86
Irrigated Small Grains	8	17080	13873230.00	3428.14
Range/Pasture/Grass	9	332793	270311114.25	66795.07
Urban Land	10	4683	3803766.75	939.93
Open Water	11	1967	1597695.75	394.80
Riparian Forest and Woodlands	12	29643	24077526.75	5949.66
Wetlands	13	5711	4638759.75	1146.26
Other Agricultural Lands	14	2773	2252369.25	556.57
Irrigated Sunflower	15	5754	4673686.50	1154.89
Summer Fallow	16	354182	287684329.50	71088.06
Roads	17	3055	2481423.75	613.17
Dryland Corn	18	16653	13526399.25	3342.43
Dryland Soybeans	19	1119	908907.75	224.60
Dryland Sorghum (Milo, Sudan)	20	2	1624.50	0.40
Dryland Dry Edible Beans	21	1936	1572516.00	388.58
Dryland Alfalfa	22	1601	1300412.25	321.34
Dryland Small Grains	23	448446	364250263.50	90007.84
Dryland Sunflower	24	104724	85062069.00	21019.21
Dryland Sugar Beets	25	1117	907283.25	224.19

Frontier County

Frontier County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	177792	144411552.00	35684.73
Irrigated Sugar Beets	2	22	17869.50	4.42
Irrigated Soybeans	3	18191	14775639.75	3651.13
Irrigated Sorghum (Milo, Sudan)	4	29679	24106767.75	5956.89
Irrigated Dry Edible Beans	5	602	488974.50	120.83
Irrigated Potatoes	6	4	3249.00	0.80
Irrigated Alfalfa	7	18488	15016878.00	3710.74
Irrigated Small Grains	8	11319	9193857.75	2271.84
Range/Pasture/Grass	9	1762419	1431524832.75	353736.08
Urban Land	10	5421	4403207.25	1088.05
Open Water	11	12706	10320448.50	2550.23
Riparian Forest and Woodlands	12	43642	35448214.50	8759.41
Wetlands	13	21325	17321231.25	4280.15
Other Agricultural Lands	14	36281	29469242.25	7281.98
Irrigated Sunflower	15	109	88535.25	21.88
Summer Fallow	16	231119	187726407.75	46388.02
Roads	17	9099	7390662.75	1826.27
Dryland Corn	18	186342	151356289.50	37400.81
Dryland Soybeans	19	24496	19896876.00	4916.61
Dryland Sorghum (Milo, Sudan)	20	160383	130271091.75	32190.56
Dryland Dry Edible Beans	21	2657	2158148.25	533.29
Dryland Alfalfa	22	54043	43896426.75	10847.00
Dryland Small Grains	23	315360	256151160.00	63296.08
Dryland Sunflower	24	1826	1483168.50	366.50
Dryland Sugar Beets	25	45	36551.25	9.03
Dryland Potatoes	26	19	15432.75	3.81

Gosper County

Gosper County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	297869	241944095.25	59785.45
Irrigated Soybeans	3	37841	30736352.25	7595.09
Irrigated Sorghum	4	19773	16060619.25	3968.65
Irrigated Potatoes	6	1	812.25	0.20
Irrigated Alfalfa	7	13190	10713577.50	2647.37
Irrigated Small Grains	8	7971	6474444.75	1599.86
Range/Pasture/Grass	9	683230	554953567.50	137131.47
Urban Land	10	2557	2076923.25	513.22
Open Water	11	12571	10210794.75	2523.13
Riparian Forest and Woodlands	12	15722	12770194.50	3155.57
Wetlands	13	14116	11465721.00	2833.23
Other Agricultural Lands	14	26587	21595290.75	5336.29
Summer Fallow	16	63039	51203427.75	12652.59
Roads	17	8593	6979664.25	1724.71
Dryland Corn	18	62986	51160378.50	12641.95
Dryland Soybeans	19	6088	4944978.00	1221.93
Dryland Sorghum	20	75885	61637591.25	15230.92
Dryland Alfalfa	22	17951	14580699.75	3602.96
Dryland Small Grains	23	109155	88661148.75	21908.56

Hall County

Hall County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	840322	682551544.50	168661.49
Irrigated Soybeans	3	82844	67290039.00	16627.66
Irrigated Sorghum	4	15129	12288530.25	3036.55
Irrigated Potatoes	6	3	2436.75	0.60
Irrigated Alfalfa	7	20000	16245000.00	4014.21
Irrigated Small Grains	8	6952	5646762.00	1395.34
Range/Pasture/Grass	9	266701	216627887.25	53529.70
Urban Land	10	77293	62781239.25	15513.52
Open Water	11	17542	14248489.50	3520.86
Riparian Forest and Woodlands	12	78567	63816045.75	15769.23
Wetlands	13	34213	27789509.25	6866.91
Other Agricultural Lands	14	66418	53948020.50	13330.79
Summer Fallow	16	1578	1281730.50	316.72
Roads	17	25357	20596223.25	5089.42
Dryland Corn	18	86421	70195457.25	17345.61
Dryland Soybeans	19	22505	18279686.25	4516.99
Dryland Sorghum	20	27194	22088326.50	5458.12
Dryland Alfalfa	22	75367	61216845.75	15126.95
Dryland Small Grains	23	14425	11716706.25	2895.25

Hamilton County

Hamilton County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	958392	778453902.00	192359.38
Irrigated Soybeans	3	141117	114622283.25	28323.67
Irrigated Sorghum	4	14564	11829609.00	2923.15
Irrigated Alfalfa	7	7948	6455763.00	1595.25
Irrigated Small Grains	8	9837	7990103.25	1974.39
Range/Pasture/Grass	9	130695	106157013.75	26231.87
Urban Land	10	14468	11751633.00	2903.88
Open Water	11	7233	5875004.25	1451.74
Riparian Forest and Woodlands	12	40698	33056950.50	8168.52
Wetlands	13	37440	30410640.00	7514.60
Other Agricultural Lands	14	67962	55202134.50	13640.69
Summer Fallow	16	99	80412.75	19.87
Roads	17	2595	2107788.75	520.84
Dryland Corn	18	178030	144604867.50	35732.50
Dryland Soybeans	19	65154	52921336.50	13077.10
Dryland Sorghum	20	25566	20765983.50	5131.37
Dryland Alfalfa	22	23994	19489126.50	4815.85
Dryland Small Grains	23	18339	14895852.75	3680.83

Kearney County

Kearney County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	831398	675303025.50	166870.35
Irrigated Soybeans	3	100439	81581577.75	20159.17
Irrigated Sorghum	4	19069	15488795.25	3827.35
Irrigated Potatoes	6	2991	2429439.75	600.33
Irrigated Alfalfa	7	20350	16529287.50	4084.46
Irrigated Small Grains	8	8124	6598719.00	1630.57
Range/Pasture/Grass	9	202025	164094806.25	40548.55
Urban Land	10	12050	9787612.50	2418.56
Open Water	11	609	494660.25	122.23
Riparian Forest and Woodlands	12	21854	17750911.50	4386.33
Wetlands	13	19519	15854307.75	3917.67
Other Agricultural Lands	14	56477	45873443.25	11335.53
Summer Fallow	16	30572	24832107.00	6136.12
Roads	17	20394	16565026.50	4093.29
Dryland Corn	18	127468	103535883.00	25584.17
Dryland Soybeans	19	28771	23369244.75	5774.64
Dryland Sorghum	20	61711	50124759.75	12386.05
Dryland Alfalfa	22	35820	29094795.00	7189.45
Dryland Small Grains	23	52170	42375082.50	10471.07
Dryland Potatoes	26	3	2436.75	0.60

Keith County

Keith County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	303383	246422841.75	60892.17
Irrigated Sugar Beets	2	5056	4106736.00	1014.79
Irrigated Soybeans	3	13234	10749316.50	2656.20
Irrigated Sorghum (Milo, Sudan)	4	10321	8383232.25	2071.53
Irrigated Dry Edible Beans	5	23123	18781656.75	4641.03
Irrigated Alfalfa	7	39008	31684248.00	7829.32
Irrigated Small Grains	8	43294	35165551.50	8689.56
Range/Pasture/Grass	9	2000548	1624945113.00	401531.09
Urban Land	10	8427	6844830.75	1691.39
Open Water	11	150830	122511667.50	30273.17
Riparian Forest and Woodlands	12	90358	73393285.50	18135.80
Wetlands	13	70255	57064623.75	14100.92
Other Agricultural Lands	14	16947	13765200.75	3401.44
Irrigated Sunflower	15	7283	5915616.75	1461.77
Summer Fallow	16	253662	206036959.50	50912.64
Roads	17	10089	8194790.25	2024.97
Dryland Corn	18	113190	91938577.50	22718.43
Dryland Soybeans	19	13893	11284589.25	2788.47
Dryland Sorghum (Milo, Sudan)	20	20373	16547969.25	4089.08
Dryland Dry Edible Beans	21	9071	7367919.75	1820.65
Dryland Alfalfa	22	35952	29202012.00	7215.95
Dryland Small Grains	23	282512	229470372.00	56703.14
Dryland Sunflower	24	17493	14208689.25	3511.03
Dryland Sugar Beets	25	1085	881291.25	217.77

Kimball County

Kimball County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	29009	23562560.25	5822.41
Irrigated Sugar Beets	2	9170	7448332.50	1840.52
Irrigated Soybeans	3	8500	6904125.00	1706.04
Irrigated Sorghum (Milo, Sudan)	4	40	32490.00	8.03
Irrigated Dry Edible Beans	5	4902	3981649.50	983.88
Irrigated Alfalfa	7	23682	19235704.50	4753.23
Irrigated Small Grains	8	41741	33904127.25	8377.86
Range/Pasture/Grass	9	1448743	1176741501.75	290778.00
Urban Land	10	7880	6400530.00	1581.60
Open Water	11	1644	1335339.00	329.97
Riparian Forest and Woodlands	12	14739	11971752.75	2958.27
Wetlands	13	38976	31658256.00	7822.89
Other Agricultural Lands	14	248	201438.00	49.78
Irrigated Sunflower	15	2860	2323035.00	574.03
Summer Fallow	16	630063	511768671.75	126460.29
Roads	17	246	199813.50	49.37
Dryland Corn	18	19597	15917663.25	3933.32
Dryland Soybeans	19	7550	6132487.50	1515.36
Dryland Sorghum (Milo, Sudan)	20	10	8122.50	2.01
Dryland Dry Edible Beans	21	4782	3884179.50	959.80
Dryland Alfalfa	22	17569	14270420.25	3526.28
Dryland Small Grains	23	720206	584987323.50	144552.94
Dryland Sunflower	24	13417	10897958.25	2692.93
Dryland Sugar Beets	25	661	536897.25	132.67

Merrick County

Merrick County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	645103	523984911.75	129478.98
Irrigated Soybeans	3	134993	109648064.25	27094.52
Irrigated Sorghum	4	1187	964140.75	238.24
Irrigated Alfalfa	7	13839	11240727.75	2777.63
Irrigated Small Grains	8	558	453235.50	112.00
Range/Pasture/Grass	9	354284	287767179.00	71108.54
Urban Land	10	10379	8430342.75	2083.17
Open Water	11	18806	15275173.50	3774.56
Riparian Forest and Woodlands	12	65147	52915650.75	13075.69
Wetlands	13	44665	36279146.25	8964.74
Other Agricultural Lands	14	92519	75148557.75	18569.54
Summer Fallow	16	7	5685.75	1.40
Roads	17	8954	7272886.50	1797.16
Dryland Corn	18	83956	68193261.00	16850.85
Dryland Soybeans	19	45374	36855031.50	9107.04
Dryland Sorghum	20	1366	1109533.50	274.17
Dryland Alfalfa	22	33323	27066606.75	6688.28
Dryland Small Grains	23	932	757017.00	187.06

Lincoln County

Lincoln County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	776506	630716998.50	155852.95
Irrigated Sugar Beets	2	89	72290.25	17.86
Irrigated Soybeans	3	51294	41663551.50	10295.25
Irrigated Sorghum (Milo, Sudan)	4	27410	22263772.50	5501.48
Irrigated Dry Edible Beans	5	6535	5308053.75	1311.64
Irrigated Potatoes	6	1	812.25	0.20
Irrigated Alfalfa	7	87930	71421142.50	17648.48
Irrigated Small Grains	8	21661	17594147.25	4347.59
Range/Pasture/Grass	9	5724114	4649411596.50	1148890.06
Urban Land	10	46233	37552754.25	9279.45
Open Water	11	47830	38849917.50	9599.99
Riparian Forest and Woodlands	12	310094	251873851.50	62239.14
Wetlands	13	81959	66571197.75	16450.04
Other Agricultural Lands	14	24046	19531363.50	4826.29
Irrigated Sunflower	15	1714	1392196.50	344.02
Summer Fallow	16	143456	116522136.00	28793.13
Roads	17	24395	19814838.75	4896.33
Dryland Corn	18	316119	256767657.75	63448.42
Dryland Soybeans	19	56117	45581033.25	11263.27
Dryland Sorghum (Milo, Sudan)	20	62390	50676277.50	12522.33
Dryland Dry Edible Beans	21	18557	15072923.25	3724.59
Dryland Alfalfa	22	200572	162914607.00	40256.92
Dryland Small Grains	23	176705	143528636.25	35466.56
Dryland Sunflower	24	2398	1947775.50	481.30
Dryland Sugar Beets	25	146	118588.50	29.30
Dryland Potatoes	26	1	812.25	0.20

Morrill County

Morrill County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	233729	189846380.25	46911.88
Irrigated Sugar Beets	2	23706	19255198.50	4758.04
Irrigated Soybeans	3	59313	48176984.25	11904.74
Irrigated Sorghum (Milo, Sudan)	4	123	99906.75	24.69
Irrigated Dry Edible Beans	5	60541	49174427.25	12151.22
Irrigated Alfalfa	7	81690	66352702.50	16396.04
Irrigated Small Grains	8	63626	51680218.50	12770.41
Range/Pasture/Grass	9	3124758	2538084685.50	627171.89
Urban Land	10	6432	5224392.00	1290.97
Open Water	11	30147	24486900.75	6050.82
Riparian Forest and Woodlands	12	127438	103511515.50	25578.15
Wetlands	13	273643	222266526.75	54923.04
Other Agricultural Lands	14	1097	891038.25	220.18
Irrigated Sunflower	15	8043	6532926.75	1614.31
Summer Fallow	16	160465	130337696.25	32207.02
Roads	17	3067	2491170.75	615.58
Dryland Corn	18	29846	24242413.50	5990.41
Dryland Soybeans	19	7721	6271382.25	1549.69
Dryland Sorghum (Milo, Sudan)	20	19	15432.75	3.81
Dryland Dry Edible Beans	21	5024	4080744.00	1008.37
Dryland Alfalfa	22	19178	15577330.50	3849.23
Dryland Small Grains	23	239741	194729627.25	48118.55
Dryland Sunflower	24	7478	6074005.50	1500.91
Dryland Sugar Beets	25	1515	1230558.75	304.08
Dryland Potatoes	26	3	2436.75	0.60

Perkins County

Perkins County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	486613	395251409.25	97668.36
Irrigated Sugar Beets	2	4967	4034445.75	996.93
Irrigated Soybeans	3	17622	14313469.50	3536.92
Irrigated Sorghum (Milo, Sudan)	4	21333	17327729.25	4281.76
Irrigated Dry Edible Beans	5	26504	21527874.00	5319.63
Irrigated Alfalfa	7	16948	13766013.00	3401.64
Irrigated Small Grains	8	66772	54235557.00	13401.84
Range/Pasture/Grass	9	624231	507031629.75	125289.75
Urban Land	10	6403	5200836.75	1285.15
Open Water	11	784	636804.00	157.36
Riparian Forest and Woodlands	12	15806	12838423.50	3172.43
Wetlands	13	26194	21276076.50	5257.41
Other Agricultural Lands	14	8684	7053579.00	1742.97
Irrigated Sunflower	15	4521	3672182.25	907.41
Summer Fallow	16	586408	476309898.00	117698.27
Roads	17	4200	3411450.00	842.98
Dryland Corn	18	173218	140696320.50	34766.68
Dryland Soybeans	19	22426	18215518.50	4501.13
Dryland Sorghum (Milo, Sudan)	20	59787	48561990.75	11999.88
Dryland Dry Edible Beans	21	19058	15479860.50	3825.14
Dryland Alfalfa	22	14426	11717518.50	2895.45
Dryland Small Grains	23	596854	484794661.50	119794.89
Dryland Sunflower	24	18112	14711472.00	3635.27
Dryland Sugar Beets	25	228	185193.00	45.76

Phelps County

Phelps County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	1008708	819323073.00	202458.34
Irrigated Soybeans	3	75957	61696073.25	15245.37
Irrigated Sorghum	4	22503	18278061.75	4516.59
Irrigated Potatoes	6	3342	2714539.50	670.77
Irrigated Alfalfa	7	34878	28329655.50	7000.38
Irrigated Small Grains	8	6061	4923047.25	1216.51
Range/Pasture/Grass	9	214023	173840181.75	42956.67
Urban Land	10	16894	13722151.50	3390.80
Open Water	11	3068	2491983.00	615.78
Riparian Forest and Woodlands	12	18033	14647304.25	3619.41
Wetlands	13	21280	17284680.00	4271.12
Other Agricultural Lands	14	49737	40398878.25	9982.74
Summer Fallow	16	9549	7756175.25	1916.59
Roads	17	26519	21540057.75	5322.64
Dryland Corn	18	87742	71268439.50	17610.74
Dryland Soybeans	19	17278	14034055.50	3467.88
Dryland Sorghum	20	43296	35167176.00	8689.96
Dryland Alfalfa	22	40709	33065885.25	8170.73
Dryland Small Grains	23	23700	19250325.00	4756.84
Dryland Potatoes	26	5	4061.25	1.00

Polk County

Polk County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	474415	385343583.75	95220.10
Irrigated Soybeans	3	160381	130269467.25	32190.16
Irrigated Alfalfa	7	4226	3432568.50	848.20
Irrigated Small Grains	8	45	36551.25	9.03
Range/Pasture/Grass	9	196631	159713529.75	39465.92
Urban Land	10	8920	7245270.00	1790.34
Open Water	11	3915	3179958.75	785.78
Riparian Forest and Woodlands	12	36835	29919228.75	7393.17
Wetlands	13	26196	21277701.00	5257.81
Other Agricultural Lands	14	76962	62512384.50	15447.09
Roads	17	4473	3633194.25	897.78
Dryland Corn	18	233732	189848817.00	46912.48
Dryland Soybeans	19	153302	124519549.50	30769.33
Dryland Alfalfa	22	23674	19229206.50	4751.62
Dryland Small Grains	23	337	273728.25	67.64

Scotts Bluff County

Scotts Bluff County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	331118	268950595.50	66458.88
Irrigated Sugar Beets	2	85389	69357215.25	17138.47
Irrigated Soybeans	3	56078	45549355.50	11255.45
Irrigated Dry Edible Beans	5	160190	130114327.50	32151.82
Irrigated Potatoes	6	1	812.25	0.20
Irrigated Alfalfa	7	132734	107813191.50	26641.11
Irrigated Small Grains	8	48834	39665416.50	9801.50
Range/Pasture/Grass	9	985816	800729046.00	197863.67
Urban Land	10	53480	43439130.00	10734.00
Open Water	11	28232	22931442.00	5666.46
Riparian Forest and Woodlands	12	92155	74852898.75	18496.48
Wetlands	13	166626	135341968.50	33443.60
Other Agricultural Lands	14	661	536897.25	132.67
Irrigated Sunflower	15	10926	8874643.50	2192.96
Summer Fallow	16	60037	48765053.25	12050.06
Roads	17	1018	826870.50	204.32
Dryland Corn	18	27929	22685330.25	5605.64
Dryland Soybeans	19	5539	4499052.75	1111.74
Dryland Dry Edible Beans	21	10078	8185855.50	2022.76
Dryland Alfalfa	22	38493	31265939.25	7725.95
Dryland Small Grains	23	80978	65774380.50	16253.14
Dryland Sunflower	24	1738	1411690.50	348.83
Dryland Sugar Beets	25	6546	5316988.50	1313.85

York County

York County				
CLASS	VALUE	PIXEL COUNT	SQUARE METERS	ACRES
Irrigated Corn	1	896167	727911645.75	179870.17
Irrigated Soybeans	3	178368	144879408.00	35800.34
Irrigated Sorghum	4	12950	10518637.50	2599.20
Irrigated Alfalfa	7	4453	3616949.25	893.76
Irrigated Small Grains	8	3430	2786017.50	688.44
Range/Pasture/Grass	9	106869	86804345.25	21449.74
Urban Land	10	26259	21328872.75	5270.46
Open Water	11	2367	1922595.75	475.08
Riparian Forest and Woodlan	12	40362	32784034.50	8101.08
Wetlands	13	42144	34231464.00	8458.75
Other Agricultural Lands	14	74893	60831839.25	15031.82
Summer Fallow	16	18	14620.50	3.61
Roads	17	1375	1116843.75	275.98
Dryland Corn	18	262002	212811124.50	52586.57
Dryland Soybeans	19	111730	90752692.50	22425.39
Dryland Sorghum	20	30541	24806927.25	6129.90
Dryland Alfalfa	22	22064	17921484.00	4428.48
Dryland Small Grains	23	19620	15936345.00	3937.94

Appendix C. Metadata

Cohyst 1997Landuse Metadata:

Identification Information:
  Citation:
    Citation Information:
      Publication Date: 200010
      Title: Delineation of 1997 Land Use Patterns for the Cooperative Hydrology Study in the Central Platte River Basin
      Publication Information:
        Publisher: CALMIT
  Description:
    Abstract: The raster land use/land cover data is a digital product of a supervised classification derived from multi-date 1997 Landsat Thematic Mapper (TM) satellite imagery. Field data for crops were obtained using Farm Service Agency (FSA) records from 1997. The National Wetland Inventory was used in assisting the wetland classification. Urban areas were defined using 1992 TIGER data, and other information were gathered using 1993 Digital Orthophoto Quarter Quadranges (DOQQ's). Irrigation information was obtained from the Nebraska Department of Natural Resources, Public Power Districts, and Natural Resource Districts. Center pivots were on-screen digitized using the 1997 Landsat TM data. All irrigation data were checked for accuracy by Nebraska Natural Resource Districts. The cell size for the data is 28.5 meters (93.48 feet) and there are 26 different land use/land cover classes. This product is in ERDAS Imagine format.

    Purpose: The landuse/land cover data can be used as a digital layer in various studies. It is useful as a background layer in a GIS, and can also be merged with other digital data (ie DEM's or DOQ's) to produce a hybrid digital file.

  Time Period of Content:
    Time Period Information:
      Single Date/Time: 200010
    Currentness Reference: Unknown
  Status:
    Progress: Complete
    Maintenance and Update Frequency: None
  Spatial Domain:
    Bounding Coordinates:
      West Bounding Coordinate: -104.162
      East Bounding Coordinate: -97.318
      North Bounding Coordinate: 42.518
      South Bounding Coordinate: 40.002

Keywords:
Theme:
Theme Keyword: Thesaurus: None
Theme Keyword: Land cover
Theme Keyword: Land use
Theme Keyword: Nebraska
Theme Keyword: Central Platte River Basin
Access Constraints: None
Use Constraints: None
Point of Contact:
Contact Information:
Contact Organization Primary: CALMIT
Contact Address:
Address: University of Nebraska, 113 Nebraska Hall
City: Lincoln
State or Province: NE
Postal Code: 68588
Country: USA

Data Quality Information:
Process Step:
Process Description:

Multidate Landsat Thematic Mapper (TM) imagery were used to generate land use/land cover maps for 1997. Cloud coverage dictated date selection to the greatest extent, although imagery was chosen to represent spring, summer, and fall growing conditions. Landsat TM channels 1 and 6 were subset from the imagery and all three dates were stacked into one 15-band file . Before the supervised classification was run, clouded and urban areas areas were removed from the imagery. Urban areas were defined using 1990 TIGER data. Clouded areas were classified in a second stage, using an unsupervised classification with the remaining unclouded dates. Field data for crops were obtained using Farm Service Agency (FSA) records from 1997. Spectral signatures for cropland were collected by identifying homogeneous areas defined on FSA reporting records. The National Wetlands Inventory (NWI) was used to locate wetland areas to collect spectral signatures. Signatures were collected from wetlands greater than 3X3 pixels or 90X90 meters square in size. 1993 Digital Orthohoto Quarter Quadrangles were used to locate signature areas for riparian or forested areas, roads, and non-ag. features. Multiple spectral signatures for each class were extracted and evaluated for continuity. Unrepresentative signatures were deleted. The remaining signatures were then merged by class and a maximum likelihood supervised classification was run on the 15-band imagery. After the classification algorithm was run, classes were evaluated for accuracy. A 'cluster busting' technique was applied to compensate for mixed classes. Irrigation information was obtained from the Nebraska Department of Natural Resources, Public Power Districts, and Natural Resource Districts. Center pivots were on-screen digitized using the 1997 Landsat TM data. All irrigation data were checked for accuracy by Nebraska Natural Resource Districts using 1997 FSA reporting records. The cell size for the data is 28.5 meters (93.48 feet) and there are 26 different land use/land cover classes.

Spatial Reference Information:
Horizontal Coordinate System Definition:
Planar:
Map Projection: State Plane Fipszone 2600

Geodetic Model:
Horizontal Datum Name: NAD 83
Ellipsoid Name: GRS 1980

Entity and Attribute Information:
Each raster entity or pixel contains a value and the associated land use/land cover classes are defined.

Land Use/ Land Cover Classes

VALUE	CLASS NAME
1	Irrigated Corn
2	Irrigated Sugar Beets
3	Irrigated Soybeans
4	Irrigated Sorghum (Milo, Sudan)
5	Irrigated Dry Edible Beans
6	Irrigated Potatoes
7	Irrigated Alfalfa
8	Irrigated Small Grains
9	Range/Pasture/Grass (Brome, Hay, CRP)
10	Urban Land
11	Open Water
12	Riparian Forest and Woodlands
13	Wetlands
14	Other Agricultural Lands (Farmsteads, Feedlots, etc.)
15	Irrigated Sunflower
16	Summer Fallow
17	Roads
18	Dryland Corn
19	Dryland Soybeans
20	Dryland Sorghum
21	Dryland Dry Edible Beans
22	Dryland Alfalfa
23	Dryland Small Grains
24	Dryland Sunflower
25	Dryland Sugar Beets
26	Dryland Potatoes

Overview Description:
Entity and Attribute Overview: NA
Entity and Attribute Detail Citation: NA

Metadata Reference Information:
Metadata Date: 200010

COHYST 1997 Center Pivots Metadata:

Identification Information:
  Citation:
    Citation Information:
      Publication Date: 200010
      Title: 1997 center pivot irrigated areas delineated for the Cooperative Hydrology Study in the Central Platte River Basin
      Publication Information:
        Publisher: CALMIT
  Description:
    Abstract: Center pivots were on-screen digitized using the 1997 Landsat TM data. All irrigation data were checked for accuracy by Nebraska Natural Resource Districts. This data was collected for use in the Platte River Cooperative Hydrology Study.
    Purpose: The irrigated areas will be a factor when running the hydrologic model on the study area. Irrigation data serve a variety of purposes, from water resources planning to landuse planning. This data could also be used for watershed analysis, environmental impact assessments, and other natural resource management activities.
  Time Period of Content:
    Time Period Information:
      Single Date/Time: 200010
    Currentness Reference:
  Status:
    Progress:
    Maintenance and Update Frequency:
  Spatial Domain:
    Bounding Coordinates:
      West Bounding Coordinate: -104.162
      East Bounding Coordinate: -97.318
      North Bounding Coordinate: 42.518
      South Bounding Coordinate: 40.002
  Keywords:
    Theme:
      Theme Keyword   Thesaurus: None
      Theme Keyword   Thesaurus: None
      Theme Keyword: Nebraska
      Theme Keyword: Irrigation
      Theme Keyword: Central Platte River Basin
      Theme Keyword: Center Pivot Irrigation
  Access Constraints: None
  Use Constraints: None
  Point of Contact:
    Contact Information:
      Contact Person Primary:

Contact Organization Primary: CALMIT
Contact Address:
Address: University of Nebraska, 113 Nebraska Hall
City: Lincoln
State or Province: NE
Postal Code: 68588
Country: USA

Data Quality Information:

Process Step:
Process Description:
Center pivot irrigation areas were identified using 1997 Landsat Thematic Mapper (TM) satellite imagery. Satellite imagery collected during the summer of 1997 was displayed while pivots were on-screen digitized. A summer date was selected so that the majority of crops would be at full canopy, allowing for easier identification of center pivots. When questions arose, spring and fall dates of imagery were also displayed. All center pivot coverages were appended into one file and printed on maps divided by Natural Resource Districts. These maps were sent out to each Natural Resource District within the study area and checked for accuracy. Maps were checked using existing knowledge of 1997 irrigated areas and Farm Service Agency reporting records from 1997. When these maps were returned the original vector files were edited and all files were merged into one map for use in the Platte River Cooperative Hydrology Study. These center pivot irrigated acres will be a factor when running the hydrologic model on the study area.

Spatial Reference Information:
Horizontal Coordinate System Definition:
Planar:
Map Projection: State Plane Fipszone 2600

Geodetic Model:
Horizontal Datum Name: NAD 83
Ellipsoid Name: GRS 1980

Entity and Attribute Information:
Detailed Description:
Entity Type:
Entity Type Label: Value
Entity Type Definition: Irrigation Value
0 = Non -Irrigated Areas

1 = Irrigated Areas
Entity Type Definition Source: NA

Overview Description:
Entity and Attribute Overview: NA
Entity and Attribute Detail Citation: NA

Metadata Reference Information:
Metadata Date: 200010

COHYST 1997 Other Irrigation Metadata:

Identification Information:
  Citation:
    Citation Information:
      Publication Date: 200010
      Title: 1997 other irrigated areas (non center pivot) delineated for the Cooperative Hydrology Study in the Central Platte River Basin
      Publication Information:
        Publisher: CALMIT
  Description:
    Abstract: Irrigation information was obtained from the Nebraska Department of Natural Resources, Public Power Districts, and Natural Resource Districts. All irrigation data were checked for accuracy by Nebraska Natural Resource Districts. This data was collected for use in the Platte River Cooperative Hydrology Study.
    Purpose: The irrigated areas will be a factor when running the hydrologic model for the Cooperative Hydrology Study in the Central Platte River Basin. Irrigation data serve a variety of purposes, from water resources planning to landuse planning. This data could also be used for watershed analysis, environmental impact assessments, and other natural resource management activities.

  Time Period of Content:
    Time Period Information:
      Single Date/Time: 200010
    Currentness Reference:
  Status:
    Progress:
    Maintenance and Update Frequency:
  Spatial Domain:
    Bounding Coordinates:
      West Bounding Coordinate: -104.162
      East Bounding Coordinate: -97.318
      North Bounding Coordinate: 42.518
      South Bounding Coordinate: 40.002
  Keywords:
    Theme:
      Theme Keyword Thesaurus: None
      Theme Keyword Thesaurus: None
      Theme Keyword: Nebraska
      Theme Keyword: Irrigation
      Theme Keyword: Central Platte River Basin

  Access Constraints: None
  Use Constraints: None
  Point of Contact:

Contact Information:
Contact Person Primary:
Contact Organization Primary: CALMIT
Contact Address:
Address: University of Nebraska, 113 Nebraska Hall
City: Lincoln
State or Province: NE
Postal Code: 68588
Country: USA

Data Quality Information:

Process Step:
Process Description:
Irrigation data were collected from a variety of sources. Irrigated acres were collected from Pathfinder Irrigation District. Pathfinder Irrigation District keeps DXF files of all of their irrigated acres. The original section sized Pathfinder Irrigation District DXF files were brought into ArcInfo, edited, attributed, and appended to create one larger area map for use in the Platte River Cooperative Hydrology Study. Irrigation maps were also 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. These maps were individually digitized and then merged into one map. Irrigation data was also obtained from the Central Nebraska Public Power and Irrigation District The Central Nebraska Public Power and Irrigation District keeps all of their irrigated acres as DXF files. The original section-sized DXF files were imported into ArcInfo, edited, attributed, and appended to create one larger area map. All of the above mentioned sources were appended into one file and printed on maps divided by Natural Resource Districts. These maps were sent out to each Natural Resource District within the study area and checked for accuracy. Maps were checked using existing knowledge of 1997 irrigated areas and Farm Service Agency reporting records from 1997. When these maps were returned the original vector files were edited and all files were merged into one map for use in the Platte River Cooperative Hydrology Study. These irrigated acres will be a factor when running the hydrologic model on the study area.

Spatial Reference Information:
Horizontal Coordinate System Definition:
Planar:
Map Projection: State Plane Fipszone 2600

Geodetic Model:
Horizontal Datum Name: NAD 83
Ellipsoid Name: GRS 1980

Entity and Attribute Information:
Detailed Description:
Entity Type:
Entity Type Label: Value
Entity Type Definition: Irrigation Value
0 = Non -Irrigated Areas
1 = Irrigated Areas
Entity Type Definition Source: NA

Overview Description:
Entity and Attribute Overview: NA
Entity and Attribute Detail Citation: NA

Metadata Reference Information:
Metadata Date: 200010