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ABSTRACT—Throughout the western United States, natural resources managers are attempting to address the growing, and often competing, demands that municipal, agricultural and environmental interests have for water. The Platte River Cooperative Hydrology Study (COHYST) is a multi-agency effort that seeks to improve understanding of the ecology, geology, and hydrology of the Platte River watershed in central and western Nebraska. Information regarding the types, areal extent, and locations of crops (especially irrigated crops) is critical for estimating consumptive use of water. Digital land-cover and land-use datasets of the central and western Platte River valley have been prepared for four years: 1982, 1997, 2001, and 2005. Mapping was carried out using multidate Landsat satellite imagery in combination with ancillary geospatial data. The mapping was validated using field observations collected independently. Overall accuracy of the maps developed ranged from 74% to 82.7%. All land-cover maps and full documentation are available online at http://www.calmit.unl.edu/cohyst/.

Key Words: crops, land cover, Nebraska, satellite remote sensing

INTRODUCTION

Throughout the western United States, natural resources managers are attempting to address the growing, and often competing, demands that municipal, agricultural, and environmental interests have for water (Gillilan and Brown 1997). Many rivers are experiencing sustained low flows, and may be dry over substantial reaches for all or part of the year. During periods of drought, such as those of the past decade, problems are exacerbated.

Water scientists are increasingly using hydrologic models to identify, assess, and manage the myriad factors, and complex interrelationships between factors, that influence instream flows. It has long been recognized that land use and land cover (LULC) are key variables that must be incorporated in hydrologic models (Srinivasan et al. 1998; Bobba et al. 2000). In areas where agriculture is important, information regarding the types, areal extent, and locations of crops (especially irrigated crops) is critical for estimating consumptive use of water, since crops exhibit different demands for water (Zheng and Baetz 1999). This information must be site-specific and have a known accuracy.

In this paper we describe how data from multiple sources have been employed to map crops and other land cover in the central and western Platte River valley of Nebraska. Satellite imagery, other geospatial datasets, and field-derived data were used together in a structured methodology that could be employed in many other areas to provide information on land cover and land use for hydrologic modeling efforts.

Platte River Cooperative Hydrology Study (COHYST)

Nebraska's central and western Platte River valley is an internationally significant area for migratory water birds traversing North America's Central Flyway (Fig. 1). It is estimated that over 500,000 sandhill cranes and several million other waterfowl migrate annually through the valley. Moreover, the area provides critical habitat for at least nine endangered species (Committee on Endangered and Threatened Species in the Platte River Basin, National Research Council 2004).

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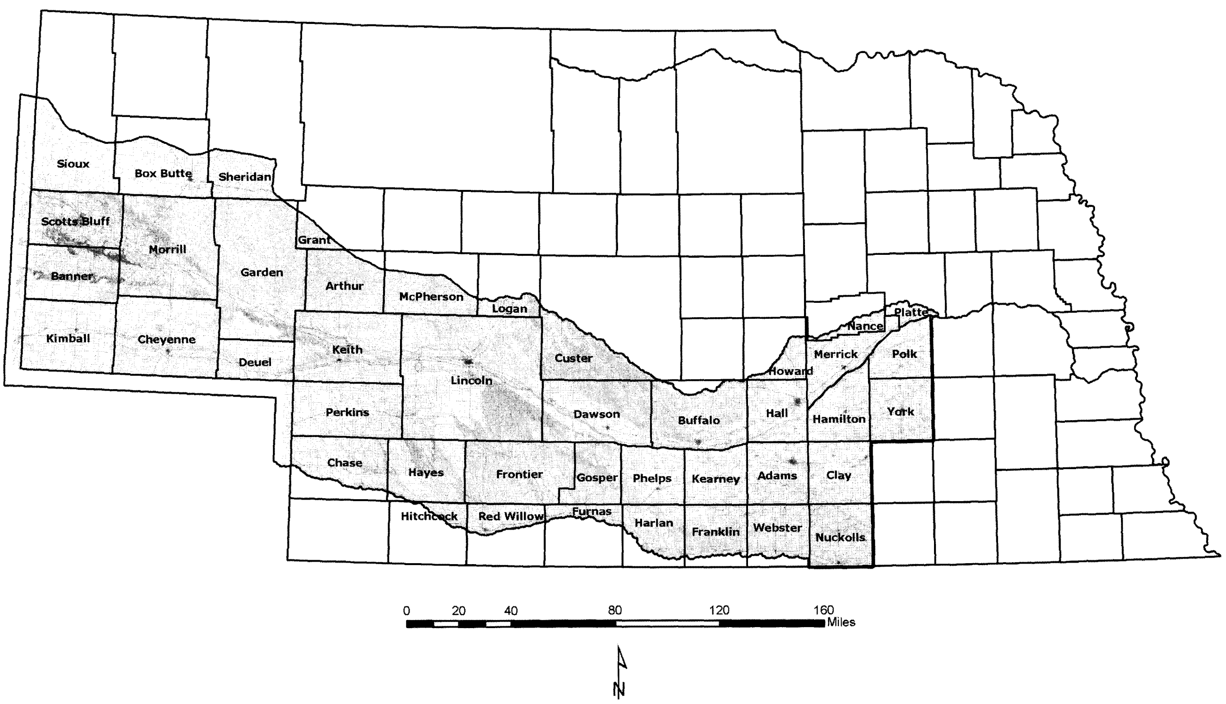

Figure 1. The Platte River valley, Nebraska, study area.

During the past 130 years, the Platte watershed has been transformed by agricultural development and urbanization (U.S. Bureau of Reclamation et al. 1983). By 1997 it was estimated that the region, about 7.6 million hectares in extent, had over 67,000 wells, most used for irrigation (COHYST Technical Committee 2004). Stream flows have been reduced and are more erratic than in the past, the river channel has narrowed as woody vegetation has encroached, adjacent wet meadows have been drained, native grasslands have been converted to cropland, and water tables have declined (U.S. Fish and Wildlife Service 1981; Committee on Endangered and Threatened Species in the Platte River Basin, National Research Council 2004). All these factors have altered and reduced habitat for migratory birds.

The Platte River Cooperative Hydrology Study (COHYST), initiated in 1997, is a federal-state, multi-agency collaborative effort that seeks to improve understanding of the ecology, geology, and hydrology of the Platte River basin in Nebraska upstream from Columbus, NE (COHYST Technical Committee 2004). Modeling is an important component of COHYST that will be used to provide a basis for developing policy and procedures related to groundwater and surface-water management. The outcomes of COHYST will be used to guide efforts to protect and restore critical wildlife habitat, while at the same time ensuring that adequate water will be available for agricultural, municipal, and other uses.

The best map of LULC that existed at the initiation of COHYST was the U.S. Geological Survey's National Land Cover Dataset (NLCD). This 30 m resolution digital dataset was developed via computer-assisted classification of circa 1992 Landsat Thematic Mapper (TM) imagery (Vogelmann et al. 2001). The NLCD portrays four types of agricultural land cover: small grains, row crops, fallow, and pasture/hay. More recently, a revised and updated version of the NLCD, based on analysis of circa 2001 Landsat TM imagery and ancillary geospatial data, has become available (Homer et al. 2007).

Although the spatial resolution of the NLCD was deemed sufficient for COHYST, the categorical detail was determined to be inadequate for modeling water demand. COHYST modelers required site-specific information on crop types and irrigation status; moreover, they needed such information for three time periods, including the 1997 base study year, a previous year, and for at least one later year so that impacts of changes in crop areas and irrigation on water use could be assessed.

The principal objective of this paper is to summarize development and implementation of a methodology used to provide LULC data required for COHYST modeling efforts. Digital LULC datasets of the central and western

Platte River valley have been prepared for four years: 1982, 1997, 2001, and 2005. Selection of these years was based on requirements for COHYST hydrological modeling and availability of satellite data. At the outset of the study, 1997 was established as the "baseline year" on which to model future consumptive use of water within the study area. Model results were validated by mapping land use in 2001 and 2005. Later, a map of LULC in 1982 was developed to provide a historic perspective. That year was selected because field data were available as part of the 1982 Census of Agriculture.

The emphasis here is on the datasets produced for the last three time periods (1997, 2001, and 2005), which were based on analysis of Landsat TM imagery augmented by other geospatial and field data. The 1982 dataset was derived primarily from lower-resolution Landsat Multispectral Scanner (MSS) imagery and will only be mentioned briefly. We describe development of the initial 1997 dataset in detail, as the basic methodology used for that year was also employed in development of the 2001 and 2005 maps. An Internet Map Service (IMS) application provides online access to all COHYST LULC maps, digital geospatial data, and full documentation (see http://www.calmit.unl.edu/cohyst/).

BACKGROUND

Satellite remote sensing has been used extensively for crop-type mapping (e.g., Congalton et al. 1998; Maxwell et al. 2004). Such work has most often been accomplished by multispectral classification of Landsat TM data. Landsat TM images cover large areas (about 34,225 km^2 per image), making them well suited to studies involving large regions, and have relatively fine spatial resolution (30 × 30 m pixels). Moreover, the data are relatively inexpensive.

The best crop classification results have been obtained when several Landsat images, acquired on key dates during the growing season (e.g., May, mid-July, and late September), are analyzed in concert (Maxwell and Hoffer 1996). This ensures that both spring and summer crops are captured in the images, and also allows the analyst to employ aspects of crop phenology in image processing (Lo et al. 1986; Price et al. 1997; Oetter et al. 2001). Maxwell and Hoffer (1996), for example, mapping agricultural crops near Fort Collins, CO, found that May imagery was best for spring- to midsummer-maturing crops and September was best for later-summer-maturing crops. The highest classification accuracies were produced when all three dates were used in analysis.

Ancillary geospatial data, such as aerial photography or field data, are also frequently used to supplement the satellite imagery (see, e.g., Ortiz et al. 1997). Ancillary data can be especially helpful in mapping irrigated lands. Irrigated lands are difficult to map spectrally because they can easily be confused with nonagricultural land cover such as wetlands, subirrigated meadows, and riparian vegetation. In this project, satellite imagery was augmented with field data and data collected via visual air-photo analysis.

Study Area

The COHYST study area includes parts of 42 counties in Nebraska and covers approximately 74,590 km^2 (Fig. 1). Elevation in this area ranges from 435 m above sea level in the east to approximately 1,655 m in the west. The central Platte River, along with its tributaries, occupies a distinct wide and flat valley positioned between sandhills on the north and rolling hills and plains to the south (Jenkins 1993).

The climate of the Platte River basin is typical of the interior of the midlatitude 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. Average minimum January temperatures range from –3.9°C in Scotts Bluff, NE, to –2.2°C Grand Island, NE. Average maximum August temperatures range from 24.5°C in Scotts Bluff, NE, to 28°C in York, NE.

Approximately 97% of the Platte River watershed is devoted to agriculture. About 58% is used for pasture and range (U.S. Fish and Wildlife Service 1981). The major crops grown 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% were in corn, 19% in wheat, 13% in hay (including alfalfa), 8% in soybeans, 3% in sorghum, and 3% in "other crops" (oats, sugar beets, and dry beans) (Nebraska Department of Agriculture 1998). Nearly two-thirds of the nonagricultural lands are urban areas. Remaining lands include privately owned irrigation and power structures, state and federal lands that are not cropped, canals, and other nonagricultural lands.

Mapping Objectives

To meet COHYST modeling requirements, mapping focused on the following LULC classes: irrigated and nonirrigated corn, irrigated sugar beets, irrigated

TABLE 1
LAND-COVER CLASSES

Land-cover classes	General description
Irrigated and nonirrigated corn	Includes corn used for grain or silage. Planted late April to early May, full cover by late July, and harvested September through November.
Irrigated sugar beets	Sugar beets are planted in April. Full cover in August and harvested in October.
Irrigated and nonirrigated 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 and nonirrigated dry edible beans	Includes great northern beans, pinto beans, white beans, and others. Planted in May to early June. Cutting starts mid-August when plants are windrowed to dry. Harvested late August to late September.
Irrigated potatoes	Potatoes are planted in late April to early May, harvested September to October.
Irrigated and nonirrigated alfalfa	Alfalfa begins to mature during April and early May, with first cut beginning in May. Harvested three to four times during the growing season ending in early October.
Irrigated and nonirrigated small grains	Includes winter wheat, spring wheat, oats, barley, rye, and millet. Winter wheat is planted September of previous year and harvest begins early July. Oats and barley are generally planted late March or early April and are harvested in July.
Irrigated and nonirrigated sunflowers	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 bromegrass and land in the Conservation Reserve Program. Greens up in spring and early summer. Grazing occurs at irregular intervals. May be subirrigated.
Urban land	Areas defined as towns or cities with a population greater than 100 people.
Open water	Lakes, streams, ponds, reservoirs. Water levels vary due to irrigation draw downs and evaporation.
Riparian forest and woodlands	Forested areas including areas next to streams, lakes, and wetlands
Wetlands	Emergent wetlands are 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 subirrigated grassland areas and areas of shallow water.
Other agricultural lands	Includes developed areas associated with farming, such as farmsteads and feedlots.
Roads	Interstate and highway roads

Source: Nebraska Agricultural Statistics Service 1990; Maxwell and Hoffer 1996; National Agricultural Statistics Service 1997.

and nonirrigated soybeans, irrigated and nonirrigated sorghum, irrigated dry edible beans, irrigated potatoes, irrigated and nonirrigated alfalfa, irrigated and nonirrigated small grains, irrigated and nonirrigated sunflowers, summer fallow, range/grass/pasture, urban land, open water, riparian forest and woodlands, wetlands, other agricultural lands, and roads. Each class is further detailed and described in Table 1.

METHODS

We adapted an approach to map the Platte Valley that used multidate Landsat TM imagery, ancillary geospatial data, and field data collection in a structured methodology (Fig. 2). Both digital and visual image analysis methods were employed in this effort.

Data Acquisition and Preliminary Data Processing

Ten Landsat-5 TM images are required to cover the study area (Fig. 3). Wherever possible, three images (spring, summer, and fall 1997) were obtained for each image. In some cases compromises had to made owing to cloud cover or image quality. A total of 24 geo-corrected and terrain-corrected TM images were purchased from the USGS EROS Data Center. TM Bands 2, 3, 4, 5, and 7 were selected for further processing. Only these spectral bands were used since prior research has shown that bands 1 and 6 are not required for crop mapping. Each TM image was processed independently. Clouded areas were digitized on screen and removed.

A number of ancillary datasets were used along with the Landsat imagery. Urban areas were masked using 1992 TIGER data (http://www.census.gov/geo/www/tiger/) and National Wetlands Inventory (NWI) data were used to identify wetlands (http://www.fws.gov/nwi/). USGS 1 m resolution digital orthophoto quarter quadrangles (DOQQs) flown in 1993 were also employed (http://www.dnr.ne.gov/databank/doqall.html).

Field data, supplied by the USDA Farm Service Agency (FSA), were available for approximately 1,500 randomly selected sections. These records provided detailed information on 1997 crop types, irrigated and dryland fields, and field boundaries (Fig. 4). The FSA data were randomly split into two subsets. One subset was used to determine training sites for specific crop types. The second was set aside to be used during accuracy assessment.

Image Classification

Image classification was carried out in several steps. Supervised classification was used when three dates of imagery were available for an image. Unsupervised classification was used in all other cases. Irrigated lands were mapped using a combination of on-screen digitizing and ancillary field data (Fig. 2).

Supervised Classification. Supervised classification is a procedure widely used in remote sensing when sufficient field data are available to "train" a classification algorithm (see Jensen 2005). Using this approach, individual pixels are assigned to classes based on assessment of "similarity" between their spectral characteristics and spectral "signatures" derived from samples ("training sites") identified for each target LULC class. We began by combining the spectral bands for each date and image into a single 15-band image. Field data from FSA were used to determine training sites for crops and most other land-cover classes. For each crop type, special attention was given to collecting spectral information from homogenous areas away from field edges. Where FSA data were not available, DOQQs were used to locate training sites for open water, roads, riparian forest and woodland areas, and other features such as homesteads and feedlots. National Wetlands Inventory (NWI) data were used to determine training sites for permanently flooded, intermittently exposed, and semipermanently flooded wetlands. Only wetland areas greater than 90 m^2 were used.

Spectral signatures were developed for each LULC class. The numbers of signatures collected for each class reflected the diversity and acreage of crops in each image, and the availability of ground data (e.g., from FSA reports). For example, sunflower and sugar beet signatures were collected only for the three Landsat images found in the western half of the study where these crops are grown. On an image-by-image basis, all signatures for each class were merged into a single signature, which was the basis for the supervised classification. This step increased computer efficiency and aided postclassification analyses.

After the initial classification, it was observed that some pixels were not acceptably associated with any single land-cover target class. These included mixed pixels (i.e., pixels containing more than one cover type). Such pixels were reclassified using "cluster busting" (Jensen 2005). Cluster busting is a procedure designed to separate pixels that are spectrally similar to one another by progressively decreasing the spectral variance between classes.

First, candidate pixels were identified and masked from the raw TM data. The candidate pixels were then reclassified using an unsupervised classification approach. The resulting output clusters were reassigned 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

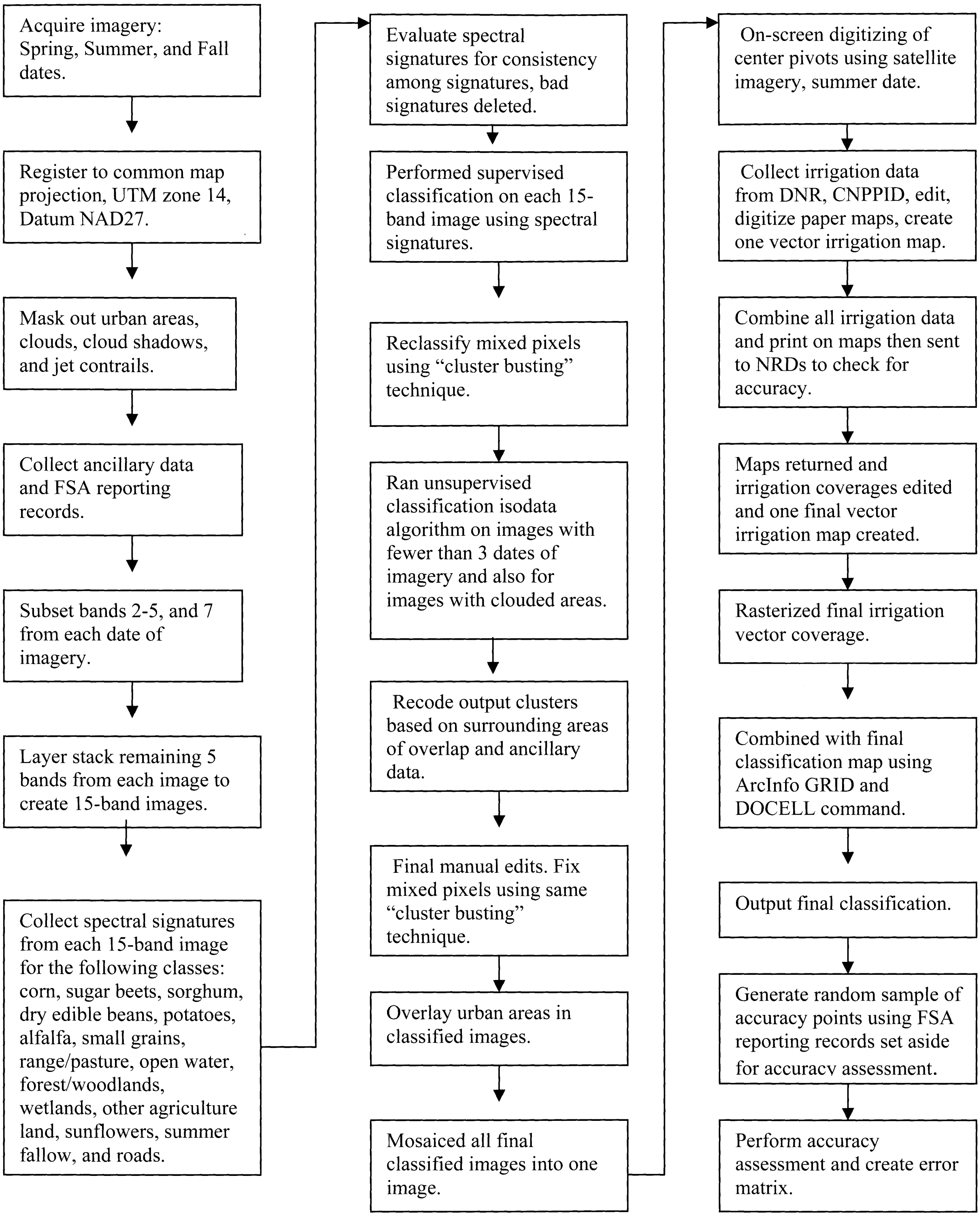

Figure 2. Flow chart outlining mapping strategy.

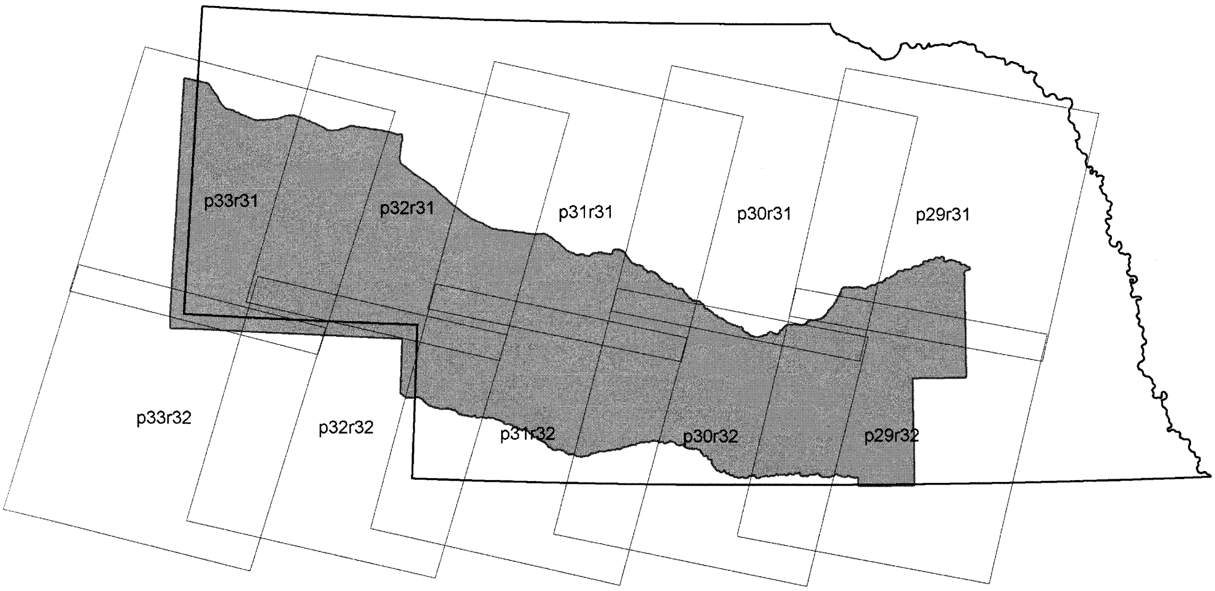

Figure 3. Ten Landsat TM images are required to cover the COHYST study area. Individual images are identified by path (orbit) and row (latitude) center points.

where mixed pixels could not be completely resolved due to the spectral similarities of certain crop types. For example, some problems remained with, respectively for the three time periods, small grains and range, alfalfa and soybeans, and sunflowers and soybeans. Difficulties in distinguishing between these classes were most prevalent in areas of cloud cover or when fewer than three dates of imagery were available during the growing season.

Unsupervised Classification. An unsupervised classification was applied to images for which fewer than three dates of imagery were available and on images 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" spectral groupings of pixels (Jensen 2005). These spectral "clusters" are then described by an analyst using ancillary and field data. For the COHYST project, clusters were initially characterized and labeled based on the surrounding areas of overlap with the supervised classification. Ancillary data such as DOQQs and the FSA reporting records were also used. Mixed pixels were reclassified using "cluster busting" techniques as described above.

Delineation of Irrigated Areas

Due to above-normal precipitation levels in August, September, and October of 1997 (NOAA 1997), irrigated and nonirrigated fields were not easily distinguished using the spectral classification methods described above. Center-pivot irrigation systems were 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 the circular fields. When needed, spring and fall dates of imagery were also used. Next, digital and paper maps of known irrigated areas were obtained from the Nebraska Department of Natural Resources, Central Nebraska Public Power and Irrigation District, and Pathfinder Irrigation District. The digital maps were converted into a common vector format and paper maps were individually digitized. All the irrigation data from the different sources were merged, and the merged data were mapped. Maps were then provided to Natural Resource District (NRD) personnel, who field checked the data. Farm Service Agency reporting records from 1997 were also used in verification. When verification was complete, the original irrigation maps were edited

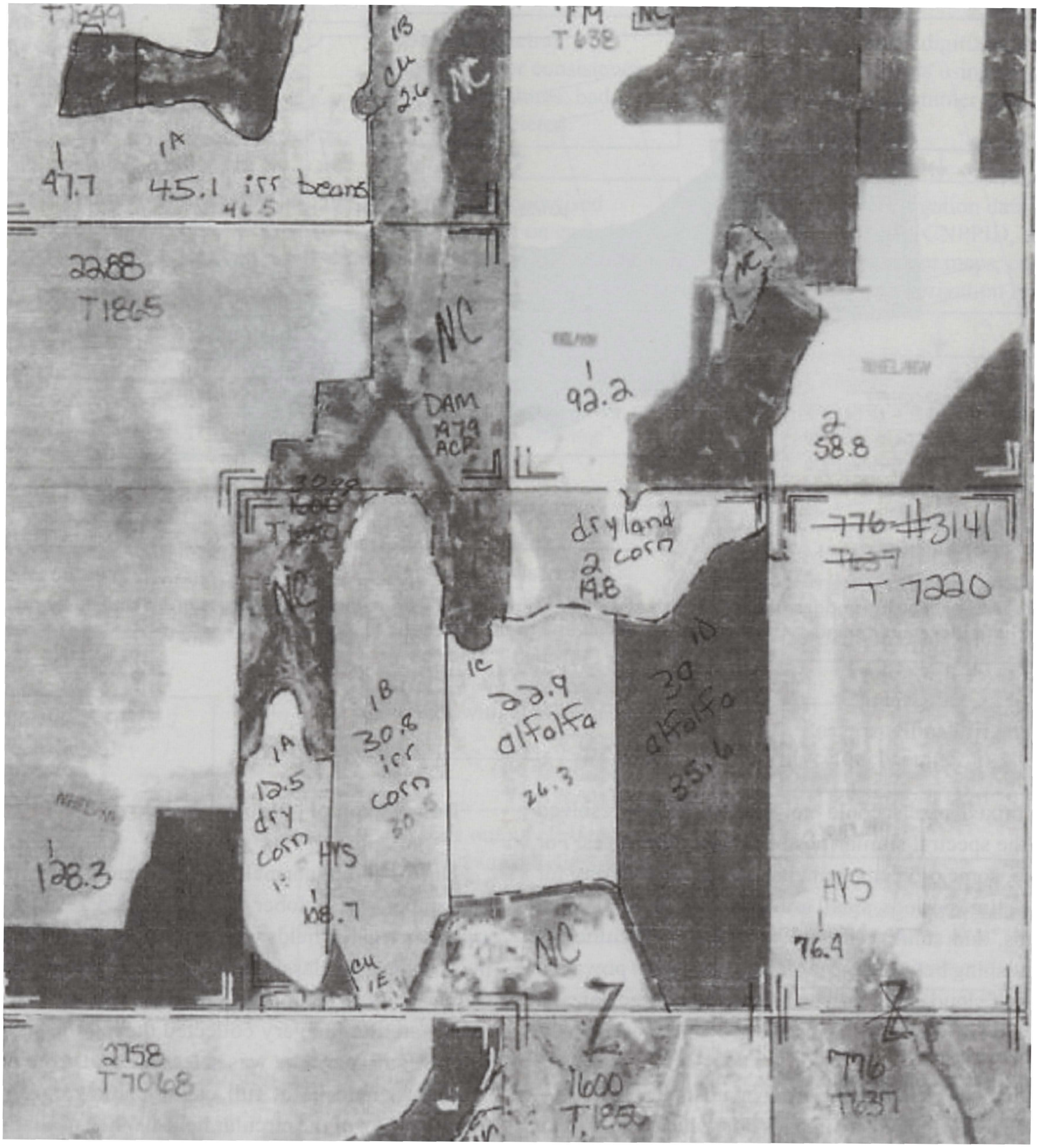

Figure 4. Example of FSA field records.

and all files were merged into one final vector irrigation dataset.

Final Map Production

After final edits were made to the classified imagery, all of the separate layers were combined to produce a single classified image. The irrigation vector coverage was gridded so that it could be wed with the classified image to create the final map (Fig. 5). The areal extent (acres and hectares) of each land-cover type was computed and summarized (Table 2).

Accuracy Assessment

The accuracy of the map was assessed by comparing, on a site-by-site (pixel by pixel) basis, land-cover classes portrayed on the map with the actual class of land cover known from field investigation (Congalton and Green 1999; Jensen 2005). Reference field data were obtained

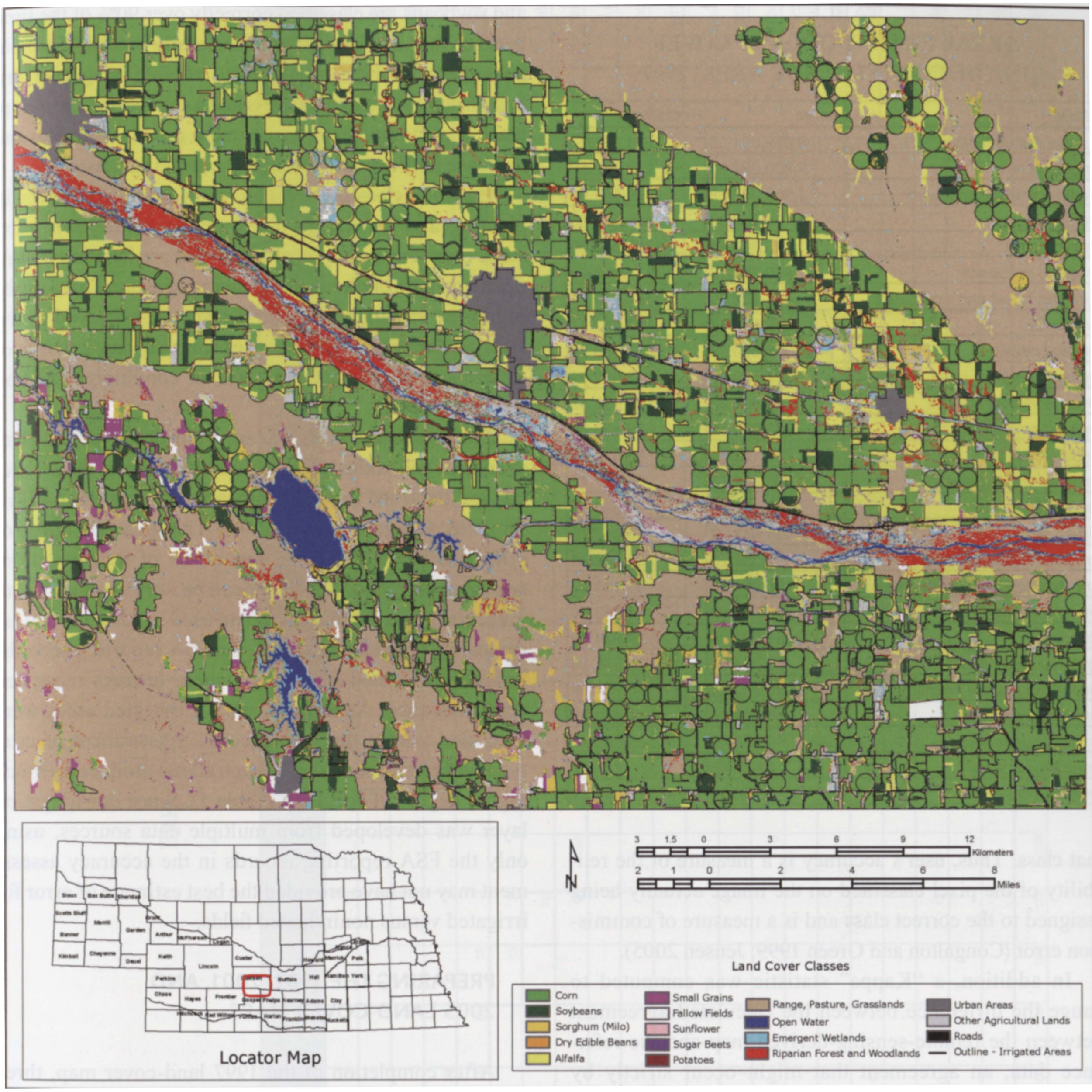

Figure 5. Example of final 1997 land-use and land-cover map.

from the Farm Service Agency (FSA) reporting records (data set aside for the accuracy assessment). A stratified random sample of 1,900 pixels was used in accuracy assessment. Results of this comparison were presented in an error matrix, wherein numbers on the diagonal represent agreement between the map classes and the reference data (Table 3).

Map accuracy was characterized in several ways: as overall accuracy, the map "producer's accuracy," the map "user's accuracy," and with the Kappa coefficient (Jensen 2005). Overall accuracy is computed by dividing the total number of correctly classified pixels by the total number of pixels sampled. "Producer's accuracy" is derived by taking the total number of correctly identified pixels in a class and dividing by the total number of reference pixels of that class. Producer's accuracy indicates the probability of a pixel being correctly classified and is a measure of omission error. By contrast, the map "user's accuracy" is obtained by dividing the total number of correct pixels in a class by the total number of pixels that were classified in

TABLE 2
AREAL EXTENT OF LAND COVER
IN THE COHYST STUDY AREA, 1997

Class	Acres	Hectares
Range/pasture/grass	9,079,001.98	3,674,221.77
Irrigated corn	2,800,094.00	1,133,182.52
Dryland small grains	1,553,240.73	628,587.91
Summer fallow	1,103,837.37	446,716.86
Dryland corn	820,924.41	332,223.56
Irrigated soybeans	430,711.79	174,306.67
Riparian forest and woodlands	414,188.30	167,619.71
Wetlands	379,577.17	153,612.77
Dryland alfalfa	328,560.76	132,966.72
Dryland sorghum (milo, sudan)	327,780.60	132,650.99
Other agricultural lands	249,695.36	101,050.33
Dryland soybeans	245,016.60	99,156.86
Irrigated alfalfa	214,172.81	86,674.55
Irrigated small grains	165,452.53	66,957.72
Open water	125,122.96	50,636.57
Urban land	114,441.14	46,313.70
Irrigated dry edible beans	82,382.25	33,339.64
Irrigated sorghum (milo, sudan)	76,959.85	31,145.22
Dryland sunflower	69,542.99	28,143.66
Roads	69,001.88	27,924.68
Irrigated sugar beets	53,314.94	21,576.26
Dryland dry edible beans	26,903.84	10,887.84
Irrigated sunflower	13,994.14	5,663.35
Dryland sugar beets	9,099.41	3,682.48
Irrigated potatoes	1,935.45	783.27
Dryland potatoes	108.58	43.94

that class. Thus, user's accuracy is a measure of the reliability of the pixel classified on the image actually being assigned to the correct class and is a measure of commission error (Congalton and Green 1999; Jensen 2005).

In addition, a "Kappa" statistic was computed to gauge the difference between the calculated agreement between the remote-sensing-derived map and the reference data, an agreement that might occur strictly by chance. A Kappa of zero occurs when the agreement between classified data and reference data is no better than chance agreement. As the Kappa value approaches a value of one, the agreement is indicated to be better than what one might obtain by chance (Jensen 2005).

RESULTS

The overall classification accuracy for the entire COHYST study area was determined to be 78.5%, with a Kappa statistic of 0.77. As expected, the accuracy of classification varied by land-cover type, since some land-cover classes are more easily separated using multispectral classification methods than others (Table 4). For example, corn and soybeans are classified correctly over 90% of the time because they can be distinguished easily by differences in phenology observed on multidate satellite imagery. Corn has a faster ascent to greenness and a sudden decline before harvest while soybeans have a more gradual increase and decrease in greenness through the growing season.

Errors in classification can result from differences in planting and harvesting dates among fields having the same crop. For example, alfalfa fields are harvested multiple times throughout the growing season. This results in a great variation in spectral response observed in the satellite data. Spectral responses can also vary because of differences in row spacing, weather conditions, and soil moisture levels.

These accuracy results are considered better than average when taking into account the types of land-cover classes identified in the classification (Maxwell and Hoffer 1996; Congalton et al. 1998). The greatest source of error can be found in the separation of irrigated from nonirrigated crops. This error can be attributed in part to inaccuracies in the reference data used in the accuracy assessment. The reference data, the FSA reporting records, indicated irrigated fields only where farmers requested crop insurance. As a result, not all irrigated areas were identified within the FSA records. Assessment of crop type without respect to irrigation status produced a much higher degree of accuracy (Table 5). Since our irrigation layer was developed from multiple data sources, using only the FSA reporting records in the accuracy assessment may not have provided the best estimate of error for irrigated versus nonirrigated fields.

PREPARING THE 1982, 2001, AND 2005 LAND-COVER MAPS

After completion of the 1997 land-cover map, three other map products were produced, one each for the years 1982, 2001, and 2005. Maps for 2001 and 2005 were developed using Landsat imagery and classification procedures similar to those used to prepare the 1997 map. A map for 1982 was developed using somewhat different data and methods. Collectively, these maps provide water modelers with information on changes in land cover and land management within the COHYST study area over a 23-year span.

Mapping 2001 Land Cover

Landsat-7 Enhanced Thematic Mapper+ (ETM+) imagery was used to map 2001 land cover. These data

TABLE 3
ERROR MATRIX

Map Data	Reference points	Irrigated corn	Irrigated sugar beets	Irrigated soybeans	Irrigated sorghum	Irrigated dry edible beans	Irrigated potatoes	Irrigated alfafa	Irrigated small grains	Range	Open water	Riparian	Wetlands	Irrigated sunflowers	Summer fallow	Dryland corn	Dryland soybeans	Dryland sorghum	Dryland dry edible beans	Dryland alfafa	Dryland small grains	Dryland Sunflowers	Row Totals
Irrigated corn	100	90	1	5	2	1		2								11		1		1			114
Irrigated sugar beets	100		77			2		1															80
Irrigated soybeans	100	2	1	91		6	4									1	1						106
Irrigated sorghum	100				26	4												4		2			36
Irrigated dry edible beans	100	1	3		8	83	19							3		1							118
Irrigated potatoes	100						73	2															75
Irrigated alfafa	100			1				76												18			95
Irrigated small grains	100		4					2	80					3							2		91
Range	100					1		4		94	1	12			1	1				3	2		119
Open water	100										93	7											100
Riparian	100									3	4	74											81
Wetlands	0									1	2	1	0										4
Irrigated sunflowers	100				6	3								87				1				15	112
Summer fallow	100		13				3		9					7	90						2		124
Dryland corn	100	7			1							5				74	25	2		1	2		117
Dryland soybeans	100			3													63	1					67
Dryland sorghum	100				57		1								2	12	1	91		2			166
Dryland dry edible beans	0																		0		1	6	7
Dryland alfafa	100							13		1		1								69		1	85
Dryland small grains	100								11	1					7		1			4	88	5	117
Dryland sunflower	100																				2	73	75
Column totals	1900	100	99	100	100	100	100	100	100	100	100	100	0	100	100	100	91	100	0	100	99	100	1889

TABLE 4
ACCURACY ASSESSMENT OF 1997 LAND-USE AND LAND-COVER DATA

Class name	Reference totals	Classified totals	Number correct	Producer's accuracy (%)	User's 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 agricultural lands	0	1	0	---	---	---
Irrigated sunflowers	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 sunflowers	100	75	73	73.00	97.33	85.17
Dryland sugar beets	0	1	0	---	---	---
Totals	1900	1900	1492			

Note: Overall classification accuracy = 78.53%.

TABLE 5
ACCURACY BY CROP TYPE WITHOUT REGARD TO IRRIGATION STATUS

Classes	Producer's accuracy (%)	User's 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 beans	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
Sunflowers	80.50	93.06	86.78

Note: Overall classification accuracy by crop without irrigation layer = 86.07%.

are spatially and spectrally comparable to the TM data used in the 1997 mapping. Image classification techniques were essentially identical to those outlined above. On-screen digitizing of center pivots, FSA irrigation records from 2001, and information on registered irrigation wells obtained from the Nebraska Department of Natural Resources were used to update the information developed for 1997 irrigated lands. The overall accuracy of mapping was determined to be 82.7% and the Kappa statistic to be 0.80.

Mapping 2005 Land Cover

Because Landsat-7 imagery of sufficient quality was not available, mapping for 2005 was carried out with

Landsat-5 TM data. Field data required for classification and accuracy assessment were provided by NRDs throughout the COHYST study area. In addition, digital orthoimagery collected under the USDA National Agricultural Imagery Program (NAIP) was used extensively. On-screen digitizing of center pivots, NRD field observations from 2005, NAIP orthophotos, and information on registered irrigation wells obtained from the Nebraska Department of Natural Resources were used to update the information developed for 2001 irrigated lands. The overall accuracy of mapping was determined to be 80.6% and the Kappa statistic to be 0.78.

Mapping 1982 Land Cover

Landsat TM imagery was not available for the 1982 growing season. Therefore, 1982 land-cover mapping was based on Landsat-3 Multispectral Scanner (MSS) data. In contrast to the TM, MSS imagery has a spatial resolution of only approximately 80 × 80 m, and there are fewer spectral bands with which to carry out classification. As a consequence, the land-cover classes mapped were somewhat more general than those mapped in 1997, 2001, and 2005. For example, potatoes, sunflowers, and dry edible beans were grouped into a single class. Mapping and accuracy assessment were aided by approximately 8,000 field observations provided by the USDA Natural Resources Conservation Service. Image classification, using a combination of supervised and unsupervised techniques, proceeded in a manner similar to that described for the 1997 project. On-screen digitizing of center pivots, and 1980 irrigation maps obtained from the Nebraska Department of Natural Resources, were used in concert to identify the irrigated lands. The overall accuracy of mapping was determined to be 74.1% and the Kappa statistic to be 0.68.

Data Availability

The spatial and categorical detail of the COHYST land-cover information can only be appreciated when digital data are viewed at full resolution. All land-cover products developed for 1982, 1997, 2001, and 2005, along with detailed descriptions of the mapping procedures, results, and accuracy assessments, are available on the Internet at http://www.calmit.unl.edu/cohyst/. The site uses Internet Map Service (IMS) technology that enables users to view maps at various scales online, print hard copy, and download digital data for analysis in a geographic information system (GIS).

SUMMARY AND CONCLUSIONS

We have described the development of a set of digital maps portraying agricultural land use and land cover of the central and western Platte Valley in Nebraska in 1982, 1997, 2001, and 2005. These maps were based on analysis of multidate Landsat satellite imagery, over 100 images in total, supplemented by ancillary geospatial data. The LULC products are being actively used in COHYST water-modeling activities (Richard Luckey, U.S. Geological Survey, pers. comm. 2005; Bitner 2005; Luckey and Cannia 2006). Subsequent work focuses on analysis of land-use and land-cover changes in the study area, and expansion of 2005 mapping to cover the entire state of Nebraska. This work was completed in late 2007 and is available on the Web site noted above.

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