TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCE
Vol. 107, no. 3/4
p. 105-118 (2004)

Identifying historical and recent land-cover changes in Kansas using post-classification change detection techniques

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Statewide land-cover change detection analysis provides a useful tool for conservation planning and environmental monitoring and addresses issues of habitat fragmentation and urban sprawl. Furthermore, land-cover data offer a historical and recent perspective on landscape dynamics. To this end, the first alliance level land-cover map of Kansas (Kansas Vegetation Map) recently completed by the KARS Program was compared to Küchler's Potential Natural Vegetation map and the 1993 Kansas Land Cover Patterns map. The post-classification change detection technique was used along with co-occurrence matrices to identify areas and directions of land-cover change.

Comparisons showed that the land cover of Kansas has changed drastically since European settlement. Over 48% of the land is now cultivated and native vegetation types such as tallgrass and shortgrass prairie have been reduced dramatically in area. There are, however, millions of ha of these vegetation types remaining in Kansas. Comparisons between the two recent land-cover maps reveal that over 80% of the land in Kansas has remained unchanged in the five years between map development. Recent land-cover changes include conversion of grassland to cropland, cropland to grassland, and grassland to woodland. Many areas changing from cropland to grassland have been identified as land being enrolled in the Conservation Reserve Program (CRP). Post-classification change detection analysis also shows that forest and woodland types have increased over the five-year period and over 1 million ha of grassland have been converted to cropland. The magnitude of increases in woodland and forest is questionable, however, and may be due to registration errors and classification methodologies used to generate the land-cover maps.

Keywords: remote sensing, change detection, land use, land cover.

INTRODUCTION

Land-cover mapping using remotely sensed data not only provides a current inventory of resources and land use, but also provides an opportunity to identify and monitor changing patterns in the landscape. Traditional methods for monitoring land-cover change rely on field data and aerial photography; however, these traditional methods can be costly and time consuming for relatively large areas. For statewide or regional studies, the use of remote sensing and geographic information systems (GIS) provides cost-effective tools and repeatable methods for monitoring land-cover change. Change detection techniques based on remotely sensed data have been used to identify changes in variety of aquatic and terrestrial environments including coastal, agricultural, forested, and urban areas (Berlanga-Robles and Ruiz-Luna 2002; Howarth and Wickware 1981; Mas 1999; Palandro et al. 2003). Loveland et al. (1999) are working currently on the first national-level change detection project. The land Cover Trends Project uses five dates of satellite data to assess land-use and land-cover changes occurring during the past 30 years. The Environmental Protection Agency and the United States Geological Survey (USGS) are collaborating in this research effort to identify rates, causes, and consequences of land-use and land-cover change for the coterminous United States.

The post-classification change detection technique is one of many change detection methods used by remote sensing scientists. The post-classification comparison technique compares, on a pixel-by-pixel basis, multiple maps created from remotely sensed data collected at different times. This change detection technique not only identifies areas of change, but also provides directional information of the observed change (Jensen 1996).

The Kansas Applied Remote Sensing (KARS) program recently completed the Kansas Vegetation Map (KV) (Egbert et al. 2001; Stewart et al. 2000), an alliance level land-cover map as part of the Kansas Gap Analysis Project (GAP). To provide a historical perspective of land-cover change, Küchler's Potential Natural Vegetation (KPNV) map (Küchler 1974) was compared with the Kansas Vegetation Map. Küchler's Potential Natural Vegetation map provides estimated land-cover information prior to European settlement. The comparison provides insight to anthropogenic and naturally driven land-cover changes in Kansas over approximately the past 150 years.

In 1993, the KARS program completed the Kansas Land Cover Patterns (KLCP) map, a modified Anderson Level I classification derived from Landsat Thematic Mapper imagery (Whistler et al. 1995). Comparing the two land-cover maps generated by KARS provides an opportunity to monitor more recent land-cover changes in Kansas. Post-classification change detection analysis was performed using the georegistered land-cover maps of Kansas.

METHODOLOGY

Mapping historical land-cover change

A comparison of the KPNV and KV maps provides a general overview of historical land-cover change in Kansas. A 1:800,000 KPNV printed map was manually digitized, resulting in a digital vector file. The vector file was then converted to a raster data file with a 30 m cell size for map comparison purposes. Given the small scale of the KPNV map, digitizing efforts likely resulted in linear inaccuracies of the defined vegetation boundaries. Nonetheless, the vast spatial extent of the vegetation regions defined somewhat subjectively by Küchler, still provides an accurate, regional account of historical land-cover change when compared to the KV map.

For comparison purposes, the KPNV map was recoded to eight classes (shortgrass prairie, mixed prairie, tallgrass prairie, oak-hickory forest, floodplain vegetation, transition of mixed and tallgrass prairie, mosaic of tallgrass prairie and forest, and lakes and reservoirs). Next, the KV map was recoded to best match the corresponding KPNV classes. A co-occurrence matrix was generated to quantify agreement (no change) and disagreement (change) between the two land-cover maps.

Mapping recent land-cover change

Comparing the KPNV data with the KV data illustrates how the Kansas landscape has changed since European settlement, but fails to identify the most recent land-cover changes. Therefore, the KLCP map was compared with the KV land-cover map to identify recent trends in land-cover change. Since the KLCP classes were more general than the KV map, the KV land-cover classes were recoded to correspond to the KLCP land-cover classes.

A co-occurrence matrix quantified agreement and disagreement between the two land-cover maps. Disagreement between the two land-cover maps indicates potential recent changes in land-cover. While a co-occurrence matrix quantifies change, it does not provide a visual representation of land-use/land-cover change. Therefore, a change detection matrix function was used to generate an image with pixels coded to reflect directional change. Each combination of change or no change was coded to a unique value. For example, pixels mapped grasslands in the KLCP map and cropland in the KV map were coded as class 2 on the change map where as pixels mapped as cropland in both land-cover maps were coded as class 7.

Kansas vegetation maps

Küchler's Potential Natural Vegetation (KPNV) map. Küchler's potential vegetation classification system divides Kansas' land-cover into four major classes: prairies; forests; mosaics, transitions, and boundaries; and lakes and reservoirs. Within each vegetation class, Küchler divides the vegetation into two levels of subclasses (Fig. 1). In the first subclass level, the prairie class is divided into three zones from east to west: tallgrass prairies, mixed prairies and shortgrass prairies. The forest class consists of oak-hickory forests and floodplain vegetation. The mosaics, transitions, and boundaries class consists of transitional zones of vegetation or mosaics of multiple vegetation types. Küchler mapped the potential vegetation of Kansas using library sources along with field and laboratory data (Küchler 1974). Geology, soils, topography, and climate data combined with field observation were key to the development of this vegetation map.

On Küchler's map, oak-hickory forests are concentrated in the eastern third of the state, and floodplain vegetation is concentrated along waterways throughout the state (Fig. 1). The prairies divide Kansas into three east-west zones. Shortgrass prairie dominates the western third of Kansas, mixed prairie dominates the central third, and tallgrass prairie the eastern third of Kansas. Mixed prairie intermixes with shortgrass prairie in the west and tallgrass prairie in the east. Sand prairies are found in the south-central and southwestern regions of Kansas. As its name suggests, sand prairie typically occurs on sandy soils and often intermixes with the other prairie types in the area. Of the four prairie types, sand prairie is the smallest mapped prairie type.

Kansas Land Cover Patterns (KLCP) map. The Kansas Land Cover Patterns map was created using an unsupervised classification approach on single-date (16 images) Landsat Thematic Mapper (TM) imagery dating from 1988 to 1991 (Whistler et al. 1995). The TM data were subset to the county level creating 105 subsets. Unsupervised classification based on ISODATA clustering was used to map ten land-use/land-cover classes: five urban classes (residential, commercial/industrial, open land, woodland, and water) and five rural classes (cropland, rangeland, woodland, water, and other) (Fig. 2). The thematic image for each county was then generalized to a 2 hectare (ha) minimum mapping unit (MMU). The county land-cover maps were then geometrically rectified to geographic coordinates and edge matched to create a statewide land-cover map.

Classification accuracy assessments were conducted on a county-level basis. Aerial photography was compared to the county-level maps to determine map accuracy levels. Sample sites were systematically selected with a minimum of 5% of the total county area sampled. The sample sites were manually digitized and interpreted from the aerial photography. The statewide land-cover map had an overall accuracy of 91% (Whistler et al. 1995).

The KCLP map shows that cropland and grasslands are the two dominant land-cover types in Kansas (Fig. 2). Woodland covers a relatively small area and is concentrated in the eastern half of Kansas and along stream corridors in central and western Kansas. Cropland dominates central and western Kansas, more so than in eastern Kansas. Large extents of grassland are scattered throughout the state with the largest extent located in the Flint Hills.

Kansas Vegetation (KV) map. The Kansas Vegetation Map was created using a hybrid two-stage classification approach on multitemporal Landsat Thematic Mapper data. Forty-eight Landsat Thematic Mapper scenes dating from 1992 to 1996 were acquired to provide multitemporal (spring, summer, and fall) coverage of the state. Forty-one land-cover classes were mapped including 38 alliance-level vegetation classes, cropland, urban and water (Lauver et al. 1999; Egbert et al. 2001) (Fig. 3). An alliance is defined as an aggregation of community types where the same dominant species and physiognomy exist (Lauver et al. 1999). In the vegetation classification hierarchy, the alliance level resides between the formation level and community level with the community level being more detailed.

Land-use/land-cover in each multitemporal image was mapped using a two-stage hybrid classification approach. The first stage (unsupervised classification) separated cropland from natural vegetation. The second stage (supervised) mapped the natural vegetation class into the 38 alliance-level vegetation classes. Over 3500 field sites visited during the summers of 1996 to 1998 were used to train the classification algorithm. Following the supervised classification process, the land-cover maps were generalized to a minimum mapping unit of 2 ha. Lastly, the sixteen image-based vegetation maps were mosaicked to create a statewide vegetation map.

A number of post-hoc techniques were used to refine the statewide map as determined by ecologists/biologists and by remote sensing scientists from the Kansas Biological Survey and KARS Program, respectively. Refinements were conducted on a statewide, regional, county, or scene-by-scene basis, depending on the refinement performed. Ancillary data such as geology, soils, and hydrography were used to refine the land-cover map.

Map accuracy levels were assessed by land-cover type and were reported along with overall accuracy, and the Kappa statistic. Accuracy levels were calculated by comparing the classified data with 828 field sites that were collected throughout the state in 2000. Error matrices were generated at three classification levels: the alliance level, formation, and Anderson Level I. Overall accuracy levels for the state at Anderson Level I, formation, and alliance level were 88%, 65%, and 52%, respectively (Egbert et al. 2001). An Anderson Level I classification is a commonly used land-use and land-cover USGS classification system consisting of nine general classes (urban, agriculture, rangeland, forest, water, wetland, barren, tundra, and perennial snow or ice). Anderson's classification system is a hierarchy of classification levels (e.g. Anderson Level II and Level III) with more detailed land-use/land-cover classes with each numeric increase (Anderson et al. 1976).

The Kansas Vegetation Map is the first alliance-level land-cover map of Kansas. The map indicates cropland and grassland dominate the Kansas landscape (Fig. 3). Of the grassland types remaining in Kansas, there is a mixture of non-native grasslands, former cropland enrolled in the Conservation

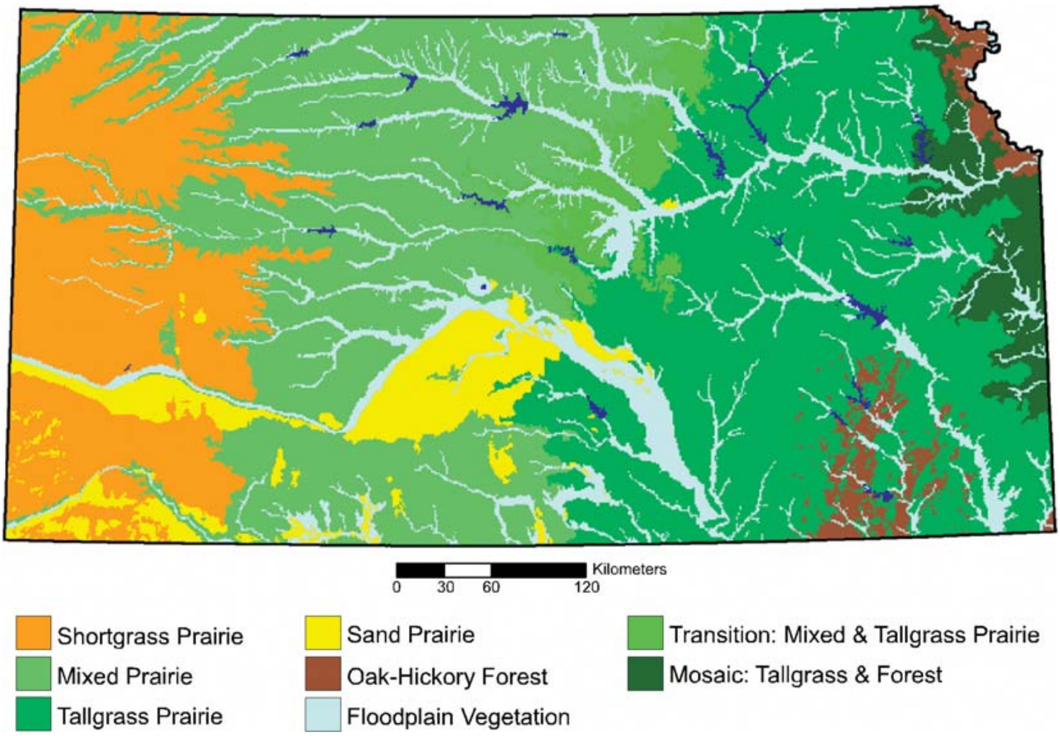

Figure 1. Küchler's (1974) Potential Natural Vegetation (KPNV) map of Kansas. Classes are coded to dominant prairie and forest types.

Reserve Program and native prairies including tallgrass, mixed, and shortgrass prairie that follow an east-west gradient similar to the KPNV and KLCP maps. Forest and woodland land-cover types are concentrated in eastern Kansas and along stream corridors in central and western Kansas.

Results and discussion

Historical land-cover change

According to the KPNV map, tallgrass prairie (including mosaic and transition zones) once covered up to 36% of the state (Table 1). The KV map shows that nearly half of the potential tallgrass prairie region has changed to either cropland, non-native grassland, or to land enrolled in the CRP (Fig. 4c; Table 2). Of the three major prairie types shown, tallgrass prairie has the highest percentage changing to non-native grasslands (~11%). Other dominant alliance level land-cover types within the tallgrass prairie region include oak-hickory forest (~2%) and ash-elm-hackberry floodplain forest (~2%). The KV database estimates that 2.8 million ha of tallgrass prairie remain and cover 13.1% of the state (Fig. 4c).

Table 1. Statewide areas and percentages obtained from the KPNV database.

Land-cover type	Hectares	% Area
Shortgrass prairie	3,549,048	16.7
Mixed prairie	5,976,878	28.1
Tallgrass prairie	6,328,069	29.7
Sand prairie	1,223,678	5.7
Forests	477,438	2.2
Floodplain vegetation	2,336,220	11.0
Transition of mixed & tallgrass	687,342	3.2
Mosaic of tallgrass & forest	728,295	3.4

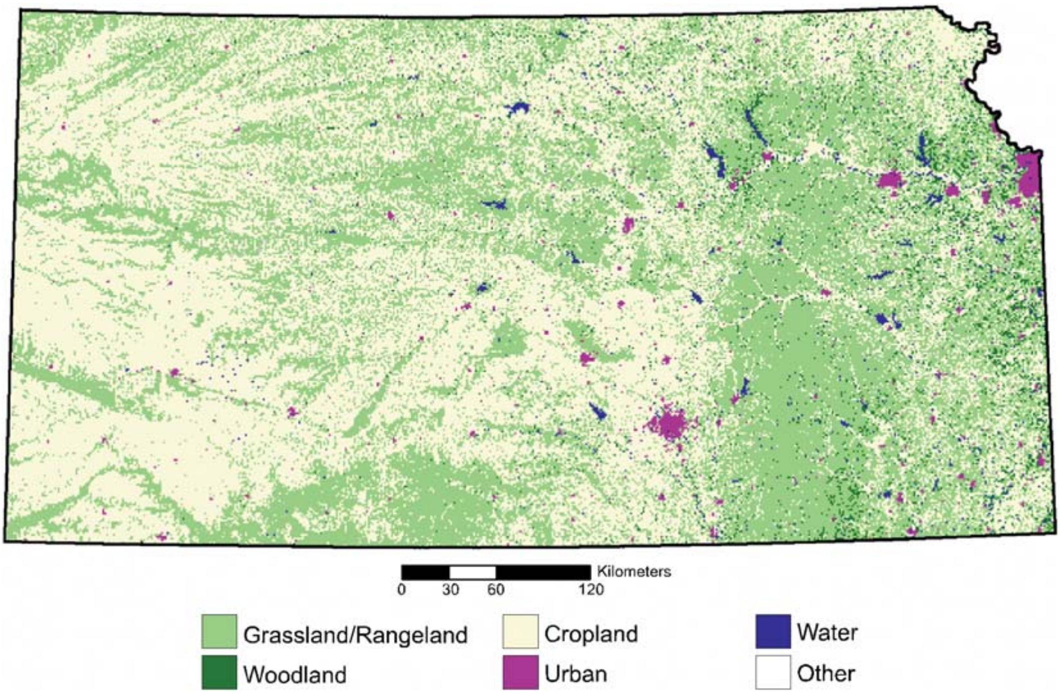

Figure 2. Kansas Land-Cover Patterns (KLCP) map produced using single date Landsat Thematic Mapper imagery. For the change detection analysis, the number of land-use/land-cover classes was recoded from ten to six.

The KPNV map indicates mixed and tallgrass prairie formerly covered similar percentages of the state (28.1% and 36%, respectively). The KV data show fewer hectares of mixed than tallgrass prairie remain in Kansas; 2.01 million ha of mixed prairie remain in Kansas, covering 9.8% of the state. According to the co-occurrence matrix, more mixed prairie has been converted to cropland than tallgrass prairie. This is because most of the remaining tallgrass prairie is located on rocky substrate (e.g. in the Flint Hills), making it less desirable for cultivation and more suitable for livestock grazing purposes. Other dominant alliance vegetation types currently found within the mixed prairie region include western wheatgrass prairie (~4%) and mixed prairie disturbed (~2%) (Fig. 4b).

Additionally, the KPNV map indicates shortgrass prairie once covered 16.7% of Kansas. Over 76% of this area is currently used as cropland and over 8% is enrolled in CRP; the highest percent of CRP occurring among the three dominant prairie regions (Table 2). The KV land-cover map shows that over 757,000 ha of shortgrass prairie remain, covering almost 9% of the state (Fig. 4a). Other native grassland and shrubland vegetation types also occur within this region including western wheatgrass prairie (~1% remains) and sandsage shrubland (~2% remains) (Fig. 4a).

Recent land-cover change

Both KLCP and KV show that cropland and grasslands dominate the Kansas landscape (Table 3). The KLCP database mapped 52.8% of Kansas as cropland and 42.6% as grasslands. The KV database mapped 48.4% as cropland and 41.7% as grasslands. The KLCP database mapped 2.7% of Kansas as forest/ woodland while the KV database mapped

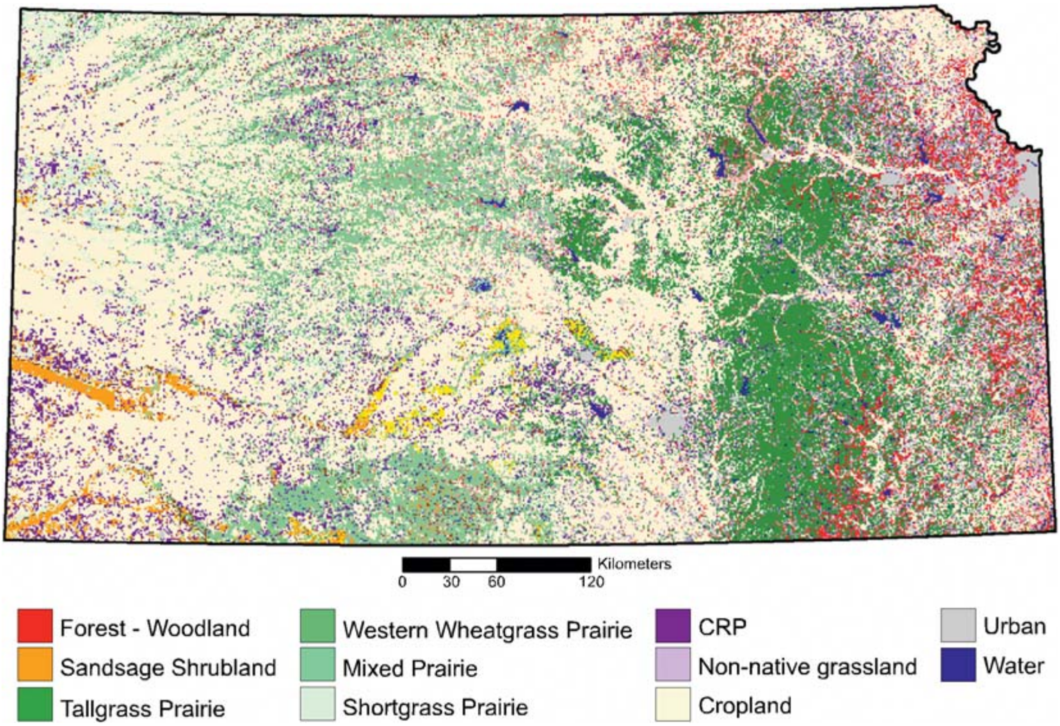

Figure 3. Alliance level Kansas Vegetation (KV) map. The map contains 41 land-use/land-cover classes and was derived using multitemporal Landsat Thematic Mapper satellite imagery. The legend shows dominant land-cover types.

Table 2. Co-occurrence matrix highlighting historical changes in land cover.

KPNV	KV				
	Cropland (%)	Non-native (%)	CRP (%)	Urban (%)	Unchanged (%)
Shortgrass prairie	75.6	0	8.6	0.3	8.8
Mixed prairie	43.4	1.7	5.0	0.2	27.1
Tallgrass prairie	36.7	10.5	2.7	1.2	34.4
Sand prairie	52.7	0.3	11.2	0.3	7.7
Oak-hickory forest	17.1	13.8	1.5	4.7	7.2
Floodplain vegetation	53.9	3.2	3.5	2.9	na
Transition of mixed & tallgrass	35.7	5.3	4.2	0.2	45.3
Mosaic of tallgrass & forest	26.0	22.8	2.5	5.6	na

8.0%; the largest difference in percentages mapped between the two databases. Urban and water land-cover types increased in the KV map slightly, suggesting that statewide urban expansion may be occurring at a relatively slow pace.

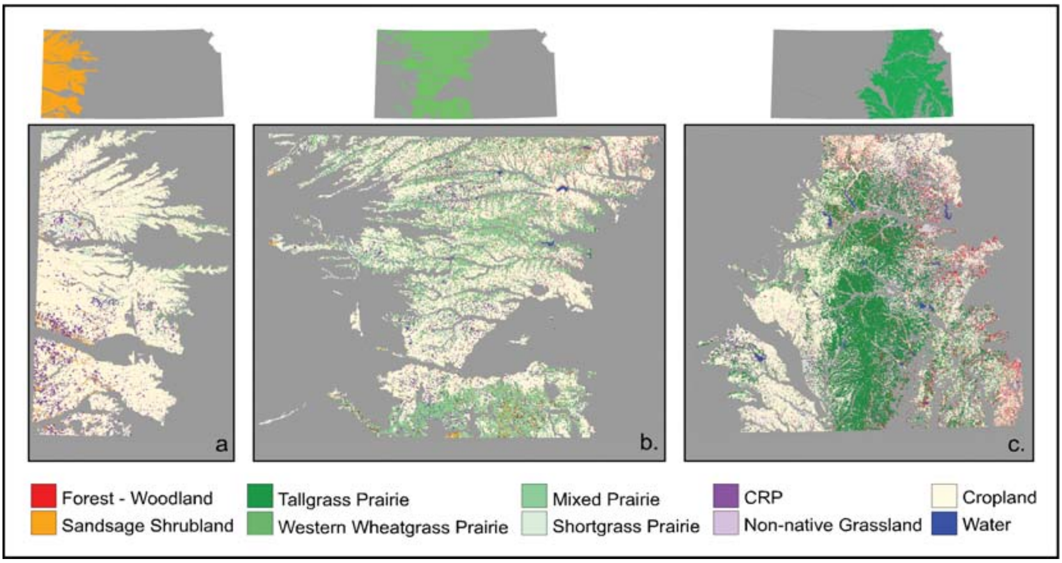

Figure 4. KV alliance level land-use/land-cover types mapped within Küchler's (a) shortgrass prairie, (b) mixed prairie, and (c) tallgrass prairie regions.

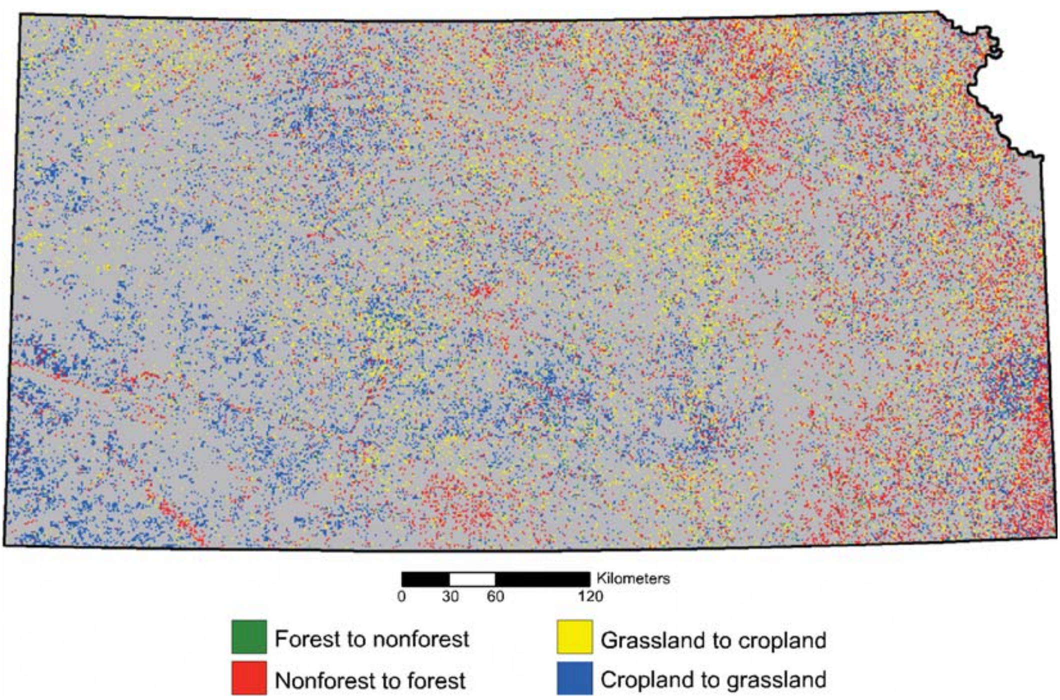

Figure 5. Post-classification change detection image showing disagreement between the KLCP and KV maps.

Table 3. Statewide land-cover estimates from the KLCP and KV databases.

Land-cover type	KLCP		KV	
	hectares	%	hectares	%
Grassland	9,089,113	42.6	8,886,156	41.7
Forest	577,032	2.7	1,713,719	8.0
Cropland	11,245,537	52.8	10,318,549	48.4
Urban	216,044	1.0	233,844	1.1
Water	142,741	0.7	159,892	0.8
Other	41,491	0.2	na	na

The co-occurrence matrix quantified that 80.3% of Kansas has remained unchanged and 19.7% has potentially changed (Table 4). The change detection image illustrates the spatial extent of the differences or changes in land-cover types presented in the co-occurrence matrix (Fig. 5). The image shows that differences or areas of disagreement between the KLCP and KV data occur throughout Kansas. The largest disagreement occurred between grassland and cropland vegetation classes.

In the change detection image most areas, especially in western Kansas, changing from cropland to grassland appear as relatively large contiguous blocks of land, an expected pattern if large tracts of cropland were reseeded to grassland (Fig. 6). A previous study by Egbert et al. (1998) showed that post-classification change detection accurately delineated CRP lands in Finney County, Kansas. For our study, areas changing from cropland to grassland or "predicted CRP" were calculated for fifteen selected counties across the state and compared to reported enrollments (USDA 2000) (Table 5). Several counties showed that "predicted CRP" closely matched reported CRP enrollments. For the most part, however, "predicted CRP" overestimated reported CRP enrollments (Table 5).

Just as the change detection image showed areas changing from cropland to grassland, there were also areas changing from grassland to cropland. It should be noted that CRP enrollments do not automatically constitute one-for-one replacements of cropland with grassland. Conservation programs such as CRP frequently suffer from "slippage," a condition describing the simultaneous conversion of grasslands and fallow fields to cropland by producers to offset the crop acreage lost to conservation programs (e.g. Erickson and Collins 1985; Riddell and Skold 1997). According to Leathers and Harrington (2000), slippage rates attributable primarily to CRP in 14 counties in southwestern Kansas averaged 53% annually from 1988 to 1994.

While it is probable that grasslands have been plowed and cultivated in the past 8-10 years, it

Table 4. Co-occurrence matrix comparing the KLCP and KV databases.

KV	KLCP											
	Grassland/shrubland		Forest/woodland		Cropland		Urban		Water		Other	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Grassland/ Shrubland	**7,130,012**	78.4	743,348	11.6	1,653,082	14.7	1,542	0.7	7,825	5.5	26,694	64.3
Forest/ Woodland	867,086	9.5	**458,212**	79.4	374,440	3.3	763	0.4	6,720	4.7	6,417	15.5
Cropland	1,063,751	11.7	42,911	7.4	**9,203,043**	81.8	1,153	0.5	2,019	1.4	5,611	13.5
Urban	8,537	0.1	1,493	0.3	7,906	0.1	**212,462**	98.3	1,649	1.2	1,787	4.3
Water	19,709	9.5	7,513	1.3	7,035	0.1	123	0.1	**124,488**	87.2	983	15.5

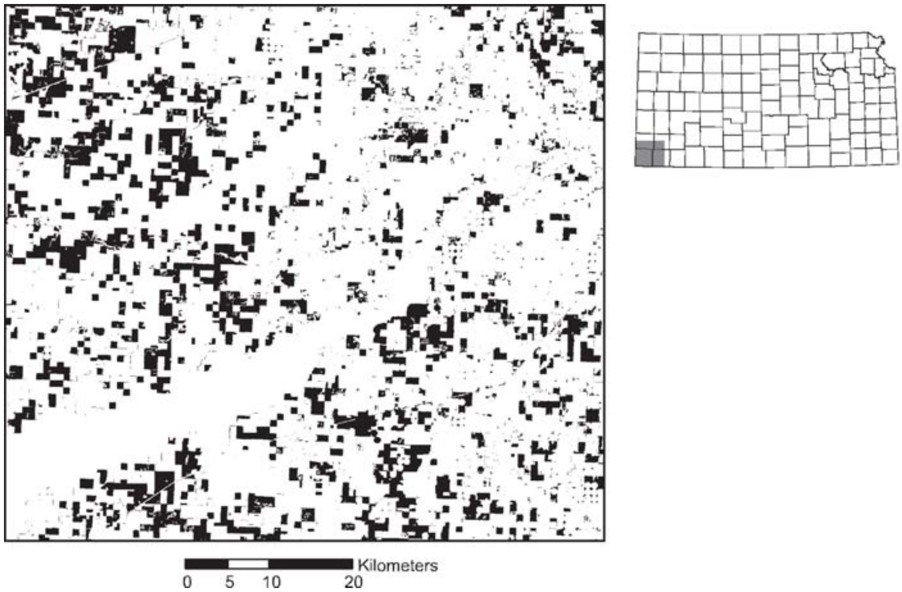

Figure 6. Potential CRP land (shown in black) in southwestern Kansas identified from the post-classification change detection image.

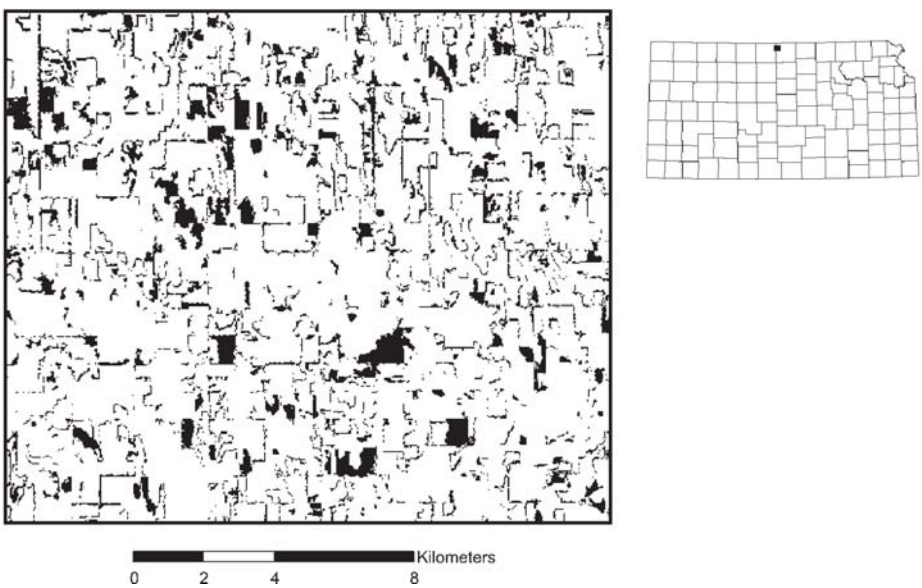

Figure 7. Small slivers of disagreement occurring along cropland or grassland field boundaries may not indicate areas of change, but are likely registration errors between the two maps.

is unlikely that slippage accounts for 1.06 million ha that have been converted as indicated in the change detection image. One should not assume all areas of disagreement between the two databases indicate true land-cover change. Registration errors, differences in map class definitions, and image classification errors may also be contributing factors. Registration errors (pixel misalignment) result from comparing two

Table 5. A comparison of "predicted CRP" and reported CRP values (in hectares) for 15 selected counties.

Region	County	Predicted CRP	Reported CRP*
Eastern Kansas	Brown	9,481	4,443
	Chase	3,191	635
	Coffey	10,205	4,839
	Geary	4,112	919
	Neosho	12,382	7,443
Central Kansas	Barton	15,427	11,544
	Lincoln	7,127	7,844
	Rice	8,790	7,041
	Russell	16,541	21,010
	Sumner	9,295	3,348
Western Kansas	Finney	31,715	23,430
	Gray	26,460	16,273
	Kearny	28,025	29,721
	Morton	34,208	35,922
	Sherman	21,754	16,860

* Reported ha from 1986-1993 (Source: Economic Resource Service, 2000).

spatial databases created at different times using different preprocessing techniques (Gordon 1980). In this study, registration errors may account for a large percentage of the area reported as changing from grassland to cropland. Using a generalization technique, we eliminated areas changing from grassland to cropland that were less than 2 ha. Most of these areas were small slivers occurring along field boundaries (Fig. 7). As a result, areas shown as changing from grassland to cropland decreased by 19%. However, a large number of registration artifacts still remained after the generalization process indicating the misalignment of pixels likely account for more than the 19% of areas changing from grassland to cropland. While a larger threshold would eliminate more "false" change, identifying the appropriate threshold is somewhat subjective and could also eliminate areas of true change.

To determine whether classification errors contributed to the large extents reported as changing from grassland to cropland, 170 areas shown as changing from grassland to cropland were randomly selected throughout the state and compared on-screen with the satellite imagery used to generate the KV map. Of the 170 selected sites, 95% were visually interpreted on the satellite imagery as being accurately mapped as cropland in the KV map. While overall accuracy levels were relatively high for both land-cover maps (91% and 88% for the KLCP and KV land-cover maps, respectively), the results suggest that the KLCP map may have misclassified some extents of cropland as grassland. The KLCP map used a single-date classification approach while the KV map used a multitemporal classification approach. Previous research at the KARS Program has shown that a multitemporal approach increases the spectral separability of vegetation types based on differences in vegetation phenology throughout the growing season (Egbert et al. 1995). The single-date classification approach may have limited the spectral separability of grassland and cropland resulting in classification errors. Furthermore, a study by Wardlow and Egbert (2001) showed that the KV database closely matched the amount of cropland in Kansas reported by the USDA. The USDA reported 10,090,775 ha of cropland in Kansas and the KV database mapped 10,293,104 ha during the same time period.

Another major difference detected between the two land-cover maps was the area classified as forest/woodland land-cover types. The KLCP database mapped 2.7% of the state as woodland and forest while the KV database mapped 8.0%. A study by the USDA (Leatherberry et al. 1999) reported that from 1981 to 1994, forested land in Kansas increased by 13%. Furthermore, the study estimated that there were 1.37 million ha of forest and land containing at least one tree per acre in Kansas in 1994. The 1.71 million ha of woodland and forest mapped in the KV database more closely matches the USDA's estimate of forest and woodland in Kansas than the 0.58 million ha mapped by the KLCP database.

While an increase for forest and woodland land-cover types due to natural vegetation growth (e.g. old field succession, juniper invasion, and fire suppression) may be expected, it is questionable that natural vegetation growth is the single contributing factor to the differences observed. Additionally, the KLCP database mapped areas as forest/woodland land-cover types that the KV database mapped as other land-cover types. Several factors contributed to the observed differences in mapped forest/ woodland land-cover types.

Differences in the methodologies used to generate the land-cover maps may be one contributing factor. As previously mentioned, the KLCP land-cover map used an unsupervised classification approach. Following the unsupervised classification, remote sensing analysts overlaid each spectral class on satellite imagery and used aerial photos to assign a land-cover type to each spectral class. When determining whether a spectral class should be assigned as woodland, density of the stand was one of the guidelines used. The density of the stand had to be greater than 80% cover to be labeled as woodland. Therefore, estimates of woodland from the KLCP map appear conservative. While woodland and forests were mapped in the KLCP database using stand density and visual interpretation, woodland and forests in the KV database were mapped using supervised classification. While post-hoc techniques were used to refine the classification of floodplain forest and woodland types in the land-cover map, the classification was ultimately based on training sites collected in the field and the maximum likelihood classifier. However, in an effort to use recent cloud-free data, several TM scenes used in the generation of the KV map were from the flood year of 1993. As a result, there were multiple areas mapped as forest or woodland that appear to be inundated cropland and grassland on the satellite imagery. For example, areas surrounding Tuttle Creek near Manhattan, Kansas were classified as forest and woodland, but upon visual interpretation of non-flood year satellite imagery, most of these areas were actually cropland and grassland-cover types. Other areas that were erroneously classified as forest/woodland-cover types include contiguous areas in the Flint Hills that appear to be grassland cover types. It seems that such areas were spectrally confused with forest and/or woodland cover types due to land management practices, namely spring burning. These results indicate that the KV map likely overestimated forest and woodland cover types in several areas of Kansas.

Conclusions

The use of co-occurrence matrices and post-classification change detection analysis successfully identified historical and recent land-cover change in Kansas. Conversion of grassland to cropland was the most prominent historical land-cover change and some prairie types have been reduced in area more dramatically than others. While there have been dramatic land-cover changes in Kansas since European settlement, the data show that large tracts of natural vegetation still remain.

The most important recent land-cover change has been the conversion of cropland to grassland. Most of these areas were identified as land taken out of cultivation and enrolled in CRP. Meanwhile, changes in forest and woodland cover types were attributable to natural vegetation growth and differences in mapping techniques that resulted in conservative and liberal estimates of forest and woodland extents in the KLCP and KV maps, respectively.

Registration errors, classification methodologies (i.e. unsupervised vs. supervised), dates of satellite imagery, and class definitions used to generate the initial land-cover maps were additional factors examined in this paper. These factors contributed to reported areas of change in Kansas. Results from this study illustrate the importance of understanding how land-cover databases are generated in order to accurately interpret results from post-classification change detection analysis.

Acknowledgements

We thank the National Aeronautics and Space Administration (NASA) for financial support provided through the Great Plains Regional Earth Science Applications Center (GP-RESAC) at the Kansas Applied Remote Sensing Program of the University of Kansas and through NASA's Earth Science Enterprise program (grants NAGW 3810 and NAG 5-4990). We further acknowledge financial and other assistance from numerous state and federal partners who made the Kansas Vegetation Map possible: Kansas State University; the Kansas GIS Policy Board; the Kansas Department of Wildlife and Parks; the Kansas Biological Survey; the National Aeronautics and Space Administration; the Biological Resources Division of the U.S. Geological Survey; the U.S. Environmental Protection Agency, Region 7; and the National Park Service.

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