IDENTIFYING AND UNDERSTANDING LAND USE/LAND COVER CHANGE IN KANSAS

Dana Peterson[1], Research Assistant, dpete@ukans.edu
Egbert, Stephen[1,2], Assistant Research Scientist, Assistant Professor, s-egbert@ukans.edu
Lauver, Chris[3], Associate Scientist, c-lauver@ukans.edu
Stewart, Aimee[1], Research Assistant, amstewart@ukans.edu
Martinko,Ed[1,2,3,4], Director, Director, Associate Professor, e-martinko@ukans.edu
Price, Kevin[1,2], Associate Director, Associate Professor, k-price@ukans.edu
Park, Sunyurp[1,2], Graduate Research Assistant, sunyurp@ukans.edu

[1] Kansas Applied Remote Sensing Program, University of Kansas
[2] Department of Geography, University of Kansas
[3] Kansas Biological Survey, University of Kansas, 2041 Constant Ave., Lawrence, KS 66047
[4] Department of Ecology and Evolutionary Biology, University of Kansas

ABSTRACT

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, using historical and recent land cover data offers two perspectives on landscape dynamics. To this end, the first alliance level land cover map of Kansas recently completed by the KARS Program was compared to Kuchler'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 drastically changed since European settlement. Over 48% of the land is now cultivated and native vegetation types such as tallgrass and shortgrass prairie have been dramatically reduced in area. There are, however, millions of ha of these vegetation types remaining in Kansas. Comparisons between the more recent land cover maps reveal that over 80% of the land in Kansas has remained unchanged in the past 8-10 years. Recent land cover changes include grassland to cropland, cropland to grassland, and grassland to woodland. 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 last 8-10 years and over 1 million ha of grassland have been converted to cropland. The extents of these increases are questionable, however, due to misregistration errors and classification methodologies used to generate the land cover maps.

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 monitor and understand changing patterns in the landscape. Traditional methods for monitoring land cover change have relied on field data and aerial photography. 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.

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 classified maps created from remotely sensed data collected at different times. This change detection technique not only identifies areas of change, but also provides information about the direction of the observed change (Jensen, 1996).

The Kansas Applied Remote Sensing (KARS) program has recently completed the Kansas GAP land cover (KSGAP) map, an alliance level land cover map as part of the Kansas Gap Analysis Project (GAP). In 1993, the KARS program completed the Kansas Land Cover Patterns (KLCP) map, an Anderson Level I classification derived from Landsat Thematic Mapper imagery. These two land cover maps provide an opportunity to monitor recent land cover changes in Kansas. Post-classification change detection was performed using the two georegistered land cover maps of Kansas. To provide a historical perspective of land cover change, Kuchler's Potential Natural Vegetation (KPNV) map was compared with the Kansas GAP map. Kuchler's Potential Natural Vegetation map provides estimated land cover information prior to European settlement. A comparison of these two maps provides insight to anthropogenic and naturally driven land cover changes in Kansas.

BACKGROUND

KPNV

Kuchler's potential vegetation classification system divides Kansas' vegetation into four major classes: prairies; forests; mosaics, transitions, and boundaries; and lakes and reservoirs. Within each vegetation class, Kuchler breaks down the vegetation into subclasses (Figure 1). 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. Kuchler mapped the potential vegetation of Kansas using library sources and laboratory and field work (Kuchler, 1974). Geology, soils, topography, and climate data combined with field observation were key to the development of this potential vegetation map.

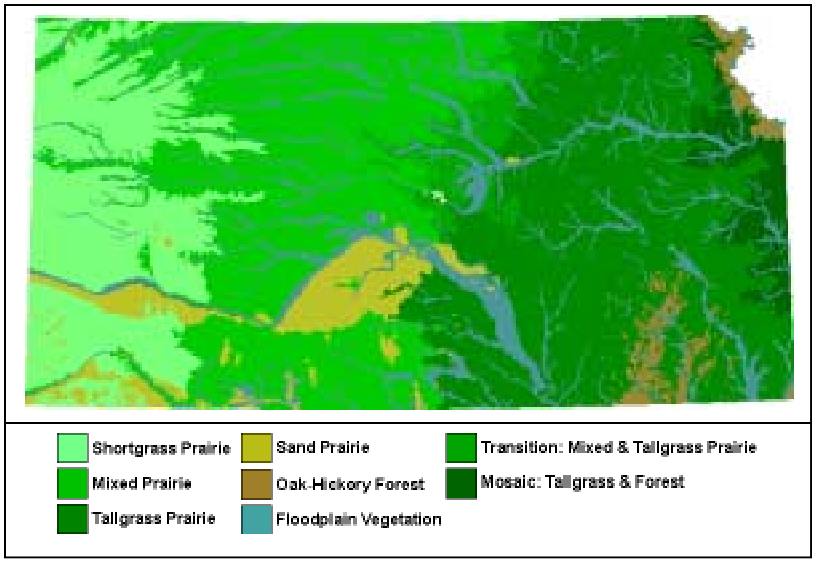

Figure 1. Kuchler's (1974) Potential Natural Vegetation of Kansas.

KLCP

The Kansas Land Cover Patterns map was created using an unsupervised classification approach on single date Landsat Thematic Mapper (TM) imagery (Whistler et al. 1995). A total of 10 classes were mapped: five urban classes (residential, commercial/industrial, open

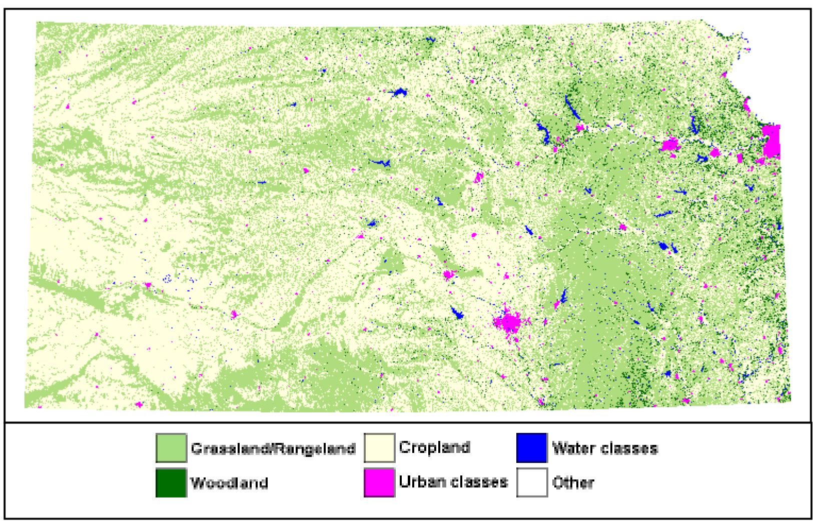

Figure 2. Kansas Land Cover Patterns map produced using single date Landsat TM data (Whistler et al., 1995).

land, woodland, and water) and five rural classes (cropland, rangeland, woodland, water, and other) (Figure 2).

Preprocessing. A total of 16 Landsat TM scenes were obtained to cover the entire state of Kansas. To maximize spectral distinction between land use and land cover classes, images captured during the growing season (between June 1 and September 30) were selected. The images selected dated from 1988 to 1991. The TM data were subset to the county level creating 105 subsets.

Classification. An unsupervised classification approach was used to map 10 land use/land cover classes. The unsupervised classification was performed using the county subsets of the satellite imagery. For each county subset ISODATA clustering and minimum-distance-to-means classification were used to create 100 spectral classes for rural classes. For the urban classes, remote sensing analysts used a subset of the image, primarily containing urban land cover types, to cluster and classify 50 spectral classes. Each of the spectral classes were displayed onscreen and then assigned to one of the land use/land cover classes. Features such as highways, sandbars, and major dams that were visually apparent on the imagery, but were classified incorrectly, were manually digitized and recoded to the appropriate class. The classified image for each county was then generalized to a 2 hectare (ha) minimum mapping unit (MMU). After the generalization process, the county maps were geometrically rectified to geographic coordinates. The geometric transformation model estimated the pixel locations within each county to within 0.33 pixels of the ground control points (GCPs). After rectifying all land cover maps for each county, the counties were edge matched to create a land cover mosaic of the state.

Accuracy Assessment. Accuracy assessments were conducted for each county and were based on comparing of the classified data with aerial photography. Sample sites were systematically selected with a minimum of 5% of the total county area sampled. Sample sites were manually digitized and interpreted from the aerial photography by remote sensing scientists. A raster file was then created from the polygon file and a co-occurrence matrix was generated that compared the sample sites to the classified data. Error matrices were generated for each county. The classified map for the state had an overall accuracy of 91% (Whistler et al., 1995).

KSGAP

The Kansas GAP Land cover map was created using a hybrid two-stage classification approach. A total of 41 land cover classes were mapped including 38 natural vegetation classes, cultivated land, urban and water (Stewart et al., 2000) (Figure 3). The classification system used in the Kansas GAP Project is a conversion of the 1989 system into the National Vegetation Classification System developed by The Nature Conservancy in cooperation with state, federal, and academic partners (Anderson et al., 1998; Grossman et al., 1998). The new classification of the natural vegetation of Kansas (Lauver et al., 1999) contains 38 vegetation alliances in classes of forest, woodland, shrubland, and herbaceous vegetation.

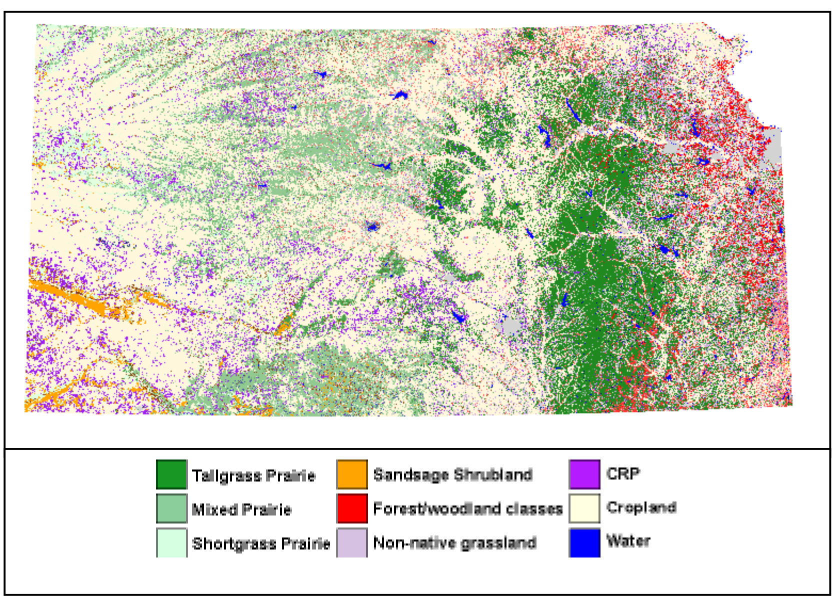

Figure 3. The alliance level land cover map of Kansas. This database mapped 41 land cover classes and was produced using multitemporal Landsat TM data. The legend shows dominant land cover types.

Preprocessing. Forty-eight Landsat Thematic Mapper scenes from 1991 to 1996 were obtained to provide multitemporal (spring, summer, and fall) coverage of the state. Previous research 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). To reduce the volume of data, only bands 3, 4, 5 and 7 were used in the hybrid classification.

One scene for each path/row was then geometrically rectified to a Universal Transverse Mercator (UTM) projection using a minimum of 50 ground control points (GCPs) and the cubic convolution interpolation technique. 1:100k public land survey system (PLSS) digital line graphs (DLGs) were used as the reference data for georectification. After one scene for each path/row was rectified, it was used as the base image to georegister the other two scenes. The cubic convolution transformation model estimated the pixel locations within each scene to within 0.5 pixels of the GCPs. After rectifying all forty-eight scenes, the three dates of imagery for each path/row were combined to create one 12-band multitemporal image file.

Next, to eliminate non-vegetated areas, an urban and water mask was created. A classified data file generated at the KARS program from the Kansas Land Cover Mapping project (Whistler et al., 1995) was used as a preliminary mask. The mask was then updated to include expanded urban areas and additional water bodies. Urban areas and water bodies were then masked from the 12-band images to eliminate non-vegetated features. The vegetation in each path/row was classified using a two-stage hybrid classification approach. The first stage classified the data into two classes, cropland and natural vegetation. The second stage classified the natural vegetation into the 38 alliance-level vegetation classes.

Unsupervised Classification. The first stage classified the 12-band images using an unsupervised classification approach. The ISODATA clustering algorithm and maximum likelihood classifier were used to generate 100 spectral classes per scene. Next, with the three dates of imagery displayed in separate windows on-screen, each class was highlighted and assigned as cultivated land, natural vegetation, or confused. For confused classes, a "cluster-busting" technique was used where unsupervised classification was used to break out the confused classes into 15 additional classes (Jensen et al., 1987). This process was repeated until no confused classes remained. The unsupervised classification resulted in a cultivated/natural vegetation map of Kansas. Cultivated areas were then masked out, leaving only the naturally vegetated areas for further classification.

Supervised Classification. Once the first stage of the classification was completed for each path/row, the second stage of the classification was performed using a supervised approach. A total of 3572 field sites collected during the summers of 1996 to 1998 were used to train the maximum likelihood classifier.

Each field site was screen digitized using the multitemporal imagery as a backdrop. The field sites were then used to train the maximum likelihood classifier for naturally vegetated areas in each path/row. Following the supervised classification, each classified image for each path/row was generalized to a minimum mapping unit of 2 ha. A mosaic of the vegetation of the state was created using the mosaic tool in ERDAS Imagine.

Post-hoc Classification. After the mosaic was created, the statewide map was inspected by ecologists/biologists from the Kansas Biological Survey and by remote sensing scientists. A number of post-hoc techniques were used to refine the statewide map. While some refinements were conducted on a statewide basis and on a county level basis, the majority of refinements were performed on a scene by scene basis. The post-hoc analysis used ancillary data such as geology, soils, and hydrography to refine the classification. For example, in two path/rows there was an overestimation of floodplain forest types in areas outside of floodplains. To refine the map, areas classified as floodplain forest types outside of the floodplains were reclassified to upland forest types. A 250 meter buffer on the Surface Waters Information Management System (SWIMS) hydrologic data set was used to identify floodplain forest pixels that were classified outside of the floodplains. These areas were then masked out of raw data. Only the upland forest field sites were used to train the classifier in the supervised classification of the masked data set. Following the supervised classification, the reclassifed area was generalized and added back to the initial classified image. In another example there was an overestimation of playa lakes throughout path/row 29/34. The Soil Survey Geographic (SSURGO) database was used to identify Randall Clay, Ness Silty Clay, and Pleasant soils where playa lakes are likely to occur. Pixels classified as playa lakes outside of these soil types were recoded to mixed prairie.

Accuracy Assessment. Accuracy by land cover class, overall accuracy, and the Kappa statistic were provided for the state. Accuracy was calculated by comparing the classified data with 828 field sites that were collected throughout the state in 2000. Error matrices were generated at the alliance level and at an Anderson Level I classification. The overall accuracy for the state at the alliance level and Anderson Level I was 64.5% and 88.0%, respectively. Alliance level classes were often confused with similar classes. For example, tallgrass prairie was confused with non-native grasslands and oak-hickory forest was confused with ash-elm-hackberry floodplain forests. The increased accuracy obtained by aggregating the alliance level classes reveals the difficulty in mapping alliance level vegetation in Kansas.

Land Cover Patterns

KPNV. The three oak-hickory forest types are concentrated in the eastern third of the state (Figure 1). Meanwhile, floodplain land cover types are concentrated in floodplain areas along waterways throughout the state. The prairies are divided into east-west zones. Shortgrass prairie dominates the western third of Kansas while mixed prairie dominates central Kansas. Mixed prairie intermixes with shortgrass prairie in the west and tallgrass prairie in the east. Tallgrass prairie is concentrated in the eastern third of the state. Lastly, sand prairies occur in the south central and southwestern regions of Kansas. This prairie type occurs on sandy soils and often intermixes with the other prairie types in the area. Of the four prairie types, sand prairie covers the smallest area in Kansas.

KLCP. The KCLP map shows that cultivated land and grasslands are the two dominant land cover types in Kansas (Figure 2). Woodland covers a relatively small area within Kansas and it is generally concentrated in the eastern half of the state.

KSGAP. The Kansas GAP land cover map is the first alliance level land cover map of Kansas. The map shows that a mix of cultivated land and herbaceous land cover types dominates the current vegetation in Kansas (Figure 3). Of the herbaceous land cover types remaining in Kansas, there is a mixture of non-native grasslands, former cropland enrolled in the Conservation Reserve Program and native herbaceous vegetation types including tallgrass prairie, mixed prairie, and shortgrass prairie. Forest and woodland land cover types are concentrated in the eastern part of the state.

METHODOLOGY

Change Detection/Map Comparisons

Historical Land Cover Change. A comparison of the KPNV map to the KSGAP map provides a general understanding of historical land cover changes in Kansas. A hard copy of the 1:800,000 KPNV map was manually digitized, resulting in a digital polygon file. The polygon file was then converted to a raster file using ESRI Arc/Info software. The raster file was then imported into ERDAS Imagine for change detection analysis.

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, mosiac of tallgrass prairie and forest, lakes and reservoirs). Next, the KSGAP map was recoded to best match corresponding KPNV classes. The summary function in ERDAS Imagine was used to generate a co-occurrence matrix. The co-occurrence matrix shows how land cover has changed within each KPNV vegetation class.

Recent Land Cover Change. Comparing the KPNV data with the KSGAP data illustrates how the Kansas landscape has changed since European settlement, but does not identify more recent changes in the landscape. Therefore, the KLCP land cover map was compared with the KSGAP land cover map to detect more recent trends in land cover change. Since the KLCP land cover classes were more general than the KSGAP map, the KSGAP land cover types were recoded to correspond to the KLCP land cover classes. This resulted in five land cover classes for the KSGAP data (grassland/shrubland, woodland/forest, cultivated land, urban, and water) and six for the KLCP data (grassland/shrubland, woodland/forest, cultivated land, urban, water, and other).

A co-occurrence matrix was generated to show the agreement between the two land cover maps as well as the disagreement. Disagreements between the two land cover maps may indicate recent changes in land cover. To get a spatial understanding of recent land cover changes, the change detection matrix function in ERDAS Imagine was used. This function generates an output image with each pixel coded to reflect each type of directional change. For example, pixels that were classified as grasslands in the KLCP land cover map and cultivated land in the KSGAP land cover map were coded as 2 while pixels that were classified as cultivated land in both land cover maps were coded as 7. Each combination of change or no change was coded to a unique value.

RESULTS & DISCUSSION

Historical Land Cover Change

KPNV vs. KSGAP. Table 1 summarizes the potential vegetation for Kansas. According to the KPNV database, tallgrass, mixed, and shortgrass prairie contributed the largest percent of land area in Kansas. Table 2 highlights historical land cover change for the KPNV vegetation classes.

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

	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

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

	KSGAP			
KPNV	Cultivated (% area)	Non-Native (% area)	CRP (% area)	Urban (% area)
Shortgrass Prairie	75.6	0	8.6	0.3
Mixed Prairie	43.4	1.7	5	0.2
Tallgrass Prairie	36.7	10.5	2.7	1.2
Sand Prairie	52.7	0.28	11.2	0.3
Oak- Hickory Forest	17.1	13.8	1.5	4.7
Floodplain Vegetation	53.9	3.2	3.5	2.9
Transition of Mixed & Tallgrass	35.7	5.3	4.2	0.2
Mosaic of Tallgrass & Forest	26.0	22.8	2.5	5.6

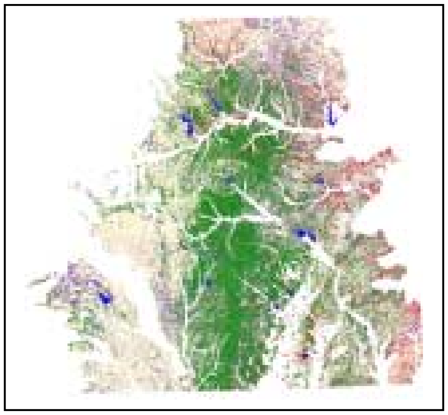

Figure 4. Current alliance level land cover within Kuchler's tallgrass prairie region.

The KPNV data shows that tallgrass prairie once covered up to 36% of the state. The KSGAP database shows that almost half of the potential tallgrass prairie region has changed to cropland, non-native grassland, or has been taken out of cultivation and enrolled in the Conservation Reserve Program (CRP) (Table 2). Of the three major prairie types shown, tallgrass prairie has the highest percentage changing to non-native grasslands (10.5%). Other dominant vegetation alliance types within the tallgrass prairie region include oak-hickory forest (2.3%) and ash-elm-hackberry floodplain forest (2.1%). The KSGAP database estimates that 2.8 million ha of tallgrass prairie remains and covers 13.1% of the state (Figure 4).

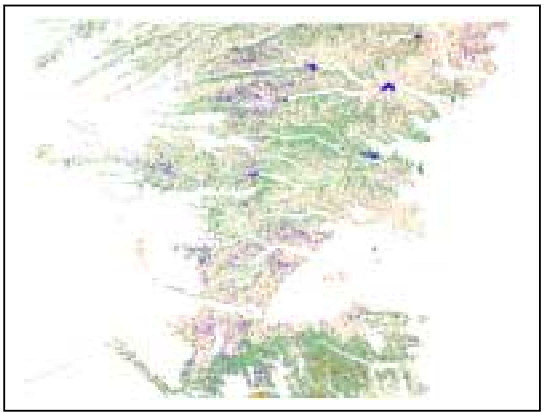

Figure 5. Current alliance level land cover within Kucher's mixed prairie region.

According to the KPNV data, mixed and tallgrass prairie formerly covered similar percentages of the state, however, the KSGAP data suggests that there are now fewer hectares of mixed prairie remaining in Kansas. The KSGAP database shows that 2.01 million ha of mixed prairie remain in Kansas covering 9.8% of the state. The co-occurrence matrix shows that 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 (3.8%) and mixed prairie disturbed (1.6%) (Figure 5).

Figure 6. The current alliance level land cover within Kucher's shortgrass prairie region.

Additionally, the KPNV data shows that shortgrass prairie covered 16.7% of Kansas. Over 75% of this area is currently used as cropland and over 8% is enrolled in CRP; the highest percent occurring within any one potential natural vegetation region (Table 2). The KSGAP land cover map shows that over 757, 000 ha of shortgrass prairie remain and cover almost 9% of the state (Figure). Other native grassland and shrubland alliance vegeation types also occur within this region including, western wheatgrass prairie (1.3% remains) and tamarisk shrubland (< 1% remains) (Figure 6).

Recent Land Cover Change

KLCP vs. KSGAP. Both databases show that cultivated land and grasslands are the two dominant land cover types in Kansas (Table 3). The KLCP database showed that 52.8% of Kansas was cultivated land and 42.6% was grasslands. The KSGAP database shows that 48.4% is cultivated land and 41.7% is grasslands. The largest difference in percent area covered by a land cover type between the two databases is for the forest/woodland land cover type. The KLCP database had 2.7% in forest/woodland while the KSGAP database has 8.0%. Urban and water land cover types have increased in the KSGAP map slightly suggesting that statewide urban expansion may be occurring at a relatively slow pace.

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

Land Cover Type	KLCP		KSGAP	
	Hectares	% Area	Hectares	% Area
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

Comparison of the KLCP and KSGAP databases reveals that there were no recent changes in land cover for 80.3% of the total state area. With the remaining 19.7%, the co-occurrence matrix reveals that the two data sets largely disagree when comparing grasslands, cultivated, and woodland/forest land cover types (Table 4). While 78.4% of the grassland cover types agree between the two data sets, there is some disagreement between the two land cover maps. Of the total area classified as grasslands in the KLCP database, KSGAP has 867,086 ha classified as forests and woodland and over 1 million ha classified as cultivated land. Additionally, the KSGAP database has over 1.6 million ha of cultivated land classified as grasslands in the KLCP database and 374,440 ha of forested land cover types classified as cultivated land. The differences observed between the two maps may indicate recent land cover changes or may be a result of differences in class definitions or errors in image classification which are discussed further, below.

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

KSGAP	KLCP											
	Grassland/ Shrubland		Forest/ Woodland		Cultivated		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
Cultivated	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

The image generated from the post-change detection function illustrates the spatial extent of the differences or changes in land cover types that were presented in the co-occurrence matrix (Figure 7). The image shows that the differences between the KLCP data and the KSGAP data span across the state. One of the primary differences was the amount of cultivated land in the KLCP database that changed to grassland cover types in the KSGAP database.

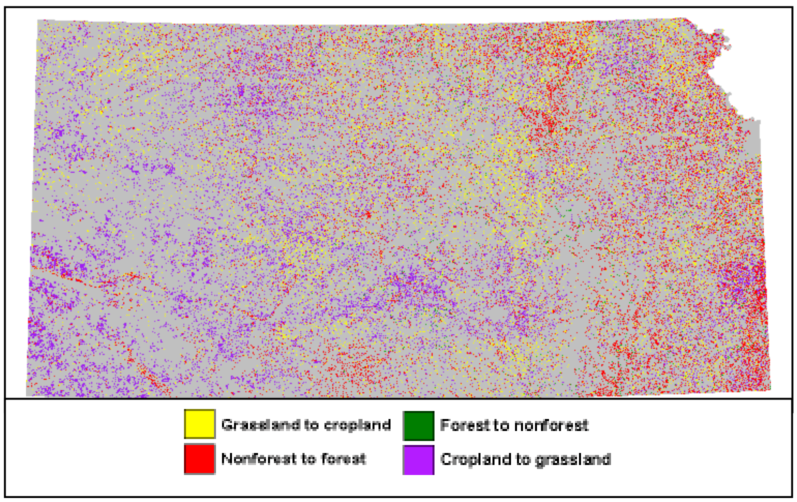

Figure 7. Post-classification change detection image showing land cover differences between the KLCP and KSGAP databases.

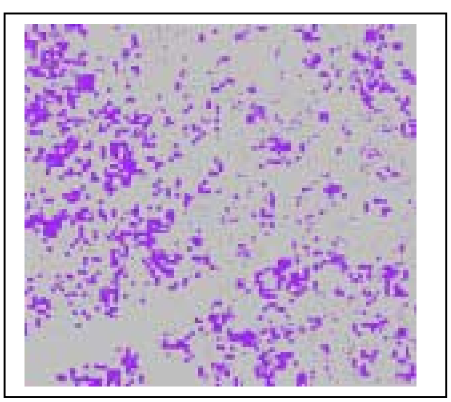

Figure 8. Potential CRP land in southwest Kansas identified from the post-classification change detection image.

In 1986, the USDA initiated the Conservation Reserve Program. This conservation program encouraged farmers to take land on highly erodible soils out of cultivation and convert it to grassland by reseeding. The KLCP database developed in 1993 used late 1980's satellite imagery to map land cover types. Since the CRP program was initiated in 1986, the satellite imagery for the KLCP database was earlier than many CRP enrollments. The satellite imagery used for the development of the KSGAP database, on the other hand, was later than most initial CRP enrollments. Therefore, the change in cultivated land to grasslands reflect enrollments in CRP. Most of the areas, especially in western Kansas, changing from cropland to grassland appear on the change detection image as relatively large contiguous blocks of land (Figure 8).

A previous study by Egbert et al. (1998) showed that post-classification change detection accurately delineated CRP lands in Finney County, Kansas. For this study, the area changing from cultivated land to grassland or "predicted CRP" was calculated for a selected group of counties across the state and compared to reported enrollments by the USDA (2000) (Table 5). It appears that "predicted CRP" was relatively close to the reported areas of land enrolled in CRP. For each county selected, the "predicted CRP" area was slightly higher than the reported area.

Table 5. A comparison of "predicted CRP" and reported CRP values for 15 select counties.

Region	County	Predicted CRP (ha)	Reported CRP (ha)
Eastern Kansas	Brown	9,481	7,193
	Chase	3,191	2,591
	Coffey	10,205	8,090
	Geary	4,112	3,245
	Neosho	12,382	9,861
Central Kansas	Barton	15,427	13,130
	Lincoln	7,127	5,224
	Rice	8,790	6,421
	Russell	16,541	13,710
	Sedgwick	29,434	27,021
Western Kansas	Finney	31,715	28,127
	Gray	26,460	23,216
	Kearny	28,025	26,197
	Morton	34,208	33,715
	Sherman	21,754	19,710

Just as there were changes from cultivated land to grassland, there were also changes from grassland to cultivated land. While it is probable that grasslands have been plowed and cultivated in the past 8-10 years, it is unlikely that this accounts for the 1.6 million ha shown to have changed in the change detection image. Some of the differences are again due to misregistration errors between the two land cover maps where small slivers are showing up as a change.

Overall accuracy levels were fairly high for both land cover maps (91% and 88% for the KLCP and KSGAP land cover maps, respectively) and furthermore, a study by Wardlow and Egbert (2001) showed that the KSGAP database was very close in the estimation of cropland in Kansas. The USDA reported 24,933,963 acres of cropland and KSGAP estimated 25,433,911 acres during the same time period. More analysis is needed to fully understand the cause(s) of this change.

Another major difference 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 KSGAP database mapped 8.0%. A study by the USDA (Leatherberry et al., 1999) reports that from 1981 to 1994, forest 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. While it may be expected for forest and woodland land cover types to increase due to natural vegetation growth (e.g. old field succession, juniper invasion, and fire suppression), it is questionable that this was the single contributing factor to the differences observed. The KSGAP land cover map clearly has more area classified as forest/woodland land cover types, but the KLCP database also has areas mapped as forest/woodland land cover types that were not mapped on the KSGAP database. Several factors may be contributing to these differences in forest/woodland land cover types.

In addition, differences in the methodologies used to generate the land cover maps may also contribute to the differences observed in areas classified as forest/woodland land cover types. As previously mentioned, the KLCP land cover map was generated using an unsupervised classification. Following the unsupervised classification, remote sensing scientists displayed each class over the satellite imagery and used aerial photos to determine what land cover type to assign each class. When determining whether a spectral class should be assigned to the woodland land cover type, density of the stand was one of the guidelines used. The stand had to be fairly dense (>80 % cover) to be labeled as woodland. Therefore, the land cover estimates of woodland from the KLCP map may be somewhat conservative.

On the other hand, the KSGAP land cover mapping project used a hybrid classification approach and may have overestimated some forest and woodland land cover types. While woodland and forests were classified in the KLCP database using density and the interpretation of a remote sensing analyst, woodland and forests were classified in the KSGAP database 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.

Several TM scenes used in the classification were from the flood year of 1993. There were areas classified as forest or woodland that appear to be inundated on the satellite imagery (Figure 9). For example, areas surrounding Tuttle Creek near Manhattan, Kansas were classified as forest and woodland, but when looking at the satellite imagery, it appears that some of these areas are cultivated land and grassland cover types. In an effort to use recent cloud-free data, it was necessary to use eight images from 1993 in the land cover classification. Furthermore, there were contiguous areas in the Flint Hills that were classified as forest or woodland land cover types that appear to be grassland cover types. These areas appear to have been burned in the spring and may have been confused with forest and/or woodland cover types during the classification process.

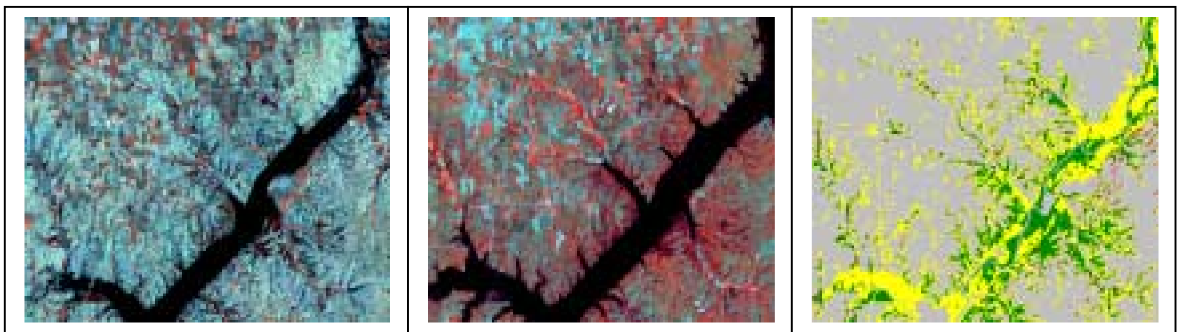

Figure 9. 1993 spring and summer false color composites of Landsat TM imagery (bands 4, 5, & 7) and change detection image highlighting changes in forest cover. Areas upstream of Tuttle Creek near Manhattan, Kansas were inundated during the 1993 flood and were incorrectly classified as woodland and forest land cover types.

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. While there have been dramatic land cover changes in Kansas since European settlement, the data indicated that large tracts of natural vegetation still remain.

More recent land cover change included cropland changing to grassland. These areas were identified as land enrolled in CRP. Furthermore, changes in forest and woodland cover types were identified as a combination of natural vegetation growth and incorrectly classified data. There were land cover changes that were more difficult to explain namely, areas of grassland changing to cropland. Further study is needed to assess this particular land cover change.

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REFERENCES

Anderson, M., P. Bourgeron, M. T. Bryer, R. Crawford, L. Engelking, D. Faber-Langendoen, M. Gallyoun, K. Goodin, D. H. Grossman, S. Landaal, K. Metzler, K. D. Patterson, M. Pyne, M. Reid, L. Sneddon, and A. S. Weakley. (1998). The National Vegetation Classification System: list of types. In: *International classification of ecological communities: terrestrial vegetation of the United States. Volume II*. The Nature Conservancy, Arlington, Virginia.

Egbert, S. L., K.P. Price, M. D. Nellis, and R. Lee, R. (1995). Developing a land cover modelling protocol for the high plains using multi-seasonal Thematic Mapper imagery. In *Proceedings*, *ASPRS/ACSM Annual Meeting*, 27 February - 2 March, Charlotte, North Carolina, pp. 836-845.

Egbert, S.L., R. Lee, K.P. Price, R.Boyce, and M.D. Nellis. (1998). Mapping Conservation Reserve Program (CRP) grasslands using multi-seasonal Thematic Mapper imagery, *Geocarto International*, 13(4):17-24.

Grossman, D. H., D. Faber-Langendoen, A. S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. D. Patterson, M. Payne, M. Reid, and L. Sneddon. (1998). The National Vegetation Classification System: development, status, and applications. In: *International classification of ecological communities: terrestrial vegetation of the United States. Volume I.* The Nature Conservancy, Arlington, Virginia.

Kuchler, A.W. (1974). A new vegetation map of Kansas. *Ecology*, 55:586-604.

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

Jensen, J.R. (1996). *Introductory Digital Image Processing: A Remote Sensing Perspective*. Upper Saddle River, NJ: Prentice Hall, pp. 107-124.

Lauver, C. L., K. Kindscher, D. Faber-Langendoen, and R. Schneider. (1999). A Classification of the Natural Vegetation of Kansas. *The Southwestern Naturalist* 44(4):421-443.

Leatherberry, E.C., T.L. Schmidt, J.K. Strickler, and R.G. Aslin. (1999). An analysis of the forest resources of Kansas, *USDA Research Paper NC-334*.

Stewart, A., D. Peterson, S. Egbert, K. Price, C. Blodgett, S. Park, C. Lauver, E. Martinko, J. Cully. (2000). Land cover mapping for GAP: A hybrid classification approach to identifying the vegetation of Kansas. In *Proceedings, ASPRS 2000, Annual Meeting of the American Society for Photogrammetry and Remote Sensing*, 23 - 26 May, Washington D.C.

USDA. (2000). Farm Service Agency. *Conservation Reserve Program*. http://www.fsa/usda/gov/dafp/cepd/crpinfo.htm

Wardlow, B.D., and S. L. Egbert. (2001). A Comparison of the GAP and Regional MRLC Land Cover Data Sets for the State of Kansas - Classification Systems, Methods and Results. In *Proceedings, ASPRS 2001: Gateway to the New Millenium*. 27-23 April, St. Louis, Missouri.

Whistler, J.L., M.E. Jakubauskas, S.L. Egbert, E.A. Martinko, D.W. Baumgartner, and R. Lee. (1995). "The Kansas State Land Cover Mapping Project: Regional Scale Land Use/Land Cover Mapping Using Landsat Thematic Mapper Data". In *Proceedings*, *ASPRS/ACSM Annual Meeting*, 27 February - 2 March, Charlotte, North Carolina, pp. 773-785.