Ecological Mapping Systems of Kansas and Nebraska

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Executive Summary

Leaders within the Kansas Department of Wildlife, Parks and Tourism and the Nebraska Game and Parks Commission recognized the need for current vegetation datasets and maps to facilitate conservation planning and management. Prior to the initiation of this project, Ecological Mapping System (EMS) datasets had been completed by the Missouri Resource Assessment Partnership (MoRAP) for Texas and Oklahoma (Elliott et al. 2014, Diamond and Elliott 2015). The U.S. Fish and Wildlife Service facilitated meetings among states that highlighted the Texas and Oklahoma datasets. This led state leaders in Kansas and Nebraska to initiate the current project, with the aims of (1) producing the highest quality digital and map datasets possible, and (2) leveraging funds from each state by combining efforts. MoRAP was the overall project coordinator, and primary funding and oversight came from the states.

Key elements of the EMS datasets include (1) use of 5,000 georeferenced ground data points to drive the outcomes, (2) use of European Space Agency Sentinel 2 satellite imagery which allowed for mapping at 9X better spatial resolution than common nationwide datasets (10 sq m versus 30 sq m see https://sentinel.esa.int/web/sentinel/home), and (3) use of local, state-based ecological expertise to define mapping targets, including the geographic location (e.g. region) and geophysical setting (e.g. soils, landforms) for target map types, which used the national Ecological Systems Classification as a starting point (see https://www.natureserve.org/conservation-tools/terrestrial-ecological-systems-united-states). Some specific methods included use of three dates of satellite imagery, use of image objects to improve spatial accuracy and facilitate modeling, and grouping of soils into ecoclass groups (ecogroups) from original digital soil Map Unit and Ecological Site information provided by NRCS (see https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/ecoscience/desc/).

A total of 47 EMS Types occurred in Kansas, and 46 in Nebraska. These included 68 types total, with 27 in common and 41 in just one of the two states. Cropland made up more than 40% of the region, while Central Mixedgrass Prairie, and the closely-related Western Mix-grass Prairie in NE, made up more than 16%. Sandhills grasslands made up more than 13% of the area, mostly in Nebraska, and Flint Hills Tallgrass Prairie make up 3.5%, all within Kansas. Cool-season, mainly non-native, grasslands, which were only mapped in the eastern third of the study area, made up more than 5% of the area. Upland Ruderal Deciduous Woodland, at about 1.5%, covered about twice as much area as all native upland deciduous woodlands and forests combined. Ruderal eastern redcedar woodland and shrubland covered 579,757 hectares, more than any native upland woodland type.

Introduction

The National Landcover Dataset (NLCD) (http://landcover.usgs.gov/uslandcover.php), the USGS GAP Analysis dataset (http://gapanalysis.nbii.gov/portal/server.pt), the NatureServe National Map (https://www.natureserve.org/conservation-tools/terrestrial-ecological-systems-united-states) and the national LandFire map (http://www.landfire.gov) datasets are all done at 30 m spatial resolution using the NASA Operational Land Sensor (see https://landsat.gsfc.nasa.gov/operational-land-imager-oli/). These maps lack the spatial resolution to map some vegetation features that are important to conservation planning, such narrow woodland breaks (Figure 1).
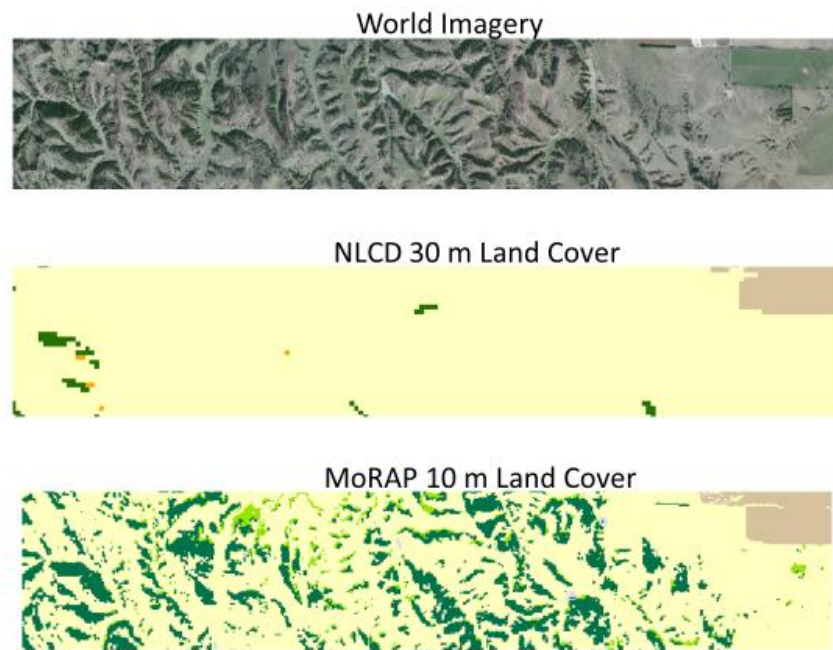
Figure 1. Data from that National Land Cover Dataset (NLCD, center) versus the Ecological Mapping Systems map for Kansas and Nebraska (bottom). NLCD 30 m resolution is not adequate to map some important small features, such as woodland breaks.

All of these efforts access available georeferenced ground data, but they do not specifically collect high volumes of georeferenced data to support mapping the way this project has. Finally, these efforts often lack the type of tight coordination between vegetation ecologists and geospatial analysts during the mapping process that is needed to adjust and provide the best results (Diamond et al. 2014).

The goal of the EMS project for Kansas and Nebraska was to address the primary shortcoming in other mapping efforts in order to provide better datasets and maps. Therefore, we included:
1. Use of 10 m resolution Sentinel 2 satellite imagery to provide better spatial resolution,
2. Use of image objects to further improve spatial accuracy by serving as a filter for 10 m pixel data, and to facilitate modeling of mapped types via flexible incorporation of geophysical setting information together with land cover information,
3. Collection of georeferenced ground data by qualified vegetation ecologists that was specifically designed to enhance mapping and development of the datasets, and

4. Close cooperation between state-based vegetation ecologists and geospatial analysts during the entire mapping process to ensure that datasets reflect the best current knowledge of vegetation in Kansas and Nebraska.

Methods

Kansas and Nebraska were treated as a single study area. Ecologists in Kansas and Nebraska were key contact points to identify mapping targets, collect field data, provide input on EMS type descriptions, and review draft results and suggest improvements. European Space Agency 10 m Sentinel 2 data served as the basis for land cover classification, and the footprints of Sentinel satellite orbits (overhead passes) were used as subdivisions. The orbits were further subdivided to reduce dataset size and facilitate classification (Figure 2). We considered clipping satellite data to ecoregion boundaries for processing, but the mapping team decided that the vegetation was uniform enough across ecoregion lines (e.g. largely herbaceous or row crop in most cases) that this process would not result in better outcomes.
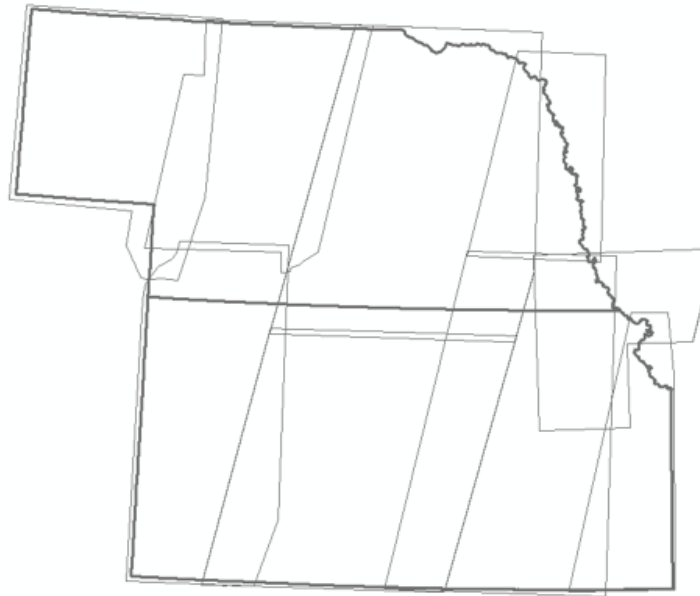
Figure 2. Sentinel orbital footprints were reviewed and two leaf-on and one leaf-off, cloud free dates were selected. The footprints were subdivided into 8 zones for processing and classification.

Workflow

Aspects of the project workflow included coordination between MoRAP staff and staff from agencies and organizations based in each state. A fairly complex and time intensive set of tasks was performed. In broad outline, these steps included:

1. Identification of mapping targets starting with the Ecological Systems Classification, followed by iterative adjustments based on work accomplished.
2. Collection of field data was coordinated and accomplished by state-based vegetation ecologists.
3. Remote sensing classification of land use/landcover. Three date mosaics of 10 m resolution Sentinel 2a and 2b imagery were used for each of 8 zones. Zone results were feathered together to form the final land use/land cover dataset.
4. Development of geophysical setting information, primarily digital soils and slope.
5. Development of image objects (segmentation) from Sentinel 2, 10 m resolution imagery.
6. Attribution of image objects with land use/landcover (from step 3) and geophysical setting information (from step 4).
7. Modeling and mapping of EMS Types using land cover, geophysical setting, and geographic region information (Figure 3). The result of this step was a draft final dataset and map.
8. Rapid field survey and collection of strategic, georectified data points related to issues discovered in the draft map, and revision of the map.
9. Development of final map and database. This step involved use of ancillary data, such as roads and previously developed maps.
10. Development and delivery of interpretive materials and final geodatabase.
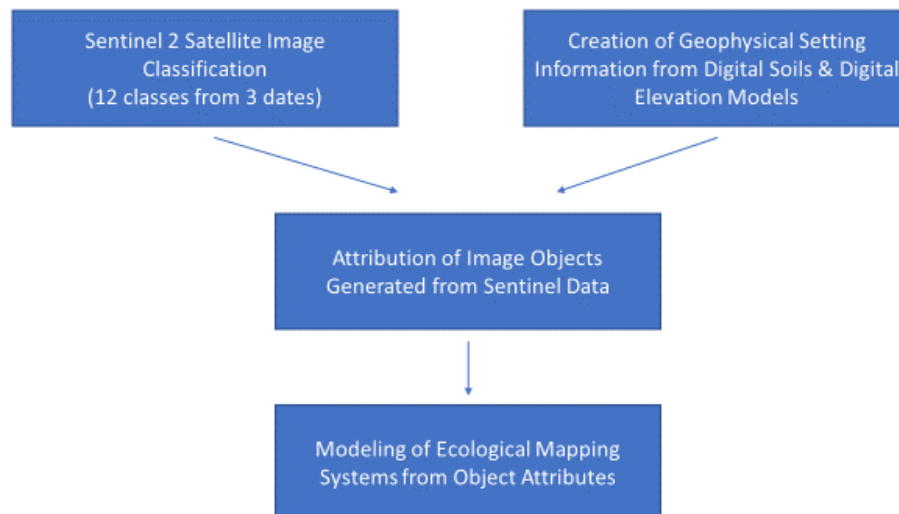
Figure 3. General process by which Ecological Mapping Systems were modeled based on land cover and geophysical setting information attributed to image objects.

Ecological Mapping System Targets

Lauver et al. (1999) and Rolfsmeier and Steinauer (2010) were used to modify the national Ecological Systems Classification to define mapping targets. State-based ecologists, including Kelly Kindscher in Kansas and Gerry Steinauer and Steve Rolfsmeier in Nebraska, met with MoRAP staff to refine initial drafts. The mapping targets were refined iteratively based on rapid statewide surveys and intensive ground data collection. Special thought was given to the geophysical setting and geographic range of each type. Common ruderal or disturbance vegetation types were also mapped. Iterative modification of mapping targets occurred throughout the mapping process.

Field Data

The Kansas Biological Survey, University of Kansas, and the Nebraska Natural Heritage Inventory, Nebraska Game and Fish Commission, coordinated field data collection efforts by directly collecting some data, and by contracting with qualified vegetation ecologists to collect data. A standardized methodology developed for the Texas Ecological Mapping System project was modified and adopted (Elliott et al. 2014). The general data collection procedure included:

1. In the office, ecologists designed sampling efforts to cover major areas of different vegetation cover by geographic region. Large areas of uniform land cover, especially row crops, were identified and data collection efforts were reduced in these areas.
2. Sample plots were collected on both sides of a road at approximately 1-mile intervals from a random starting point.
3. Sample plots consisted of visually homogeneous land cover within a circle with 50 m radius far enough from the road to avoid disturbances related to the right of way. Locations were precise, based on use of a GPS and GIS software on a computer in the field vehicle.
4. Views were limited, and air photos and digital soils maps loaded on the laptop were used to help facilitate data collection.

A standardized suite of data was collected using a digital feature data form that included drop-down lists for many data field to reduce mistakes. A photograph was taken at each plot location. Collected data included cover by cover class for the tree, shrub, and herbaceous vegetation layer, and the top three species in rank order by cover for each layer (Table 1). Plant species names were generally from the USDA Plants database (see https://plants.sc.egov.usda.gov/java/). Finally, the land cover type and EMS Type were recorded for each plot based on expert opinion of field ecologists, and these were later reviewed and modified by team leaders for each state. A total of 3114 plots was collected for Kansas, and 4665 for Nebraska (Figure 4).

Table 1. Example of information within the feature database used for field data collection.

Field Name	Data Type	Description & Exmple
SampleDate	Date	7/7/2020
TeamLeader	Text	Gerry Steinauer
SiteID	Integer	291
PictureID	Integer	421
EcoSysName	Text	Dry Oak Woodland
EcoSysConf	Text	High (confidence in EcoSysName)
LandCover	Text	Forest
Woody_PC	Text	76-100 (percent cover by cover class)
NLEG_PC	Text	0-5
Tree_PC	Text	76-100
Shrub_PC	Text	0-5
Herb_PC	Text	0-5
Tree1	Text	*Quercus macrocarpa*
Tree2	Text	*Quercus muehlenberia*
Tree3	Text	*Celtis occidentalis*
Shrub1	Text	*Cornus drummondii*
Shrub2	Text	*Cercis canadensis*
Shrub3	Text	*Symphoricarpos orbiculatus*
Herb1	Text	*Bromus inermis*
Herb2	Text	*Schizachyrium scoparium*
Herb3	Text	*Elymus canadensis*
Notes	Text	Sideslope
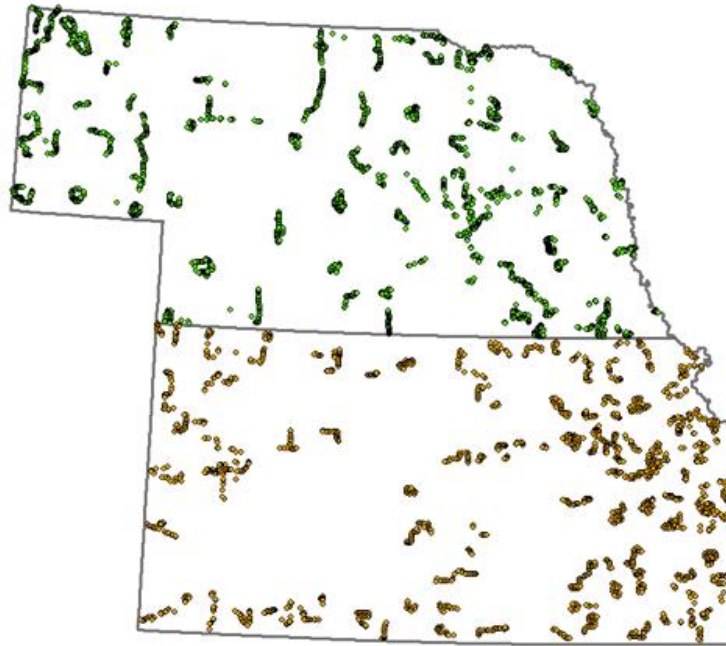
Figure 4. A total of 7779 field data plots were collected for KS and NE. The methodology featured stratified random design, a standardized data form with drop-down windows, and collection by qualified vegetation ecologists.

Remote Sensing Classification

Remotely sensed data from the Copernicus Programme Sentinel-2 earth observation mission (ESA, 2021a) was surveyed in order identify cloud-free imagery within the Nebraska/Kansas study region. The Sentinel-2 mission consists of two satellites (Sentinel-2A and Sentinel-2B), each carrying a MultiSpectral Instrument (MSI) designed to measure the reflected radiance of Earth in 13 spectral bands (ESA, 2021b). Level-1C image tiles were obtained from the Copernicus Open-Access Hub (Copernicus, 2021). The imagery for the study region was selected based on a combination of recency and clarity (i.e. the absence of clouds). A subset of the available spectral bands for each tile was used; the selected bands included: band 2 (blue), band 3 (green), band 4 (red), band 8 (near-infrared), band 11 (shortwave infrared 1), and band 12 (shortwave infrared 2). The spatial resolution of bands 2 through 8 was 10 meters. Bands 11 and 12, whose native resolution was 20 meters, were resampled to 10 meters. Image stacks for each tile and date were generated and mosaicked. Afterward, the mosaicked stacks for each date were compiled to produce image stacks consisting of three dates for each of the image processing zones (Table 2). These image processing zones (Figure 2) were defined based on contiguous areas within a given orbit that were absent of any cloud or snow cover. In addition to the spectral bands, the Normalized Difference Vegetation Index (NDVI) (Glenn, Nagler, Huete, 2010), Enhanced Vegetation Index-2 (EVI2) (Jiang et al., 2008), and the Normalized Difference Water Index (NDWI) (Gao, 1996), were calculated and added to the zonal image stacks. Since it was designed as a complementary index to capture changes in canopy water content, the NDWI was calculated only for the late leaf-on dates, as they reflected peak vegetation/canopy growth.

Table 2. Dates of Sentinel-2 imagery selected for the Nebraska/Kansas study region by relative orbit. Orbits are listed from east (relative orbit 69) to west (relative orbit 98).

	Relative Orbit/Zone Number							
	69/1	112/1	112/2	12/1	12/2	55/1	55/2	98/1
Leaf-on (Early)	2017-05-07	2017-08-23	2017-08-23	2017-05-13	2017-05-13	2018-06-05	2018-06-05	2018-06-03
Leaf-on (Late)	2017-07-21	2018-09-22	2018-09-22	2017-10-15	2017-10-15	2018-08-04	2018-08-04	2018-09-21
Leaf-off	2018-01-27	2017-12-01	2018-03-01	2018-02-17	2017-02-22	2018-03-12	2018-03-27	2017-11-30

Training data for land use/land cover classification were generated primarily from photointerpretation of a random grid of points within each zone. For some types, such as cool-season grasses and sand sagebrush, samples were initially collected near field-collected virtual plots. A few samples were collected from previously mapped vegetation provided by state partners. Note that the field collected virtual plots were not directly used as samples for the land cover classification.

The samples were then used to train a RandomForest (Breiman, 2001) classifier. Parameter values for all model runs were set as follows: number of trees = 1500, number of variables randomly sampled at each split = 9. In order to optimize the results, multiple model runs were executed for each zone based on iteratively modified training data. From 2500 to 3000 samples were collected within each of the eight mapping zones (Figure 5). The final RandomForest model for each of the zones was then applied to their respective image stack in order to generate a prediction raster, one for each zone.
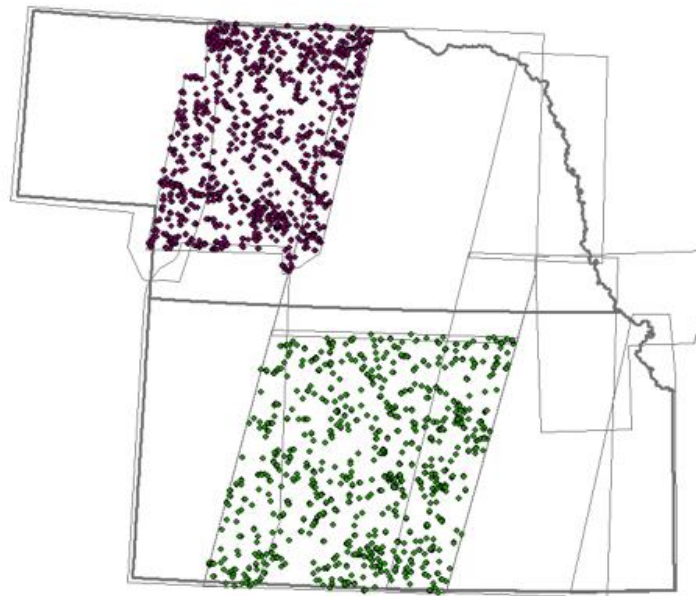
Figure 5. At total of 2509 training samples were used for zone 55-2 (upper left, brown) and 3079 samples were used for zone 12-1 (lower right, green).

Several raster-based mask layers were developed in order to further refine the RandomForest prediction outputs for each of the mapping zones. These included: 1) an urban area mask, outside of which pixels classified as urban were coded to barren and inside of which wooded and herbaceous land cover were coded as Urban Trees and Shrubs or Urban Grasses, 2) a crop area

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mask, outside of which pixels classified as crop were coded to herbaceous and inside of which a heads-up process was used to code other land cover types to crop as needed, and 3) a water mask, within which pixels classified as urban were coded to barren (to alleviate the issue of errant pixels classified as urban around water bodies). The urban area mask was created based on various datasets, including: rasterized versions of the Microsoft US Building Footprints buffered by 20 m (Microsoft, 2021), Nebraska/Kansas airport point data buffered by 2 km (BTS, 2018, railroad lines for both states buffered by 50 m (BTS, 2016), municipal area polygons for both states buffered by 1 km (US Census Bureau, 2019), and National Land Cover Database (NLCD; Jin et al., 2019) urban class pixels extracted and resampled to 10 m. The crop mask was also produced from the NLCD dataset by reference to the cultivated crops land cover class.

The water mask was created using the Copernicus Programme Global Surface Water dataset (GSW; Pekel et al., 2016). Multiple 30 m surface water occurrence tiles were mosaicked, resampled to 10 m, and expanded by 50 m. The GSW occurrence dataset shows where surface water occurred between the years 1984 and 2015.

Edge feathering was performed at zonal boundaries (~25 km overlap) in order to generate a seamless landcover raster for the entire study region. This was done by assigning the overall landcover based on the proximity of a given pixel to the nearest zone boundary, resulting in a distance-weighted probability of landcover assignment relative to zone boundaries.

Target land cover types varied across the study area due to variation in vegetation (Table 3). Cool-season grassland was a target land cover class only in the eastern third of Kansas, and sand sagebrush was a target in the western third of the study area.

Table 3. Twelve land cover classes from three season mosaics of 10 m resolution satellite remote sensing data.

Land Cover	Description and Example
Barren	quarries, river channel sand and mud
Cool-season Grassland	smooth brome, tall fescue
Cropland	wheat, corn
Deciduous Shrubland	a variety of shrubs and young woodlands
Deciduous Woodland and Forest	a variety of cold deciduous trees
Evergreen Shrubland and Woodland	eastern redcedar, ponderosa pine
Herbaceous Vegetation	a variety of grasslands
Sand Sagebrush Shrubland	sand sagebrush >50% cover
Urban, Low Intensity	residential areas
Urban, High Intensity	impervious urban cover
Water	reservoirs, rivers
Wet Herbaceous Vegetation	wet grasslands, marshes

Ecological Mapping Systems (EMS) Modeling

Generation of Image Objects

Trimble eCognition software (https://geospatial.trimble.com/products-and-solutions/ecognition) was used to generate image objects. Two dates of Sentinel 2 data were used: late leaf on and leaf off. Data stacks included the red, green, blue, and near infrared (RGBN) bands, plus NDVI. The RGB bands had a weight of 1 and the near infrared and NDVI bands were weighted 2. The scale parameter was 35, shape 0.1, and compactness 0.5. Objects were developed by 100 km square tile. This process produced a vector feature class containing polygons that represented relatively homogeneous units (relative to the Sentinel 2 datasets). The average size of the polygons was approximately 0.3 hectares. Since this represents the same area as 30, 10 m Sentinel 2 pixels, any 'salt and pepper' created from land cover assigned to 10 m pixels was substantially smoothed.

Attribution of Land Cover and Geophysical Setting to Image Objects

Land cover class, geophysical setting, and some ancillary information was assigned to each image object based on the majority (most common) class of all pixels contained within each object. Geophysical variables generated included soil ecogroup and percent slope from digital elevation models. Ecogroup was generated by grouping of ecoclasses assigned to soil map units within the NRCS gSSURGO database (see https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/home/?cid=nrcs142p2_053628; Diamond and Elliott 2015). Heads-up inspection and re-grouping of soil map units were accomplished based on field plot data information, as well as texture, flooding, and parent material information extracted from the gSURRGO data. Wooded/not wooded data from USDA Forest Service data (see USDA data commons, https://data.nal.usda.gov/dataset/high-resolution-land-cover-kansas-2015; https://www.fs.usda.gov/rds/archive/Catalog/RDS-2019-0038) was summarized to 10m (to match satellite imagery resolution) and was assigned to image objects and used to inspect areas where woody vegetation was identified in the land cover but not by the USDA dataset. In addition, transportation corridors were constructed by rasterizing, to 10m pixels, the center lines from large roads within the National Transportation Atlas Dataset (see https://www.bts.gov/geography/geospatial-portal/NTAD-direct-download) and overlaying the result on the map.

EMS Type Modeling and Mapping

Modeling and mapping were accomplished by assigning each combination of land cover, geophysical setting, and geographic region to a unique EMS Type. For example, herbaceous vegetation land cover within central Nebraska was modeled to several different final EMS Types (Table 4).

Table 4. Example of how herbaceous land cover from remote sensing was mapped as several ecological mapping system types based on geophysical setting (ecoclass) and geographic location in Central Nebraska.

Geophysical Setting (Ecoclass Group)	Geographic Location	Mapped Ecological Mapping System
Deep sandy soils	Sandhills & Outliers	Sandhills Dune Prairie
Typic soils	South of Sandhills	Central Mixed-grass Prairie
Typic soils	West of Sandhills	Western Mixed-grass Prairie
Subirrigated/wet soils	Sandhills & Outliers	Sandhills Wet Meadow/Marsh
Subirrigated/alkaline soils	Sandhills & Outliers	Western Lowland Alkaline Herbaceous Vegetation

Python scripts (using the arcpy interface to ArcGIS) were used to implement the modeling rules which were based on combinations of landcover and abiotic attributes. This provided a flexible, repeatable, and transparent method for model implementation.

Some EMS assignments were modified by reference to ancillary data or by heads-up modifications. The heads-up modifications were accomplished by selection of image objects (or object-based polygons dissolved on land cover or EMS type) based on reference to fine resolution imagery, followed by re-assignment of either land cover or final EMS type for those selected objects (polygons). Some examples include re-assignment of land cover other than cropland to cropland within a cropland mask, re-modeling of shrubland to forested types in the Scotts Bluff region of Nebraska, re-assignment of some deciduous forest land cover objects to other types for areas where USFS fine-resolution wooded/non-wooded data had no wooded vegetation, and selection of deciduous forest land cover for assignment to either oak or ruderal EMS types via photointerpretation. Objects with woodland/forest land cover that were adjacent to named streams (as portrayed in the National Hydrography Dataset; https://www.usgs.gov/core-science-systems/ngp/national-hydrography) were coded to floodplain vegetation types.

Range maps were produced for each mapped type by producing a feature class containing the centroid of each image object for the type as points. A raster was then produced using the point density tool in ArcMap with an output cell size of approximately 1 km and a circular neighborhood of approximately 9km. Darker colors indicate a higher density of the mapped type in the final map.

Ecological Mapping System (EMS) Dataset Summary and Discussion
The spatial accuracy afforded by 10 m Sentinel Satellite imagery resulted in capture of smaller features versus other available mapping products that use 30 m satellite imagery such as the National Landcover Database (NLCD; see https://www.usgs.gov/centers/eros/science/national-land-cover-database?qt-science_center_objects=0#qt-science_center_objects) and LandFire (see

https://landfire.gov/). In Kansas and Nebraska, narrow, wooded draws and valleys, for example, were better mapped (see Figure 1).

The NLCD dataset for KS and NE mapped 16 types, four of which were different kinds of urban land cover. Direct comparisons between the MoRAP land cover and NLCD were not possible, because the land cover types did not exactly match. Some class comparisons are possible, however (Table 5). NLCD mapped 40.9% less evergreen plus mixed forest in Kansas, and 47.5% less in Nebraska, versus the MoRAP classification. These forests are entirely eastern redcedar (*Juniperus virginiana*) in KS and about 70% eastern redcedar in NE (based on the Ecological Systems mapping results). This under-mapping is mainly related to (1) failure of the 30 m NLCD to capture narrow eastern redcedar breaks and other small patches of redcedar as evergreen forest, and (2) pooling of evergreen and deciduous forest within the NLCD wooded wetland class on floodplains, rather than separating deciduous from evergreen land cover on floodplains. NLCD mapped 15.5% and 14.8% less forest overall in KS and NE, respectively, versus the MoRAP dataset.   NLCD and MoRAP mapped similar amounts of grassland and cropland, about 5% less grassland and 5% more cropland mapped by NLCD. NLCD also mapped 102.1% and 89.6% more total urban area in Kansas and Nebraska, respectively, versus the MoRAP dataset. Visual inspection shows many more urban trees, shrubs, and grasses were mapped by MoRAP, mainly due to the finer spatial resolution of the data. Therefore, urban areas as we mapped them appear much more realistic in terms of interspersion of trees, grasses, roads and buildings versus the NLCD.

LandFire Existing Vegetation Type (EVT) results were too inconsistent with our mapping targets to be analyzed for comparison to our results. Many types were mapped in Kansas and Nebraska, for example, that do not occur in these states. Many other mistakes and inconsistencies seemed apparent in the EVT map. Accuracy and Database Limitations

Use of NRCS Digital Soils for Ecological Mapping System Models

NRCS digital soils maps served as the primary basis for geophysical setting. These maps were mostly drafted by hand, county by county, on paper maps, and then georeferenced to create digital maps. For that reason, they are not entirely spatially accurate. Inaccuracies may show up most clearly where dramatic differences in landform occur. For example, a river floodplain may be mapped 20 m upslope from the actual location of a bluff due to the inaccuracy of soil map unit lines. Some soil concepts, such as alkaline or saline, were simply accepted, even though field inspections sometimes show minimal influence of alkalinity or salinity on vegetation in the modern landscape. Finally, soil concepts may have varied from county to county, such that soil map units do not match at county lines. These types of inaccuracies are often masked because landscapes are similar across county lines in the study area, but they may sometimes show up as county-line artifacts in the final map.

Table 5. Comparison between NLCD and MoRAP land cover for selected classes by state for Kansas and Nebraska.

Land Cover	NLCD KS Area (Ha)	NLCD NE Area (Ha)	MoRAP KS Area (Ha)	MoRAP NE Area (Ha)	KS Diff	Percent	NE Diff	Percent
Cropland	9,725,080	7,648,658	9,248,177	7,297,571	476903	5.2%	351087	4.8%
Forest: All Types	1,051,531	531,973	1,244,521	624,659	(192,990)	-15.5%	(92,686)	-14.8%
Forest: Mixed and Evergreen NLCD vs Evergreen MoRAP	58,027	109,996	98,197	209,454	(40,170)	-40.9%	(99,458)	-47.5%
Grassland (excluding wet)	9,094,209	10,613,615	9,859,063	10,955,141	(764,853)	-7.8%	(341,527)	-3.1%
Urban: All Types	573,488	363,634	283,835	191,756	289,653	102.1%	171,879	89.6%

Land Cover Accuracy Assessment

Since the 10-meter land-cover results for the study region were produced zonally, classification accuracy was assessed by evaluating the final RandomForest out-of-bag (OOB) scores (Gislason, Benediktsson, Sveinsson, 2006) for each of the zones. Overall OOB error rates ranged from 8.01% (orbit 69, zone 1) to 14.23% (orbit 98, zone 1). In addition to overall OOB error rates, error rates by class for each of the zones are presented in Appendix A. Less prevalent classes tended to exhibit higher error rates relative to classes that comprised larger proportions of the respective classification zones, and these types of issues represent absolute (non-correctable) limitations of the remote sensing classification. Land cover classes that were particularly hard to separate accurately included deciduous shrub and sand sagebrush, which appear to be often misclassified as grassland, and wet herbaceous vegetation which was misclassified as several other types.

The final land cover accuracy was improved by an unknown amount versus the OOB numbers via use of masks and heads-up methods to re-code mistakes as earlier described (see Methods, Remote Sensing Classification). Also, sometimes two related land cover types were mapped as the same EMS type (e.g. herbaceous and wet herbaceous land cover over lowland soils). For this reason, we provided an estimate of land cover accuracy based on field virtual plot data for both KS and NE (Appendix B, C). Each virtual field plot was scored as 1 (land cover correct or essentially so), 2 (land cover closely related, such as shrub called in the field and grassland EMS type on the map), and 3 (field call and land cover map disagree). Using this method, overall land cover accuracy was 88.8% for Kansas and 84.7% for Nebraska. These numbers are in line with the overall OOB accuracy assessment. Note that the field data tended to avoid cropland, water, and urban classes, which were among the most accurately mapped land covers based on OOB analysis, so overall accuracy was almost certainly higher than these values.

Ecological Mapping System (EMS) Accuracy Assessment

Determination of accuracy for an EMS Type map is fraught with difficulty. Field data collection focused on several types that were ultimately not mapped (alfalfa, orchards, planted grass, Conservation Reserve Program plantings), and other types that were merged in the final map. Cropland areas were avoided (thus reducing measured accuracy), and areas with questionable distribution of EMS types were focused on, especially in Nebraska. Many EMS type concepts have similar aspect and species composition such that vegetation ecologists may have different interpretations of the same location on the ground.

Despite these limitations, virtual plots (4665 for Nebraska, and 3114for Kansas) collected in the field were used to provide an index to the accuracy of EMS type mapping. Each combination of mapped EMS type and field EMS type call was summarized and scored in terms of accuracy: 1 – exact match or essentially so, 2 – near match/closely related type, or 3 – incorrect/unrelated type. For Nebraska, the overall accuracy was 74.4% exact match, 17.9% near match, and 7.7% incorrect. For Kansas, the overall accuracy was 73.0% exact match, 23.7% near match, and

3.3% incorrect (Appendix D, E). Hence, 92.3% and 96.7% of virtual field plots were mapped correctly or as a related EMS type for Nebraska and Kansas, respectively.

Use of land cover assigned to image objects created some fine-resolution mistakes, especially at the edges of large patches of one type and small patches of a different one. For example, a narrow band of woodland along a fence line in a grassland landscape may be been coded as grassland. At the same time, noise in the data caused by use of 10 m pixels was smoothed by assigning majority land cover to polygons (objects) that averaged about 0.3 hectares in area. Reservoir inflows and larger river systems are highly dynamic in some instances, with flooding or elevated water levels in some seasons and drying in other seasons. Land cover in these areas was visually less accurate versus adjacent uplands. Cropland, likewise, may go into, and out of, cultivation over short periods of time, rotating between shallow water, barren, herbaceous, and cropland land use/land cover. This caused some mistakes in mapping cropland, although OOB accuracy assessment generally showed only about 5% error rates (Appendix A). Small features such as trees in small headwater drainages, wooded breaks, and trees and grasses in urban neighborhoods are visually much more accurately mapped versus available 30 m resolution national products such as NLCD and LandFire.

Future Refinements

Workers may want to access a variety of ancillary data for specific purposes. The NRCS maintains a Common Land Unit (CLU) dataset (field boundaries) with a variety of useful attributes. Among these, the location of planted grasses with the Conservation Reserve Programs may be useful, since these grasslands make up a substantial subset of grasslands of the western part of the study area. The NRCS datasets are not available for public-facing map products such as ours due to privacy concerns, but permission for their use may be obtained for specific partners and uses. National land cover and existing vegetation type datasets that appear to use some of this information do indeed show mistakes and artifacts related to inconsistencies in the NRCS data. Community element occurrence records or other fine-resolution maps (e.g. National Park Service vegetation inventory maps) may also be useful for specific needs.

Since the EMS dataset is available in vector form as small image objects, workers can select polygons and re-assign EMS types as needed. Heads-up work using fine-resolution imagery along specific river reaches to identify wetlands or wet shrublands may be desired. Likewise, heads-up work to separate ponderosa pine from junipers, or ruderal woodlands from oak woodlands (to the extent that these can be reliably recognized on-screen), may also be desirable. Substantial effort was placed on heads-up corrections for this project, but many areas and issues could not be addressed due to time constrains.

Cool-season grass species, mainly smooth brome (*Bromus inermis*) in the north and smooth brome and tall fescue (*Schedonorus arundinaceus*) in the south occur as components in most grasslands within the eastern quarter to third of the study area. Fields range from heavily dominated by these species and managed for hay without many warm-season species, to different admixtures of cool-season and warm-season grasses that may be hayed, grazed by domestic livestock, or both. Hence, separation of the grassland continuum into two unique classes is conceptually problematic as well as technically difficult. Also, management such as mowing,

grazing, herbicide application, fertilizer application, and prescribed fire remove or increase greenness and biomass, and these are applied to grasslands at different rates and times. The intersection of grasslands with different composition and different management practices with the timing of remote sensing data (e.g. different seasons and weather) results in a multitude of possible different spectral reflectance signatures for any given field at any given time. The NLCD and CDL attempt to separate cool season from warm season grasses, and workers in both Kansas and Nebraska have made special attempts as well (see https://kars.ku.edu/products/maps/ for Kansas; https://snr.unl.edu/data/geographygis/land.aspx for Nebraska; Peterson, 2019). Users should consult these datasets, as well as the EMS Types dataset, in this regard, although attempts to map grassland quality across large areas in eastern Kansas and Nebraska may be doomed to failure.

Kansas Ecological Mapping Systems Summary and Short Descriptions

Short descriptions of each 0f the 49 mapped type were prepared based on expert knowledge and on review of species frequency within mapped types from field sampling (3114 virtual plots; Table 6). A total of 277 species was found in virtual plots, including 192 herbaceous species (Appendix F). A total of 56 species was recorded in the shrub stratum and 29 species in the tree stratum. Twenty-four woody species were recorded in both the shrub and tree stratum. The most commonly recorded herbaceous species were little bluestem (*Schizachyrium scoparium*) and big bluestem (*Andropogon gerardii*). The most commonly recorded woody species (in either the shrub or tree layer) included Osage orange (*Maclura pomifera*), common hackberry (*Celtis occidentalis*), and slippery elm (*Ulmus rubra*).

Cropland covered more than 9.2 million hectares of Kansas, or more than 43% of the state (Table 6). Mixedgrass Prairie made up 3.1 million hectares or almost 15%, and Flint Hills Tallgrass Prairie covered 1.4 million hectares or almost 7%. Mapped Cool-season Grasses covered 2.3%. In addition, Unglaciated Eastern Upland Grassland and Glaciated Upland Grassland are mainly dominated by cool-season grasses, and make up 5.5% and 1.9%, respectively. Hence, these three disturbance grassland types which were formerly tallgrass prairies, cover almost 10% of the state. Ruderal Deciduous Woodland was the most abundant wooded type, covering 2% of the state. Ruderal Redcedar Woodland/Shrubland covered 89,289 hectares, or 0.42% of Kansas. Twenty-one out of 48 mapped types covered fewer than 50,000 hectares each.

Table 6. Area, percent, and short descriptions for Kansas Ecological Mapping Systems.

Code	Area (Hectares)	Percent	Name	Short Description
102	247,527	1.16%	Ark River Tallgrass Prairie/Pasture	Common components of these generally grazed grasslands in the modern landscape include introduced cool-season grasses such as smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*). Common native grasses include little bluestem (*Schizachyrium scoparium*) and sideoats grama (*Bouteloua curtipendula*). Tall grasses such as big bluestem (*Andropogon gerardii*) and switchgrass (*Panicum virgatum*) are present where grazing is lighter, whereas species such as blue grama (*Bouteloua gracilis*), three-awns (*Aristida* spp.), and buffalograss (*Buchloe dactyloides*) may dominate more heavily grazed areas, together with cool-seasons grasses.
31	102,179	0.48%	Barren	This type includes both natural and human-caused barren or very sparsely vegetation areas. This type can include sand roads, crushed limestone, dried water bodies, and rock outcrops
78	26,856	0.13%	Chalkflat Mixedgrass Prairie	Common species include little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), buffalograss (*Buchloe dactyloides*), and other grama species. Broom snakeweed (*Gutierrezia sarothrae*) is a common forb.
89	210	0.0010%	Cimarron Breaks Deciduous Shrubland	Small trees and shrubs such as common hackberry (*Celtis occidentalis*), Chickasaw plum (*Prunus angustifolia*), smooth sumac (*Rhus glabra*), and soapberry (*Sapindus saponaria*) and common components. Eastern redcedar (*Juniperus virginiana*) is also a common element, and open areas have elements of Cimarron Breaks Grassland.
26	15,427	0.07%	Cimarron Breaks Grassland	This type is similar to Mixedgrass Prairie but is over shallower, often sloping soils, with patches of more discontinuous vegetation cover. Species such as sideoats grama (*Bouteloua curtipendula*), little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), and grama species (*Bouteloua gracilis*, *B. hirsuta*) are common. Eastern redcedar (*Juniperus virginiana*) and other woody shrubs or small trees may form patches within these breaks grasslands.
25	2,781	0.0131%	Cimarron Breaks Redcedar Woodland/Shrubland	This type includes both fairly dense eastern redcedar (*Juniperus virginiana*) low woodland and shrubland and more sparse shrublands. Nearly monoculture patches may occur, or deciduous small trees or shrubs may be present. Common hackberry (*Celtis occidentalis*), Chickasaw plum (*Prunus angustifolia*), smooth sumac (*Rhus glabra*), and soapberry (*Sapindus saponaria*) are common woody components. Elements of Cimarron Breaks Grassland may be present in more open shrublands.
112	4,968	0.0233%	Cimarron Breaks Sparse Vegetation and Barren	This type represents nearly barren soils of hills and breaks in the Cimarron Hills region of southwest Kansas.

Code	Area (Hectares)	Percent	Name	Short Description
72	493,443	2.32%	Cool-season Grasses	This type was mapped in the eastern third of Kansas, and generally consists of cool-season species such as smooth brome (*Bromus inermis*) and tall fescue (mainly south, *Schedonorus arundinaceus*), and Kentucky bluegrass (*Poa pratensis*). In the modern landscape, these species tend to be important in many grasslands of eastern Kansas, including the Glaciated Upland Grassland and Unglaciated Eastern Upland Grassland types.
81	9,254,700	43.43%	Cropland	This type consists of annual row and close-grown crops.
7	52,895	0.25%	Crosstimbers Woodland	Composition varies based on past history, with post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*) common in less disturbed areas. Other common trees may include ash species (*Fraxinus* spp.) and American elm (*Ulmus americana*). Roughleaf dogwood (*Cornus drummondii*) and coralberry (*Symphoricarpos orbiculatus*) are common shrubs, and eastern redcedar (*Juniperus virginiana*) may be present. Dwarf chinquapin oak (*Q. prinoides*) and dwarf hackberry (*Celtis pumila*) are species that are most common in this type.
3	105,430	0.49%	Eastern Floodplain Forest (North)	This floodplain forest occurs on glacial landforms, glacial deposits, and alluvium derived from these deposits throughout the northern third of eastern Kansas. Streams generally drain toward and include the Kansas and Missouri Rivers. The overstory is characterized by species such as hackberry (*Celtis occidentalis*), black walnut (*Juglans nigra*), slippery elm (*Ulmus rubra*), and bur oak (*Quercus macrocarpa*). Pecan (*Carya illinoinensis*) may be present on big river floodplains but is absent from most areas. Younger or more sparse shrublands and woodlands may be included in this mapped type.
101	199,650	0.94%	Eastern Floodplain Forest (South)	These forests closely resemble forests to the north, but occur in erosional landforms through Pennsylvanian sedimentary strata of the Central Irregular Plains and Permian strata further west in the Flint Hills. The overstory is characterized by species such as hackberry (*Celtis occidentalis*), slippery elm (*Ulmus rubra*), black walnut (*Juglans nigra*), and northern red oak (*Quercus rubra*). Pecan (*Carya illinoinensis*) may be present and is generally lacking in the northern expressions. Streams drain towards the south and east, eventually draining into the Arkansas and Osage Rivers. Younger or more sparse shrublands and woodlands may be included in this mapped type.

Code	Area (Hectares)	Percent	Name	Short Description
9	188,460	0.88%	Eastern Floodplain Ruderal Grassland	Most areas consist of managed grassland, including hay fields or pastures. Cool-season grasses such as smooth brome (*Bromus inermis*), tall fescue (*Schedonorus arundinaceus*), and Kentucky bluegrass (*Poa pratensis*) are common in the modern landscape. Johnsongrass (*Sorghum halepanse*) is also a common element. Disturbance species such as great ragweed (*Ambrosia trifida*) and Russian thistle (*Salsola kali*) may be present. Woody species as described in the Ruderal Deciduous Shrubland/Young Woodland are also common components.
5	18,814	0.09%	Eastern Wetland	Both natural and non-natural areas such as reservoir in-flows, ditches, and mine reclamation areas are included in this type. Native moist soils species such as cattails (*Typha* spp.), sedges (*Carex* spp.), rushes (*Juncus* spp.), spike rushes (*Eleocharis* spp.) and bulrush (*Schoenoplectus* spp.) may be present. In slightly drier areas, prairie cordgrass (*Spartina pectinata*), big bluestem (*Andropogon gerardii*), and eastern gamagrass (*Tripsacum dactyloides*) may be present, but these natives have been eliminated from most areas. Non-native grasses such as smooth brome (*Bromus inermis*) and tall fescue (*Schedonorus arundinaceus*) are common in the modern landscape.
94	1,471,812	6.9%	Flint Hills Tallgrass Prairie	Little bluestem (*Schizachyrium scoparium*) and big bluestem (*Andropogon gerardii*) are often among the dominant grasses in this often grazed, native grassland type. Other tall grasses such as switchgrass (*Panicum virgatum*) and Indiangrass (*Sorghastrum nutans*) are often components. Sideoats grama (*Bouteloua curtipendula*) and silver bluestem (*Bothriochloa laguroides*) are also common, and tall fescue (*Schedonorus arundinaceus*) and field brome (*Bromus arvensis*; *B. tectorum*) are common in the modern landscape. Short grasses such a buffalograss (*Buchloe dactyloides*) and blue grama (*Bouteloua gracilis*) are important in more heavily grazed areas, and over heavier-textured soils. Common herbaceous species include Baldwin's ironweed (*Vernonia baldwinii*) and Cuman ragweed (*Ambrosia psilostachya*).
69	28,557	0.13%	Floodplain Sand Wash/Sandpit	This type consists of sand washes and sandbars along river courses and other barren areas on floodplains, primarily sand pits. Some urban barren areas in floodplains are included.

Code	Area (Hectares)	Percent	Name	Short Description
12	406,575	1.91%	Glaciated Upland Grassland	In the modern landscape, this type is generally grazed pasture, and a mixture of cool-season grasses such as smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), and tall fescue (*Schedonorus arundinaceus*) are often important components. Hence, the type is often little distinguished from the Cool-season Grasses mapped type. Little bluestem (*Schizachyrium scoparium*) is important in more lightly grazed examples. A variety of tallgrass components such as big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), and Indiangrass (*Sorghastrum nutans*) may be present. Common broadleaf herbaceous species include Canada goldenrod (*Solidago canadensis*) and Baldwin's ironweed (*Vernonia baldwinii*).
27	15,814	0.07%	Great Plains Cliff and Outcrop	This type consists of sparsely vegetated or barren areas over shallow soils with exposed rock, often in breaks landscapes.
86	7,902	0.0371%	Green Ash-Elm-Hackberry Canyon Bottomland Woodland	Green ash (*Fraxinus pennsylvanica*), slippery elm (*Ulmus rubera*), and common hackberry (*Celtis occidentalis*) are common trees in this type, which is mapped both in bottomlands and on slopes and breaks. Eastern redcedar (*Juniperus virginiana*) may be a component.
32	42,546	0.20%	Mixed Chinquapin Oak-Bur Oak Ravine Woodland	Chinquapin oak (*Quercus muehlenbergii*) is a common dominant of this type, especially in the Flint Hills, and bur oak (*Q. macrocarpa*) may be present. Redbud (*Cercis canadensis*) is a common small tree.
1	109,367	0.51%	Mixed Oak-Hickory Woodland and Forest	Composition varies from north to south within this type, and due to past disturbance regimes. Bur oak (*Quercus macrocarpa*) and chinquapin oak (*Q. muehlenbergii*) may occur throughout, with white oak (*Q. alba*) and northern red oak (*Q. rubra*) more common in mesic soils to the east. Mesic slopes and ravines in the north may have sugar maple (*Acer saccharum*), and basswood (*Tilia americana*). Shagbark hickory (*Carya ovata*), ash species (*Fraxinus* spp.), American elm (*Ulmus americana*), black walnut (*Juglans nigra*), and common hackberry (*Celtis occidentalis*) may be important components. Eastern redcedar (*Juniperus virginiana*) may be present, especially near edges and in disturbed areas.
59	975	0.0046%	Mixedgrass Breaks Redcedar Woodland/Shrubland	Eastern redcedar (*Juniperus virginiana*) may form dense, nearly monoculture patches, or may occur with deciduous small trees or shrubs such as common hackberry (*Celtis occidentalis*), Chickasaw plum (*Prunus angustifolia*), smooth sumac (*Rhus glabra*), and soapberry (*Sapindus saponaria*). More open areas with fairly sparse woody cover and patches of mixed grasses may be mapped within this type.

Code	Area (Hectares)	Percent	Name	Short Description
18	3,112,813	14.6%	Mixedgrass Prairie	Most areas of this broadly-mapped type are grazed more or less heavily. In the modern landscape, common grasses include sideoats grama (*Bouteloua curtipendula*), little bluestem (*Schizachyrium scoparium*), blue grama (*Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*), three-awns (*Aristida* spp.), western wheatgrass (*Pascopyrum smithii*), tall dropseed (*Sporobolus compositus*), smooth brome (*Bromus inermis*), and needle and thread (north; *Hesperostipa comata*). Cuman ragweed (*Ambrosia psilostachya*), annual ragweed (*A. artemisiifolia*), and white sagebrush (*Artemisia ludoviciana*) are common, grazing-tolerant components. Planted areas (Conservation Reserve Program) on former cropland are present, especially in western Kansas. Sand sagebrush (*Artemisia filifolia*) may be a component over sandier soils in western Kansas.
20	307,737	1.44%	Mixedgrass Prairie Breaks Grassland	Grasslands within this type are similar to Mixedgrass Prairie, but these areas are over shallower soils and may include steep slopes and low scarps. Patches within the type may express more discontinuous vegetation ground cover than surrounding Mixedgrass Prairie. Species such as sideoats grama (*Bouteloua curtipendula*), little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), and grama species (*Bouteloua gracilis*, *B. hirsuta*) are common components. Other components may include soapweed yucca (*Yucca glauca*) and fragrant sumac (*Rhus aromatica*). Sand sagebrush (*Artemisia filifolia*) may be a component over sandy soils, especially in the west.
6	4,234	0.0199%	Ozark Woodland and Forest	White oak (*Quercus alba*), black oak (*Q. velutina*), shagbark hickory (*Carya ovata*), and bitternut hickory (*C. cordiformis*) are common components of this type in less disturbed areas. Ash species (*Fraxinus* spp.), common hackberry (*Celtis occidentalis*), slippery and American elm (*Ulmus rubra*, *U. americana*), and black walnut (*Juglans nigra*) may also be present.
28	13,139	0.06%	Playa	This type is seasonally and annually variable, based on precipitation. Shallow water may fill these internally-drained basins, and they may dry to barrens, or may support herbaceous vegetation. Wetter areas may contain spike-rushes (*Eleocharis* spp.), bearded sprangletop (*Leptochloa fusca*), and smartweeds (*Polygonum* spp.). Common grasses include western wheatgrass (*Pascopyrum smithii*), buffalograss (*Buchloe dactyloides*), and foxtail barley (*Hordeum jabatum*). Saltgrass (*Distichlis spicata*) may be present over salty soils. In dryer years, these areas may be used as cropland, with annual herbaceous species present intermittently.

Code	Area (Hectares)	Percent	Name	Short Description
111	24,269	0.11%	Playa/Cropped	This type was mapped where cropland occurred over playa soils. Playas may be irregularly cultivated, depending on annual and seasonal precipitation, with mostly annual herbaceous species present when not cultivated.
11	134,392	0.63%	Reservoirs, Ponds and Rivers	This type includes all open water.
60	34,335	0.16%	Ruderal Deciduous Shrubland/Young Woodland	This type is mapped throughout the state on prairie soils and represents both shrublands with few trees and young, disturbed areas with young or sparse trees. The highest density of this type is in the eastern third to half of the state. Common components include Osage-orange (*Maclura pomifera*), honeylocust (*Gleditsia triacanthos*), roughleaf dogwood (*Cornus drummondii*), smooth sumac (*Rhus glabra*), and coralberry (*Symphrocarpos orbiculatus*). Fragrant sumac (*Rhus aromatica*) may be present in the west. Eastern redcedar (*Juniperus virginiana*) is a common component.
61	444,542	2.09%	Ruderal Deciduous Woodland	This type is most abundantly mapped in the eastern third to half of the state and represents woodland on prairie soils. Composition varies, but common species include common hackberry (*Celtis occidentalis*), black walnut (*Juglans nigra*), honeylocust (*Gleditsia triacanthos*), Osage-orange (*Maclura pomifera*), and ash species (*Fraxinus* spp.). Siberian elm (Ulmus pumila) is common in the west. Roughleaf dogwood (*Cornus drummondii*), and coralberry (*Symphrocarpos orbiculatus*) are common shrubs. Eastern redcedar (*Juniperus virginiana*) is a common component. This type may include some sparse woody vegetation.
62	89,289	0.42%	Ruderal Redcedar Woodland/Shrubland	This type is mapped throughout the state on prairie soils. Dense stands of eastern redcedar (*Juniperus virginiana*) may occur, but the type also circumscribes relatively sparse shrubland areas. Common deciduous trees include honeylocust (*Gleditsia triacanthos*), Osage-orange (*Maclura pomifera*), common hackberry (*Celtis occidentalis*), and slippery and Siberian elm (*Ulmus rubra* and *U. pumila*). Roughleaf dogwood (*Cornus drummondii*), smooth sumac (*Rhus glabra*), and coralberry (*Symphrocarpos orbiculatus*) are common shrub components.

Code	Area (Hectares)	Percent	Name	Short Description
34	58,790	0.28%	Saline Grassland and Marsh	This type circumscribes vegetation over moist (or alternately wet and dry) to wet, more or less saline soils. Common species vary by salinity and hydrology, and may include alkali sacaton (*Sporobolus airoides*), saltgrass (*Distichlis spicata*), little barley (*Hordeum pusillum*), buffalograss (*Buchloe dactyloides*), blue grama (*Bouteloua gracilis*), western wheatgrass (*Pascopyrum smithii*), and in the wettest areas, cattails (*Typha* spp.) and alkali bulrush (*Schoenoplectus maritimus*). Some areas that are only slightly more saline that the matrix grassland or wetland are included.
87	2,522	0.0118%	Salt Flat Barren	This type represents sparse and barren land cover over saline soils.
38	498,113	2.33%	Sandhills Prairie	Little bluestem (*Schizachyrium scoparium*), sand bluestem (*Andropogon hallii*), switchgrass (*Panicum virgatum*), and sand dropseed (*Sporobolus cryptandrus*) are common components of this grassland type. Cool-season bromes (*Bromus arvensis*; *B. tectorum*) are common spring elements. Broadleaf herbaceous species are common, and may include Cuman ragweed (*Ambrosia psilostachya*), prairie sunflower (*Helianthus petiolaris*), spotted bee balm (*Monarda punctata*), camphorweed (*Heterotheca subaxillaris*), evening primroses (*Oenothera* spp.), and gayfeather species (*Liatrus* spp.). Sand sagebrush (*Artemisia filifolia*) is a common component in western Kansas.
37	48,578	0.23%	Sandsage Shrubland/Grassland	Sand sagebrush (*Artemisia filifolia*) is a dominant component of these shrublands or shrubby grasslands. Little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), and sand bluestem (*Andropogon hallii*) are common grasses. Cool-season bromes (*Bromus arvensis*; *B. tectorum*) are common spring elements. Broadleaf herbaceous species are common, and may include Cuman ragweed (*Ambrosia psilostachya*), tenpetal blazingstar (*Mentzelia decapetala*), and spotted bee balm (*Monarda punctata*).
44	390,715	1.83%	Shortgrass Prairie	Most areas of this type are grazed, which impacts species composition. Blue grama (*Boutelous gracilis*), buffalograss (*Buchloe dactyloides*), three-awns (*Aristida* spp.) and dropseeds (*Sporobolus* spp.) are common components. Soapweed yucca (*Yucca glauca*) maybe be a component, especially in northwestern Kansas. Planted grasses (Conservation Reserve Program) on former cropland are present.
33	4,908	0.0230%	Smoky Hills Oak Woodland	A variety of wooded communities may be represented, depending on past disturbance. Bur oak (*Quercus macrocarpa*) may be dominant in less disturbed examples. Common hackberry (*Celtis occidentalis*), American elm (*Ulmus americana*), and ash species (*Fraxinus* spp.) are common components.

Code	Area (Hectares)	Percent	Name	Short Description
8	661,342	3.10%	Smoky Hills Tallgrass Prairie	Grazing pressure influences the composition of this grassland type. Little bluestem (*Schizachyrium scoparium*), and sideoats grama (*Bouteloua curtipendula*) are common components. Tall grasses such as big bluestem (*Andropogon gerardii*) and switchgrass (*Panicum virgatum*) are present where grazing is lighter, whereas species such as blue grama (*Bouteloua gracilis*), three-awns (*Aristida* spp.), and buffalograss (*Buchloe dactyloides*) may dominate more heavily grazed areas. Cool season grasses such as smooth brome (*Bromus inermis*) are common in the modern landscape.
84	6,163	0.029%	Sparse and Barren Dunes	Sparse grassland and barren dunes characterize this type.
99	1,163,542	5.46%	Unglaciated Eastern Upland Grassland	In the modern landscape, this type is generally grazed pasture, and a mixture of cool-season grasses such as smooth brome (*Bromus inermis*) or tall fescue (*Schedonorus arundinaceus*) are often dominant. Hence, the type is often little distinguished from the Cool-season Grasses mapped type. Little bluestem (*Schizachyrium scoparium*), splitbeard bluestem (sandy soils; *Andropogon ternarius*), and sideoats grama (*Bouteloua curtipendula*) may be components. A variety of tallgrass components such as big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), and Indiangrass (*Sorghastrum nutans*) may be present, and are dominant in remnant hay meadows.
115	66,443	0.31%	Urban Grasses	This type is mainly lawns and other highly managed urban grasslands. Some native grassland patches within, or adjacent to, urban settings are included.
22	132,122	0.62%	Urban High Intensity	This type is mapped generally in areas of impervious cover in cities or industrial sites and circumscribes areas such a large building footprints and large parking lots in urban cores.
21	194,359	0.91%	Urban Low Intensity	This type is mapped in residential areas of towns and cities and circumscribes areas such as house rooftops and urban streets.
114	27,741	0.13%	Urban Trees and Shrubs	A variety of planted and native trees and shrubs may be included in this type, which is mapped in urban settings. Some native wooded patches within, or adjacent to, urban settings are included.

Code	Area (Hectares)	Percent	Name	Short Description
53	202,130	0.95%	Western Floodplain Forest	Composition varies based on water regime and past disturbance within this broadly-circumscribed type. Common components include eastern cottonwood (*Populus deltoides*), willow species (*Salix nigra, S. amygdaloides, S. exigua, S. nigra*), green ash (*Fraxinus pennsylvanica*), common hackberry (*Celtis occidentalis*), boxelder (*Acer negundo*), and bur oak (east; *Quercus macrocarpa*). Honeylocust (*Gleditsia triacanthos*) is a common disturbance element. Less dense wooded areas are also included within this type.
55	8,013	0.0376%	Western Floodplain Shrubland/Young Woodland	Common components include willow species (*Salix exigua, S. amygdaloides, S. nigra*), green ash (*Fraxinus pennsylvanica*), common hackberry (*Celtis occidentalis*), and boxelder (*Acer negundo*). Composition varies based on past disturbance and hydrologic regime.
106	595,791	2.80%	Western Lowland Grassland	This type ranges from grasslands on moist soils of larger rivers to floodplain and terrace soils along small streams that support well-watered versions of the surrounding matrix grasslands (most commonly, Mixedgrass Prairie). Composition varies widely based on both hydrologic regime and grazing pressure. Tall grasses may include switchgrass (*Panicum virgatum*) and big bluestem (*Andropogon gerardii*), and drier aeras may have species such as little bluestem (*Schizachyrium scoparium*) and grama species (*Bouteloua gracilis, B. curtipendula*). In the modern landscape, cool season grasses such as smooth brome (*Bromus inermis*) and tall fescue (*Schedonorus arundinaceus*) are common.
35	134,076	0.63%	Western Center Pivot Grassland Corners	This type generally occurs as corners or edges of center pivot irrigation lands where there is considerable disturbance including irrigation, herbicides, and farm equipment impacts. This type can contain any mixture of cropland, weedy and native grass, forb, and shrub species and/or land enrolled in the Conservation Reserve Program (CRP).

54	134,076	0.63%	Western Wetland	A wide variety of moist to wet soil herbaceous vegetation is included within this type. Most areas are managed non-native grasslands with species such as smooth brome (*Bromus inermis*) and tall fescue (Schedonorus arundinaceus). Native species such as switchgrass (*Panicum virgatum),* big bluestem (*Andropogon gerardii),* eastern gamagrass (*Tripsacum dactyloides)* and prairie cordgrass (*Spartina pectinata*) may occur but are not common in the modern landscape. Marshes with species such as cattail (*Typha* spp.), sedges (*Carex* spp.), rushes (*Juncus* spp.), and bulrush (*Schoenoplectus* spp.) are also included. Disturbance species such as burningbush (*Bassia scoparia*) and Russian thistle (*Salsola kali*) are often present.
Sum	21,309,585	100.00%		

Kansas Ecological Mapping Systems Range Maps

Range maps are provided in a separate Word document to avoid instability in this document due to file size.

Nebraska Ecological Mapping Systems Summary and Short Descriptions

Short descriptions of each 0f the 47 mapped type were prepared based on expert knowledge and on review of species frequency within mapped types from field sampling (4665 virtual plots; Table 7). A total of 394 species or subspecies were recorded on virtual plots, including 311 herbaceous species, 46 shrub species, and 37 tree species (Appendix G). The most common herbaceous species included two non-native grasses, smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*). Smooth brome was recorded in about twice as many plots as the two most common native grasses, needle-and-thread (*Hesperostipa comata*) and little bluestem (*Schizachyrium scoparium*). The most commonly recorded shrubs included soapweed yucca (*Yucca glauca*), prairie sagewort (*Artemisia frigida*), and western snowberry (*Symphoricarpos occidentalis*). Eastern redcedar (*Juniperus virginiana*) was recorded more than twice as often as any native tree other than green ash (*Fraxinus pennsylvanica*).

Cropland covered more than 7.3 million hectares of Nebraska, or more than 36% of the state (Table 7). Sandhills Dune Prairie covered 4.9 million hectares, or nearly 25% of the state, and this type together with related deep sand types Eastern Sand Prairie, Western Sand Prairie, and Sandhills Meadow/Marsh, covered over 6 million hectares, or 30% of the state. The Central Mixed-grass and the related Western Mixed-grass types made up 2.0 and 1.5 million hectares, or 17.6% of the state. Eastern Upland Grassland, most of which is dominated by introduced cool-season grasses, make up 4.11% of the state. Eastern Floodplain Forest was the most abundant wooded type, followed closely by two ruderal types, Ruderal Cedar Shrubland/Woodland and Ruderal Deciduous Woodland. Ponderosa Pine Forest/Woodland and Dry Bur Oak Woodland made up just over 60,000 hectares each, or 0.3% of the state. Twenty-seven of 48 mapped types made up fewer than 50,000 hectares each.

Table 7. Area, percent, and short descriptions for Nebraska Ecological Mapping Systems.

Code	Area (Hectares)	Percent	Name	Short Description
24	7,535	0.04%	Badlands	This type occurs on moderate to steep, highly-eroded slopes on siltstone, clay or clay with cobbles. It is mostly un-vegetated, although locally there can be sparse to moderate plant cover. Common shrubs include silver sagebrush (*Artemisia cana*), four-wing saltbush (*Atriplex canescens*) and rubber rabbitbrush (*Ericameria nauseosa*). The native mid- and short-grasses include thick spike wheatgrass (*Elymus lanceolatus*), western wheatgrass (*Pascopyrum smithii*), Sandberg bluegrass (*Poa secunda*) and blue grama (*Bouteloua gracilis*) may be common. Common forbs include few-flowered false buckwheat (*Eriogonum pauciflorum*), Nuttall's povertyweed (*Monolepis nuttalliana*), Russian thistles (Salsola spp.) and gumbo lily (*Oenothera caespitosa*). Most sites occur in association with level, Northwest Mix-grass Prairie.
31	54,571	0.27%	Barren	This type includes both natural and human-caused barren or sparsely vegetated areas, which are not described within the other barren categories.
57	293	0.0015%	Basswood-Ironwood Springbranch Canyon Forest	This type occurs on gentle to steep, mostly north- and east-facing, slopes of bluffs, canyons, and ravines, including springbranch canyons on the central Niobrara River valley. Soils are loams and sandy loams formed in eolian sand, colluvium, alluvium and Rosebud Siltstone. As mapped, this type is most often dominated by basswood (*Tilia americana*) with an understory of ironwood (hophornbeam, *Ostrya virginiana*), with paper birch (*Betula papyrifera*) and common component. Other trees include black walnut (*Juglans nigra*), bur oak (*Quercus macrocarpa*), American elm (*Ulmus americana*), common hackberry (*Celtis occidentalis*), and green ash (*Fraxinus pennsylvanica*). Eastern redcedar (*Juniperus virginiana*) may also be a component. Common shrubs and vines include chokecherry (*Prunus virginiana*), western snowberry (*Symphoricarpos occidentalis*), poison ivy (*Toxicodendron rydbergii*), Virginia creeper (*Parthenocissus quinquefolia*) and riverbank grape (*Vitis riparia*), while common herbaceous plants include common eastern woodland sedge (*Carex blanda*), long-beak sedge (*Carex sprengelii*), broadleaf enchanter's nightshade (*Circaea lutetiana*), hairy wildrye (*Elymus villosus*) and threepetal bedstraw (*Galium triflorum*).
18	2,037,613	10.17%	Central Mixed-grass Prairie	This type occurs on level ground to steep slopes on loess-mantled plains and hills. Soils are silt loams formed in loess. This type includes a variety of grassland types including pastures, planted grasslands, native prairies, and roadsides. Grazed pastures are by far the most common type. The non-natives smooth brome *(Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) frequently dominate disturbed sites, while less disturbed pastures include the native grasses big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracilis*), western wheatgrass (*Pascopyrum smithii*) and needle-and-thread (*Hesperostipa comata*). Common forbs include western Cuman ragweed (*Ambrosia psilostachya*), white sagebrush (*Artemisia ludoviciana*) and slimflower scurf-pea (*Psoralidium tenuiflorum*). Soapweed yuca (*Yucca glauca*) and western snowberry (*Symphoricarpos occidentalis*) are common shrubs, and eastern redcedar (*Juniperus virginiana*) is often invasive in this type.

Code	Area (Hectares)	Percent	Name	Short Description
81	7,316,178	36.52%	Cropland	This type includes all row and close-grown crops.
8	7,234	0.04%	Dakota Sandstone Tall-grass Prairie	This type occurs on level to steep slopes of hills and canyons on loam and sandy loam soils formed in Dakota Sandstone and associated shales. Common native grasses include big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), Junegrass (*Koeleria macrantha*) and blue grama (*Bouteloua gracilis*). The shrubs leadplant (*Amorpha canescens*), coralberry (*Symphoricarpos orbiculatus*) and rough dogwood (*Cornus drummondii*) can be common. The non-native smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis)* dominate disturbed pastures and eastern redcedar (*Juniperus virginiana*) has invaded many pastures.
32	61,211	0.31%	Dry Bur Oak Woodland	This type occurs on gentle to steep, mostly north- and east-facing, slopes of draws and bluffs often associated with streams and rivers. Soils are mostly silt loams or sandy loams formed in loess or glacial till. Bur oak (*Quercus macrocarpa*) is the most abundant trees along with common hackberry (*Celtis occidentalis*), green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*) and eastern redcedar (*Juniperus virginiana*). Common shrubs include chokecherry (*Prunus virginiana*), western snowberry (*Symphoricarpos occidentalis*) and smooth sumac (*Rhus glabra*). Dominant herbaceous plants include smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), silky wildrye (*Elymus villosus*), little bluestem (*Schizachyrium scoparium*) and sedges (*Carex* spp).
3	159,243	0.79%	Eastern Floodplain Forest	This type circumscribes a variety of lowland and floodplain soils with various hydrologic regimes which influence composition, and composition varies based on past disturbance as well. Dominant trees include cottonwood (*Populus deltoides*), peachleaf willow (*Salix amygdaloides*) and rarely diamond willow (*Salix eriocephala*). Common subcanopy trees include green ash (*Fraxinus pennsylvanica*), common hackberry (*Celtis occidentalis*), boxelder (*Acer negundo*), eastern redcedar (*Juniperus virginiana*) and white mulberry (*Morus alba*). Common shrubs and vines include Missouri gooseberry (*Ribes missouriense*), coralberry (*Symphoricarpos orbiculatus*), roughleaf dogwood (*Cornus drummondii*), chokecherry (*Prunus virginiana*), Virginia creeper (*Parthenocissus quinquefolia*) and poison ivy (*Toxicodendron rydbergii*). Many stands have a disturbed herbaceous layer dominated by the non-native smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis)* and reed canarygrass (*Phalaris arundinacea*). Least disturbed sites are dominated by native white snakeroot (*Argeratina altissima*), sedges (*Carex* spp), Virginia wildrye (*Elymus virginicus*), nodding fescue (*Festuca subverticilla*), Canadian woodnettle (*Laportea canadensis*) and Canadian blacksnakeroot (*Sanicula canadensis*).
108	1,843	0.0092%	Eastern Lowland Alkaline Herbaceous Vegetation	This type circumscribes vegetation over moist to wet, more or less saline soils on floodplains and terraces of primarily Salt Creek, Little Salt Creek and Rock Creek in Lancaster and southern Saunders counties. Soils are poorly drained silty clay loams formed in alluvium. Disturbed sites are commonly dominated by narrowleaf cattail (*Typha angustifolia*), cattail hybrids and reed canarygrass (*Phalaris arundinacea*). Common native plants in less disturbed sites include saltgrass (*Distichlis spicata*), foxtail barley (*Hordeum jubatum*), annual marsh-elder (*Iva annua*), prairie cordgrass (*Spartina pectinata*) and cosmopolitan bulrush (*Bolboschoenus maritimus*).

Code	Area (Hectares)	Percent	Name	Short Description
105	486,910	2.43%	Eastern Lowland Herbaceous Vegetation	This type occurs on floodplains and terraces of river and stream valleys and in poorly-drained upland sites. Soils are mostly deep loams, silt loams, and silty clay loams formed in alluvium, loess or glacial till. This type includes a variety of grassland types including pastures, planted grasslands, native prairies, and roadsides. Most occurrence are disturbed native and reseeded pastures dominated by smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), reed canarygrass (*Phalaris arundinacea*) and disturbance-tolerant native species. In less disturbed sites, common herbaceous plants include big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), prairie cordgrass (*Spartina pectinata*), switchgrass (*Panicum virgatum*), common threesquare bulrush (*Schoenoplectus pungens*), sedges (*Carex* spp.), flatstem spikerush (*Eleocharis compressa*), giant goldenrod (*Solidago gigantea*) and sawtooth sunflower (*Helianthus grosseserratus*). Sandy-soiled native sites have an abundance of switchgrass, Canada wildrye (*Elymus canadensis*) and sand dropseed (*Sporobolus cryptandrus*).
15	10,747	0.05%	Eastern Meadow/Marsh	This type includes both non-natural and natural moist-soil grasslands and wetlands. The former includes areas such as reservoir in-flows and ditches and pond edges with annual species such as smartweeds (*Polygonum* spp.), while occurrences of the latter are restricted to river and stream floodplains. Playa wetlands and Sandhills wetlands are not included in this type. Natural occurrences are on soils including poorly drained muck, sandy to clay loams and sands mainly formed in alluvium. Scattered trees and shrubs may occur in this type including cottonwood (*Populus deltoides*), peachleaf willow (*Salix amygdaloides*), sandbar willow (*Salix exigua*) and false indigo bush (*Amorpha fruiticosa*). Many sites are disturbed and dominated by the non-native narrowleaf cattail (*Typha angustifolia*), cattail hybrids, reed canarygrass (*Phalaris arundinacea*) and the European subspecies of phragmites (*Phragmites austalis* subsp. *australis*). Common native plants of less disturbed sites include bulrushes, arrowheads (*Sagittaria* spp.), smartweeds (*Polygonum* spp.), broadleaf cattail (*Typha latifolia*), sedges (*Carex* spp.) and prairie cordgrass (*Spartina pectinata*).
1	49,142	0.25%	Eastern Oak Forest	As mapped, this type occurs mainly in river hills and bluffs and along level stream terraces. Soils are mostly silt loams and silty clay loams formed in loess and alluvium. Composition varies due to past disturbance and moisture regime. Common trees include bur oak (*Quercus macrocarpa*), red oak (*Quercus rubra*), black oak (*Quercus velutina*), chinkapin oak (*Quercus muehlenbergii*), common hackberry (*Celtis occidentalis*), basswood (*Tilia americana*), black walnut (*Juglans nigra*), elms (*Ulmus* spp.) and hickories (*Carya* spp.). Common subcanopy trees include common hackberry, green ash (*Fraxinus pennsylvanica*) and ironwood (hophornbeam, *Ostrya virginiana*). Coralberry (*Symphoricarpos orbiculatus*), roughleaf dogwood (*Cornus drummondii*), Missouri gooseberry (*Ribes missouriense*) and Virginia creeper (*Parthenocissus quinquefolia*) are common shrubs and vines, while common herbaceous plants include silky wildrye (*Elymus villosus*), white snakeroot (*Ageratina altissima*) and Canadian woodnettle (*Laportea canadensis*). Eastern redcedar (*Juniperus virginiana*) may be present, especially near edges and in disturbed areas.

Code	Area (Hectares)	Percent	Name	Short Description
40	407,321	2.03%	Eastern Sand Prairie	This type occurs on low to moderately high, rolling sand dunes. Soils are well-drained fine sand and loamy fine sands formed in eolian sand. Common shrubs include leadplant (*Amorpha canescens*) and soapweed yucca (*Yucca glauca*), while common herbaceous plants include Cuman ragweed (*Ambrosia psilostachya*), needle-and-thread (*Hesperostipa comata*), porcupine grass (*Hesperostipa spartea*), prairie sandreed (*Calamovilfa longifolia*), sand dropseed (*Sporobolus crytandrus*), switchgrass (*Panicum virgatum*), sand bluestem (*Andropogon hallii*), little bluestem (*Schizachyrium scoparium*), blue grama (*Bouteloua gracilis*) and hairy grama (*Bouteloua hirsuta*). The non-natives smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) dominate disturbed sites.
110	822,803	4.11%	Eastern Upland Grassland	This type occurs on level ground to steep slopes. Soils are mainly deep, moderately well-drained loams, silt loams and silty clay loams formed mainly in loess and glacial tills and less frequently in weathered sandstone, limestone and shale. This type includes a variety of grasslands including native pastures, planted grasslands, hayed native prairies, and roadsides. Most abundant are native and reseeded pastures that are dominated by the non-native smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*) and disturbance-tolerant native species. Less disturbed native prairies are dominated by big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), sideoats grama *(Bouteloua curtipendula)*, porcupinegrass (*Hesperostipa spartea*), stiff sunflower (*Helianthus pauciflorus*), silverleaf scurfpea (*Pediomelum argophyllum*), Missouri goldenrod (*Solidago missouriensis*) and heath aster (*Aster ericoides*). Common shrubs include leadplant (*Amorpha canescens*), smooth sumac (*Rhus glabra*) and roughleaf dogwood (*Cornus drummondii*).
69	39,854	0.20%	Floodplain Barren	This type includes natural barrens along streams as well as human-caused disturbance areas, mainly sandpits. Soils are poorly-developed sands containing lesser amounts of clay, silt and gravel and are formed in alluvium. The type can consist of bare sand or can be sparsely vegetated. Seedlings and saplings of cottonwood (*Populus deltoides*) and willows (*Salix* spp.) may be present. Common herbaceous plants include flatsedges (*Cyperus* spp.), smartweeds (*Polygonum* spp.), bearded sprangletop (*Leptochloa fusca*), foxtail barley (*Hordeum jubatum*), cocklebur (*Xanthium strumarium*), lovegrasses (*Eragrostis* spp.), barnyardgrass (*Echinochloa crus-galli*) and the European subspecies of common reed (*Phragmites australis* subsp. *australis*).

Code	Area (Hectares)	Percent	Name	Short Description
86	9,328	0.05%	Green Ash-Elm-common hackberry Canyon Bottomland Woodland	This type is mapped in ravines and on valley bottoms and low slopes of canyons associated with escarpments and stream and river valleys. Soils are loams formed in weathered sandstone, colluvium, alluvium, eolian sand and loess. Common trees are green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), common hackberry (*Celtis occidentalis*) and boxelder (*Acer negundo*), while cottonwood (*Populus deltoides*), eastern redcedar (*Juniperus virginiana*) and the non-native white mulberry (*Morus alba*) and Siberian elm (*Ulmus pumila*) are less abundant. The most common shrubs and vines are American plum (*Prunus americana*), chokecherry (*Prunus virginiana*), western snowberry (*Symphoricarpos occidentalis*), poison ivy (*Toxicodendron rydbergii*) and woodbine (*Parthenocissus vitacea*). Common native herbaceous plants are hairy wildrye (*Elymus villosus*), little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), common eastern woodland sedge (*Carex blanda*), and longbeak sedge (*Carex sprengelii*). The non-natives smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) are abundant in disturbed sites.
103	3,071	0.0153%	Introduced Pine	This type occurs on a variety of topographic positions and soils and includes plantings of mainly ponderosa pine (*Pinus ponderosa*), Scotch pine (*Pinus sylvestris*), Austrian pine (*Pinus nigra*) and jack pine (*Pinus banksiana*). Eastern redcedar (*Juniperus virginiana*) and blue spruce (*Picea pungens*) are sometimes included in the plantings. Tree belts are included in this type. Elements of the Sandhills Dune Prairie type also occur in open patches.
63	14,472	0.07%	Native Eastern Shrubland	This type most frequently occurs on slopes, ravine bottoms and woodland edges. Soils are generally loams formed in a variety of substrates. The most abundant shrubs are American plum (*Prunus americana*) and chokecherry (*Prunus virginiana*). Less common shrubs include smooth sumac (*Rhus glabra*), western snowberry (*Symphoricarpos occidentalis*), leadplant (*Amorpha canescens*) and prairie rose (*Rosa arkansana*). The non-native smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) are the most abundant herbaceous plants, while the natives little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*) and sideoats grama (*Bouteloua curtipendula*) are less common.
68	9,652	0.05%	Native Western Shrubland/Young Woodland	This broadly circumscribed type includes both moist soil areas along streams with small trees, and uplands, especially along escarpments and on slopes and in canyons that may lack a tree component. Soils are mainly loams formed in a variety of substrates. Common shrubs include American plum (*Prunus americana*), chokecherry (*Prunus virginiana*), western snowberry (*Symphoricarpos occidentalis*), fragrant sumac (*Rhus trilobata*), mountain mahogany (*Cercocarpus montanus*), buffaloberry (*Shepherdia argentea*), prairie rose (*Rosa arkansana*) and smooth sumac (*Rhus glabra*). Scattered trees, mainly eastern redcedar (*Juniperus virginiana*), ponderosa pine (*Pinus ponderosa*), green ash (*Fraxinus pennsylvanica*) and cottonwood (*Populus deltoides*) maybe present. Common native herbaceous species include little bluestem (*Schizachyrium scoparium*), western wheatgrass (*Pascopyrum smithii*), needle-and-thread (*Hesperostipa comata*) and blue grama (*Bouteloua gracilis*). Disturbed sites have an abundance of smooth brome (*Bromus inermis*), cheatgrass (*Bromus tectorum*) and Kentucky bluegrass (*Poa pratensis*).

Code	Area (Hectares)	Percent	Name	Short Description
104	2,818	0.0141%	Northern Loess/Shale Bluff Prairie	This type occurs on the gentle to steep slopes of stream and river bluffs. Soils are shallow to steep silt loams and clay loams formed in loess and Pierre Shale. Dominant herbaceous plants include big bluestem (*Andropogon gerardii*), sideoats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), porcupine grass (*Hesperostipa spartea*), little bluestem (*Schizachyrium scoparium*), green needlegrass (*Nassella viridula*), western wheatgrass (*Pascopyrum smithii*) and white prairie clover (*Dalea candida*). The shrubs leadplant (*Amorpha canescens*), soapweed yucca (*Yucca glauca*), and prairie rose (*Rosa arkansana*) can be common. The non-native smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) dominate disturbed sites.
46	166,518	0.83%	Northwestern Mixed-grass Prairie	This type occurs on level to gently rolling to steep hills. Soils are somewhat poorly drained silty clay loams formed in Pierre Shale, and to a lesser extent siltstone. Common herbaceous plants include western wheatgrass (*Pascopyrum smithii*), green needlegrass (*Nassella viridula*), blue grama (*Bouteloua gracilis*), buffalo grass (*Buchloe dactyloides*), needle-and-thread (*Hesperostipa comata*) and non-native sweetclovers (*Melilotus* spp.). The shrubs broom snakeweed (*Gutierrezia sarothrae*), big sagebrush (*Artemisia tridentata*) and prairie sagewort (*Artemisia frigida*) may be locally common.
11	94,282	0.47%	Open Water	This type includes all open water other than playas and sandhills ponds.
28	21,531	0.11%	Playa Wetland	This type is seasonally and annually variable, based on precipitation. Shallow water may fill these internally-drained basin, and they may dry to barren, or may support herbaceous vegetation. Soils are primarily poorly drained silt clay loams underlain by a clay pan usually formed in loess, but some sites have silty to sandy soils. Most sites have been previously farmed. Common on disturbed sites are annual such as smart weeds (*Polygonum* spp.) and spike-rushes (*Eleocharis* spp.). Reed canarygrass (*Phalaris arundinacea*) and narrowleaf cattail (*Typha angustifolia*) and cattail hybrids are common weedy perennials. Common native plants of less disturbed sites include short-beak sedge (*Carex brevior*), woolly sedge (*Carex pellita*), western wheatgrass (*Pascopyrum smithii*), rice cutgrass (*Leersia oryzoides*), foxtail barley (*Hordeum jubatum*), barnyard grasses (*Echinochloa* spp.), perennial smartweed (*Polygonum coccineum*), pink smartweed (*Polygonum bicorne*), nodding smartweed (*Polygonum lapathifolium*), hooded arrowhead (*Sagittaria calycina*), river bulrush (*Bolboschoenus fluviatillis*), slender bulrush (*Schoenoplectus heterochaetus*), spikerushes (*Eleocharis* spp.) and plains coreopsis (*Coreopsis tinctoria*).
17	64,097	0.32%	Ponderosa Pine Forest/Woodland	This type occurs on gentle to steep slopes of canyons, escarpments and river bluffs. Soils are fine sandy loams, silty loams and silty clay loam formed in weathered sandstone and chalky shale, siltstone, eolian sand and loess. The dominant canopy tree is ponderosa pine (*Pinus ponderosa*), with green ash (*Fraxinus pennsylvanica*), Rocky Mountain juniper (*Juniperus scopulorum*), eastern redcedar (*Juniperus virginiana*) and cedar hybrids abundant in the subcanopy. Common shrubs include chokecherry (*Prunus virginiana*), western snowberry (*Symphoricarpos occidentalis*), poison ivy (*Toxicodendron rydbergii*) and fragrant sumac (*Rhus trilobata*). Common native herbaceous plants include little bluestem (*Schizachyrium scoparium*), needle-and-thread (*Hesperostipa comata*), green needlegrass (*Nassella viridula*), sideoats grama (*Bouteloua curtipendula*), western wheatgrass (*Pascopyrum smithii*), slender wildrye (*Elymus trachycaulus*), prairie sandreed (*Calamovilfa longifolia*) and sedges (*Carex* spp.). The non-natives smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) can be abundant in disturbed sites.

Code	Area (Hectares)	Percent	Name	Short Description
27	12,374	0.06%	Rock Outcrop	This type primarily occurs on nearly level to steep slopes and cliffs of eroded escarpments and ravines, but may also be present on ridge crests. Substrates are generally sandstone and siltstones. Soils are poorly-developed to absent and consists of very shallow sandy loams or silty loam where present. Scattered ponderosa pine (*Pinus ponderosa*) trees may be present and as well as the shrubs fragrant sumac (*Rhus trilobata*), soapweed yucca (*Yucca glauca*) and prairie sagewort (*Artemisia frigida*). The most common herbaceous species include blue grama (*Bouteloua gracilis*), little bluestem (*Schizachyrium scoparium*) and standing milkvetch (*Astragalus laxmannii*).
62	143,531	0.72%	Ruderal Cedar Shrubland/Woodland	This type occurs on a variety of topographic positions and soils and consists of stands where eastern redcedar (*Juniperus virginiana*) is the dominant tree. Some native cedar stands occur in Nebraska, but these are included within this mapped type. Deciduous trees such as green ash (*Fraxinus pennsylvanica*), common hackberry (*Celtis occidentalis*), white mulberry (*Morus alba*), and elm (*Ulmus americana, U. pumila*) may be present, but are not dominant. Common non-native herbaceous plants include smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) while common native species include little bluestem (*Schizachy*rium scoparium), big bluestem (*Andropogon gerardii*), sideoats grama (*Bouteloua curtipendula*) and needle-and-thread (*Hesperostipa comata*).
60	7,948	0.04%	Ruderal Deciduous Shrubland/Young Woodland	This type is mapped on disturbance and former upland tallgrass prairie soils and is similar to the Native Eastern Shrubland type. Trees and shrubs include both non-native and native species including cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), common hackberry (*Celtis occidentalis*), Siberian elm (*Ulmus pumila*), Osage orange (*Maclura pomifera*), honeylocust (*Gleditsia triacanthos*), rough dogwood (*Cornus drummondii*), smooth sumac (*Rhus glabra*) and American plum (*Prunus americana*). Eastern redcedar (*Juniperus virginiana*) may be present in limited abundance. The herbaceous layer is also a mix of non-native and native species, with the most common species being smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), cheatgrass (*Bromus tectorum*), little bluestem (*Schizachyrium scoparium*), Canada goldenrod (*Solidago canadensis*) and Cuman ragweed (*Ambrosia psilostachya*).
61	135,215	0.67%	Ruderal Deciduous Woodland	This type occurs on a variety of topographic positions and soils and consist mainly of weedy woodlands that occur on sites where woodlands were not present prior to settlement. Tree species vary by region and include non-native and native species including green ash (*Fraxinus pennsylvanica*), cottonwood (*Populus deltoides*), Siberian elm (*Ulmus pumila*), American elm (*Ulmus americana*), common hackberry (*Celtis occidentalis*), honeylocust (*Gleditsia triacanthos*), white mulberry (*Morus alba*) and Osage orange (*Maclura pomifera*). Eastern redcedar (*Juniperus virginiana*) may be present in limited abundance. Common shrubs include chokecherry (*Prunus virginiana*), western snowberry (*Symphoricarpos occidentalis*) and American plum (*Prunus americana*). The herbaceous layer is also a mix of non-native and native plants, the most abundant species being smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), cheatgrass (*Bromus tectorum*), marijuana (*Cannabis sativa*), Canada goldenrod (*Solidago canadensis*) and Canadian horseweed (*Conyza canadensis*).

Code	Area (Hectares)	Percent	Name	Short Description
70	8,995	0.04%	Ruderal Herbaceous Vegetation	This type is mapped on disturbance soils such as mine tailings and former quarries or pits. A variety of introduced grasses, shrubs, and young trees may be present. Common plants include kochia (*Kochia scoparia*), foxtails (*Setaria* spp.), Canadian horseweed (*Conyza canadensis*), cheatgrasses (*Bromus* spp.), black medic *(Medicago lupulina*), Russian thistles (*Salsola* spp.) and annual sunflower (*Helianthus annuus*).
87	1,229	0.0061%	Salt Flat Barren	This type occurs in association with saline soils in both western and eastern Nebraska, with barrens in the west more common. Sites have wet or alternately wet and dry, alkaline soils, and may form salt crusts. Areas may be un-vegetated to sparely vegetated. The most common herbaceous plants in the west include Nevada bulrush (*Scirpus nevadensis*), saltgrass (*Distichlis spicata*), seablite (*Suaeda* app,) and seaside arrowgrass (*Triglochin maritima*). In the east, the most common herbaceous plants include saltgrass (*Distichlis spicata*), seablite (*Suaeda* spp.) and red swampfire (*Salicornia rubra*).
38	4,936,109	24.64%	Sandhills Dune Prairie	This type occurs on low rolling to high, choppy sand dunes and dry (not subirrigated) interdunal valleys. Soils are formed in eolian sand and are poorly-developed fine to coarse sands on dunes and fine sands to loamy fine sands in valleys. Common shrubs in this type include leadplant (*Amorpha canescens*), soapweed yucca (*Yucca glauca*) and prairie rose (*Rosa arkansana*). Dominant grasses including switchgrass (*Panicum virgatum*), prairie sandreed (*Calamovilfa longifolia*), sand bluestem (*Andropogon hallii*), little bluestem (*Schizachyrium scoparium*), needle-and-thread (*Hesperostipa comata*), Indiangrass (*Sorghastrum nutans*) and prairie Junegrass (*Koeleria macrantha*). Abundant forbs include Cuman ragweed (*Ambrosia psilostachya*), white sagebrush (*Artemisia ludoviciana*) and sunflowers (*Helianthus* spp.).
65	43,153	0.22%	Sandhills Pond/Lake	This type includes open, permanent water lakes and ponds in the Sandhills. Soils range from sand to muck and the water chemistry from highly alkaline to fresh. Submerged and floating-leaved plants dominate the vegetation, where open water is not present. In freshwater, the dominant plants include duckweeds (*Lemma* spp.), coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), Siberian water milfoil (*Myriophyllum sibiricum*), pondweeds (*Potamogeton* spp.), white water-lily *(Nymphaea odorata*), yellow pond-lily (*Nuphar variegata*) and water smartweed (*Polygonum amphibium*). In alkaline water, the dominants include water smartweed, coontail, Siberian water milfoil (*Myriophyllum sibiricum*), sago pondweed (*Stuckenia pectinata*), horned pondweed (*Zannnichellia palustris*) and western widgeon grass (*Ruppia occidentalis*).

Code	Area (Hectares)	Percent	Name	Short Description
83	527,535	2.63%	Sandhills Wet Meadow/Marsh	This type circumscribes a variety of moist soils that differ in water regime, and composition varies based on hydrology as well as management. It occurs on nearly level to depressed areas along streams and rivers, in wet inter-dunal valleys and poorly-drained sand flats. Soils are poorly-drained muck, silty and clay loams, and sands mainly formed in alluvium and eolian sand. The non-native reed canarygrass (*Phalaris arundinacea*), Garrison creeping foxtail (*Alopecurus arundinaceus*), narrowleaf cattail (*Typha angustifolia*), cattail hybrids, redtop (*Agrostis gigantea*), smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratense*) and clovers dominate most drained and hayed and otherwise disturbed sites. Dominant native plants on less disturbed sites include bluejoint (*Calamogrostis canadensis*), northern reedgrass (*Calamogrostis stricta*), prairie cordgrass (*Spartina pectinata*), sedges (*Carex* spp.), flat-stem spikerush (*Eloecharis compessa*), rushes (*Juncus* spp.), common smartweed (*Polygonum coccineum*), the native subspecies of phragmites (*Phragmites australis* subsp. *americanus*), hardstem bulrush (*Schoenoplectus acutus*), common arrowhead (*Sagittaria latifolia*), large-fruit bur-reed (*Sparganium eurycarpum*) and broadleaf cattail (*Typha latifolia*). Drier areas with species typical of the Sandhills Dune Prairie may occur, especially where valleys have been artificially drained.
37	27,374	0.14%	Sand sagebrush Prairie	This type occurs on nearly level to rolling to choppy sand dunes. Soils are well-drained fine sands and loamy sands formed in eolian sand. Sand sagebrush (*Artemisia filifolia*) is the dominant and characteristic shrub of this type, although soapweed yucca (*Yucca glauca*) is also abundant at many sites. Dominant native herbaceous plants include needle-and-thread (*Hesperostipa comata*), prairie sandreed (*Calamovilfa longifolia*), sun sedge (*Carex heliophila*), blue grama (*Bouteloua gracilis*), hairy grama (*Bouteloua hirsuta*), sand dropseed (*Sporobolus crytandrus*), prairie Junegrass (*Koeleria macrantha*), little bluestem (*Schizachyrium scoparium*), Cuman ragweed (*Ambrosia psilostachya*), western sagewort (*Artemisia campestris*), desert goosefoot (*Chenopodium pratericola*). Cheatgrass and field brome (*Bromus tectorum, B. arvensis*) are the most abundant non-native species.
33	1,217	0.0061%	Sandstone Upland Bur Oak Woodland	This type occurs on moderate to steep slopes on various aspects associated with stream valleys. Soils are sandy loams formed in Dakota Sandstone. The dominant canopy tree is bur oak (Quercus macrocarpa), although composition varies with past disturbance. Eastern redcedar (*Juniperus virginiana*), American elm (*Ulmus americana*), slippery elm *(Ulmus rubra*) and common hackberry (*Celtis occidentalis*) are often abundant in the canopy and subcanopy. Common shrubs and vines include roughleaf dogwood (*Cornus drummondii*), Missouri gooseberry (*Ribes missouriense*), coralberry (*Symphoricarpos orbiculatus*), Virginia creeper (*Parthenocissus quinquefolia*) and poison ivy (Toxicodendron rydbergii). Dominant herbaceous plants include white snakeroot (*Ageratina altissima*), common eastern woodland sedge (*Carex blanda*), threepetal bedstraw (*Galium triflorum*), nodding fescue (*Festuca subverticillata*) and Canadian blacksnakeroot (*Sanicula canadensis*).
84	31,411	0.16%	Sparse and Barren Sands	This type includes blowouts (wind-excavated depressions in sand dunes), healing blowouts, peaks of very choppy sand dunes and areas severely disturbed from livestock grazing in the Sandhills. Soils are poorly-developed and formed in eolian sand. The herbaceous plant cover is absent to sparse and common species include blowout grass (*Redfieldia flexuosa*), lemon scurfpea (*Psoralidium lanceolatum*), sand muhly (*Muhlenbergia pungens*), sand bluestem (*Andropogon hallii*) and prairie sandreed (*Calamovilfa longifolia*).

Code	Area (Hectares)	Percent	Name	Short Description
115	22,727	0.11%	Urban Grasses	This type is mainly lawns and other highly managed urban grasslands. Some native grassland patches within, or adjacent to, urban settings are included.
22	94,549	0.47%	Urban High Intensity	This type is mapped generally in areas of impervious cover in cities or industrial sites and circumscribes areas such a large building footprints and large parking lots in urban cores.
21	126,817	0.63%	Urban Low Intensity	This type is mapped in residential areas of towns and cities and circumscribes areas such as house rooftops and urban streets.
114	9,539	0.05%	Urban Trees and Shrubs	A variety of planted and native trees and shrubs may be included in this type, which is mapped in urban settings. Some native wooded patches within, or adjacent to, urban settings are included.
55	2,347	0.0117%	Western Floodplain Shrubland/Young Woodland	This type occurs on a variety of bottomland soils with different water regimes and disturbance histories. Sandbars, islands and shorelines in stream and river channels, and floodplain terraces are included. Soils generally are poorly-developed and consist primarily of sand with silt, clay or gravel possibly present to a lesser extent. Tree saplings of cottonwood (*Populus deltoides*), peach-leaf willow (*Salix amygdaloides*), Russian olive (*Elaeagnus angustifolia*), green ash (*Fraxinus pennsylvanica*) and eastern redcedar (*Juniperus virginiana*) are present in this type. Common shrubs include false indigo bush (*Amorpha fruticosa*), sandbar willow (*Salix exigua*) and red osier dogwood (*Cornus sericea*). Common native herbaceous species include common ragweed (*Ambrosia artemisiifolia*), Emory's sedge (*Carex emoryi*), woolly sedge (*Carex pellita*), bald spikerush (*Eleocharis erythropoda*), common scouring rush (*Equisetum hyemale*), rice cutgrass (*Leersia oryzoides*), smartweeds (*Polygonum* spp.), goldenrods (*Solidago* spp.), docks (*Rumex* spp.), common threesquare (*Schoenoplectus pungens*) and prairie cordgrass (*Spartina pectinata*). The non-native redtop (*Agrostis gigantea*), reed canarygrass (*Phalaris arundinacea*), smooth brome (*Bromus inermis*), the European variety of phragmites (*Phragmites australis* subsp. *australis*), Kentucky bluegrass (*Poa pratensis*), narrow-leaf cattail (*Typha angustifolia*), cattail hybrids and sweetclovers (*Melilotus* spp.) dominate disturbed sites.
53	32,413	0.16%	Western Floodplain Woodland	This type occurs on floodplains, low terraces and sandbars of streams and rivers. Soils are poorly-developed and composed mostly of sand with lesser amounts of silt, clay and gravel and are formed in alluvium. The dominant tree is cottonwood (*Populus deltoides*). Green ash (*Fraxinus pennsylvanica*), peachleaf willow (*Salix amygdaloides*) and eastern redcedar (*Juniperus virginiana*) can be locally abundant in the subcanopy. Shrubs and vines include roughleaf dogwood (*Cornus drummondii*), American plum (*Prunus americana*), chokecherry (*Prunus virginiana*), sandbar willow (*Salix exigua*), western snowberry (*Symphoricarpos occidentalis*) and woodbine (*Parthenocissus vitacea*). Common herbaceous plants include switchgrass (*Panicum virgatum*), western wheatgrass (*Pascopyrum smithii*), Canada wildrye (*Elymus canadensis*), prairie cordgrass (*Spartina pectinata*), little bluestem (*Schizachyrium scoparium*), white snakeroot (*Ageratina altissima*) and late goldenrod (*Solidago gigantea*). Disturbed sites are dominated by the non-native smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), cheatgrass (*Bromus tectorum*), reed canarygrass (*Phalaris arundinacea*) and sweetclovers (*Melilotus* spp.).

Code	Area (Hectares)	Percent	Name	Short Description
107	66,446	0.33%	Western Lowland Alkaline Herbaceous Vegetation	This type circumscribes vegetation over moist to wet, more or less alkaline soils on floodplains and terraces of streams, rivers, or interdunal valleys. Soils are poorly drained, more or less strongly alkaline slit loams to sands formed in alluvium or eolian sand. Dominant plants in this type include sago pondweed (*Stuckenia pectinata*), saltmarsh bulrush (*Bolboschoenus maritimus*), Nevada bulrush (*Scirpus nevadensis*), common threesquare (*Schoenoplectus pungens*), saltgrass (*Distichlis spicata*), foxtail barley (*Hordeum jubatum*), slender wheatgrass (*Elymus trachycaulus*), scratchgrass (*Muhlenbergia asperifolia*), alkali sacaton (*Sporobolus airoides*), alkali cordgrass (*Spartina gracilis*) and the non-native narrowleaf cattail (*Typha angustifolia*). Cool-season grasses such as Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) are common in the modern landscape where soils are less wet and less saline.
106	264,465	1.32%	Western Lowland Herbaceous Vegetation	This type occurs on floodplains and terraces of river and stream valleys including ephemeral streams. Soils are non-alkaline to slightly to moderately alkaline clay loams, silt loams, and sandy loams formed in alluvium. The non-native smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), redtop (*Agrostis gigantea*) and reed canarygrass (*Phalaris arundinacea*) dominate most disturbed sites. Less disturbed sites are dominated by the native saltgrass (*Distichlis spicata*), western wheatgrass (*Pascopyrum smithii*), foxtail barley (*Hordeum jubatum*), woolly sedge (*Carex pellita*), Nebraska sedge (*Carex nebrascensis*), green needlegrass (*Nassella viridula*), wild licorice (*Glycyrrhiza lepidota*) and bee balm (*Monarda fistulosa*).
96	1,500,770	7.49%	Western Mixed-grass Prairie	This type occurs on level to steep uplands. Soils are well-drained loams, sandy loams and silt loams formed in colluvium from sandstone and siltstones, loess or eolian sand and to a lesser extent rapidly-drained coarse sands and gravels. Dominant herbaceous plants include needle-and-thread (*Hesperostipa comata*), blue grama (*Bouteloua gracilis*), blackroot sedge (*Carex filifolia*), buffalograss (*Buchloe dactyloides*), western wheatgrass (*Pascopyrum smithii*), little bluestem (*Schizachyrium scoparium*), prairie sandreed (*Calamovilfa longifolia*), and the non-native cheatgrass (*Bromus tectorum*). The shrubs fragrant sumac (*Rhus trilobata*), prairie sagewort (*Artemisia frigida*) and broom snakeweed (*Gutierrezia sarothrae*) can be locally common. Planted areas (Conservation Reserve Program) on former cropland are present within this type.
43	181,810	0.91%	Western Sand Prairie	This type is mapped on eolian sands as well as on sandy soils over sandstone or in colluvium associated with upslope sandstone outcrops. Soils are well-drained fine sands and loamy fine sands. Common native herbaceous plants include needle-and-thread (*Hesperostipa comata*), prairie sandreed (*Calamovilfa longifolia*) and blue grama (*Bouteloua gracilis*) and the non-native cheatgrass (*Bromus tectorum*). The most common shrubs include prairie sagewort (*Artemisia frigida*) and sand sagebrush (*Artemisia filifolia*).

Code	Area (Hectares)	Percent	Name	Short Description
90	7,528	0.04%	Western Wetland	This type includes both natural wetlands and non-natural, moist soil areas such as reservoir in-flows ditches and pond edges in the eastern half of the state. This type excludes playa wetlands and Sandhills wetlands. Natural occurrences are restricted to the oxbows and margins of streams and rivers and upland depressions. Soils include poorly-drained muck, sands, and sandy to clay loams mainly formed in alluvium. A sparse cover of trees and shrubs including cottonwood (*Populus deltoides*), boxelder (*Acer negundo*), Russian olive (*Elaeagnus angusitolia*), peach-leaf willow (*Salix amygdaloides*) and sandbar willow (*Salix exigua*) may be present. The non-natives narrow-leaf cattail (*Typha angustifolia*), cattail hybrids and reed canarygrass (*Phalaris arundinacea*) dominate disturbed sties. Dominant native herbaceous plants of less disturbed sites include bottlebrush sedge (Carex hystercina), Nebraska sedge (*Carex nebrascensis*), woolly sedge (*Carex pellita*), bald spikerush (*Eleocharis erythropoda*), common spikerush (*Eleocharis palustris*), foxtail barley (*Hordeum jubatum*), three-square bulrush (*Schoenoplectus pungens*), smartweeds (*Polygonum* spp.) and arrowheads (*Sagittaria* spp.).
Sum	20,033,770	100.00%		

Nebraska Ecological Mapping Systems Range Maps

Range maps are provided in a separate Word document to avoid instability in this document due to file size.

Literature Cited

Breiman, L. 2001. Random forests. *Machine Learning*.
https://doi.org/10.1023/A:1010933404324

Bureau of Transportation Statistics (BTS). 2018. National Transportation Atlas Database, Airports. https://data-usdot.opendata.arcgis.com/datasets/airports

Bureau of Transportation Statistics (BTS). 2016. National Transportation Atlas Database, Rail Network Spatial Dataset. https://www.bts.gov/newsroom/rail-network-spatial-dataset

Copernicus. 2021. Copernicus Open Access Hub. https://scihub.copernicus.eu

Diamond, D. D., D. Faber-Langendoen, L.F. Elliott, and R. Smyth. 2014. Critically evaluating existing methods and supporting a standardization of terrestrial and wetland habitat classification and mapping that includes characterization of climate sensitive systems. Northeast Climate Science Center, Amherst, MA.

Diamond, D.D. and L.F. Elliott. 2015. Oklahoma ecological systems mapping interpretive booklet: Methods, short type descriptions, and summary results. Oklahoma Department of Wildlife Conservation, Norman, OK.

Elliott, Lee F., David D. Diamond, C. Diane True, Clayton F. Blodgett, Dyan Pursell, Duane German, and Amie Treuer-Kuehn. 2014. Ecological Mapping Systems of Texas: Summary Report. Texas Parks & Wildlife Department, Austin, Texas.

European Space Agency (ESA). 2021a. Sentinel-2 Overview.
https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2

European Space Agency (ESA). 2021b. MultiSpectral Instrument (MSI) Overview.
https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-2-msi/msi-instrumentGao, B. C. (1996). NDWI - A normalized difference water index for remote sensing of vegetation liquid water from space. *Remote Sensing of Environment*. https://doi.org/10.1016/S0034-4257(96)00067-3

Gislason, P. O., Benediktsson, J. A., & Sveinsson, J. R. 2006. Random forests for land cover classification. In *Pattern Recognition Letters*. https://doi.org/10.1016/j.patrec.2005.08.011

Glenn, E. P., Nagler, P. L., & Huete, A. R. 2010. Vegetation Index Methods for Estimating Evapotranspiration by Remote Sensing. *Surveys in Geophysics*. https://doi.org/10.1007/s10712-010-9102-2

Jiang, Z., Huete, A. R., Didan, K., & Miura, T. 2008. Development of a two-band enhanced vegetation index without a blue band. *Remote Sensing of Environment*.
https://doi.org/10.1016/j.rse.2008.06.006

Jin, S., Homer, C., Yang, L., Danielson, P., Dewitz, J., Li, C., and Howard, D. 2019. Overall Methodology Design for the United States National Land Cover Database 2016 Products. *Remote Sensing*. https://doi.org/10.3390/rs11242971

Kaul, R.B. and S.B. Rolfsmeier. 2003. Native vegetation of Nebraska. Map, 1:1,000,000. Conservation and Survey Division, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln.

Lauver, C.L., K. Kindsher, D. Faber-Langendoen, and R. Schneider. 1999. A classification of the natural vegetation of Kansas. The Southwestern Naturalist 44:421-443.

Microsoft. 2021. US Building Footprints. https://www.microsoft.com/en-us/maps/building-footprints.

NaureServe. 2013. International ecological classification standard: Terrestrial Ecological Classifications. NatureServe Central Databases. Arlington, VA.

Pekel, J.-F., Cottam, A., Gorelick, N., & Belward, A. S. 2016. High-resolution mapping of global surface water and its long-term changes. *Nature*, *540*(7633), 1–19. https://doi.org/10.1038/nature20584

Peterson, D. 2019. A data-driven approach for mapping grasslands at a regional scale. Ph.D. Dissertation, University of Kansas, Lawrence.

Rolfsmeier, S.B. and G. Steinauer. 2010. Terrestrial Ecological Systems and natural communities of Nebraska. Nebraska Natural Heritage Program, Nebraska Game and Fish Commission, Lincoln. Available at tps://digitalcommons.unl.edu/nebgamewhitepap/71/.

United States Bureau of Transportation Statistics. 2021. National Transportation Atlas Dataset. Roads. https://www.bts.gov/geography/geospatial-portal/NTAD-direct-download

Unites States Department of Transportation (USDOT). 2021. National Transportation Atlas Database, Airports. https://data-usdot.opendata.arcgis.com/datasets/airports.

Unites States Forest Service. 2021. National LandFire program. Existing Vegetation Type dataset. https://landfire.gov/.

List of Appendices

Appendices are provided in a separate EXCEL spreadsheet file.

Appendix A. Out-of-Bag (OOB) RandomForest Error Matrices for Image Classification Zones in Nebraska and Kansas.

Appendix B. Kansas land cover accuracy assessment from field data virtual plot summary.

Appendix C. Nebraska land cover accuracy assessment from field data virtual plot summary.

Appendix D. Kansas ecological mapping system accuracy assessment from field data virtual plot summary.

Appendix E. Nebraska ecological mapping system accuracy assessment from field data virtual plot summary.

Appendix F. Species found in virtual field plots for Kansas.

Appendix G. Species found in virtual field plots for Nebraska.

Appendix H. Kansas State-Level Post Classification Revisions

Appendix H.

The Kansas Biological Survey analyzed the distribution of each EMS in the state. Several revisions were made to refine the class distributions and classifications.

1. Changed Barren to Urban High Density using an Urban Mask and buffered Stream Mask (created by buffering increasing distance based on stream order).
2. Redefined Barren Class definition to include sand roads, crushed limestone, dried waterbodies, and rock outcrops.

3. Changed Sand Pit to High Density Urban using an Urban Mask and unselecting those areas intersecting with larger water bodies (GT 10 acres).
4. Changed Unglaciated Upland Grassland to Flint hill Tallgrass in select areas of Riley and Pottawatomie Counties.
5. Changed Mixedgrass Prairie to Arkansas Tallgrass in select areas of Harvey, Sedgwick, Sumner, and Cowley Counties.
6. Changed Chalkflat Mixedgrass Prairie to Mixedgrass Prairie Breaks Grassland in Clark County.
7. Changed Mixedgrass Prairie to Sandhills Prairie in select areas in Dickenson County.
8. Added a new class "Western Center Pivot Grassland Corners" that represents the corners of center pivots. An irrigated land mask was created using three data sources including the 2015 CLU and the 2017 Landsat-based Irrigation Dataset (LANID). The PLSS was subdivided and intersected with the irrigation mask to select grasslands withing these parcels to change to the new class.