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Rainwater Basin 2012 Wetland Vegetation Map

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Abstract

The Rainwater Basin wetland complex (RWB) provides critical stopover habitat for spring migrating wetland-dependent birds. However, most of the wetlands in the region have been drained, filled, or modified to facilitate cropping. Efforts are currently under way to restore or improve these habitats. Knowing the vegetation and contemporary function of wetlands can allow conservation organizations to more effectively plan and deliver conservation at a landscape scale. To address this conservation bottleneck, we created a vegetation map detailing the communities present in all historical RWB wetlands based on conditions in 2012. The vegetation map was created by first collecting field survey data at 12,594 points on conserved RWB wetlands. The program eCognition Developer 8 used image object technology to generate a polygon shapefile of segments in all historical wetland footprints based on 2012 spring (March) color infrared, mid-summer (July) true color, and late-summer (August) color infrared imagery. These segments outlined groups of pixels that contained similar spectral and textural features generally representing like vegetation communities. The segments were classified as one of nine natural, non-cultivated wetland vegetation map classes based on field survey data and aerial imagery. In ArcMap 10, all polygons were manually verified twice based on field survey data, surrounding vegetation communities, elevation, and aerial imagery. All cultivated polygons were assigned the map class Agriculture. Irrigation reuse pits and “cropped wetland” areas (i.e., cultivated areas that ponded water $\geq 25\%$ of the time), were integrated into the map using identity overlays. An assessment was then conducted to determine the accuracy of the final vegetation map based on field survey data previously allotted for that purpose. The final map contained 45,777 individual historical wetland polygons that covered 79,575 ha. The Agriculture map class covered 77% of the final map area, followed by Moist-Soil Species (9%), Grass (5%), and Reed Canarygrass (3%). The accuracy of the natural vegetation (i.e., all map classes except Agriculture and Cropped Wetland) in the final vegetation map was 75.0% overall and 84.5% on surveyed properties.

Introduction

The Rainwater Basin wetland complex (RWB) in south-central Nebraska is critical to migrating wetland-dependent birds. The region is particularly important during spring migration because it occurs in the narrowest portion of the Central Flyway. During that time, >7 million waterfowl and 500,000 shorebirds stopover in the RWB, where they rely on wetlands to provide habitat and

foraging resources. While in the region, birds replenish their energy and nutrient reserves in order to complete migration and initiate nesting.

Historically, >11,000 wetlands existed in the RWB (Bishop and Vrtiska 2008). However, only 10% of the original wetlands remain, constituting 12% of the original wetland area (Schildman and Hurt 1984). Additionally, virtually all of the remaining wetlands were hydrologically impacted, which reduced their size and functionality (Schildman and Hurt 1984, Smith 1998). Wetland loss has decreased the habitat and forage available to wetland-dependent birds, which can reduce their energy and nutrient intake during spring migration. Females with lower nutrient reserves delay nesting, lay smaller clutches, or forego re-nesting if the initial clutch is lost, all of which can decrease recruitment (Krapu 1981, Dubovsky and Kaminski 1994, Devries et al. 2008). Conservation programs and management have been employed to increase the region's functional wetland area and provide additional habitat for waterfowl and other wetland-dependent species. Lands under long-term conservation include Wetlands Reserve Program sites (WRP), private easements held by a variety of agencies (i.e., "other private easements"), state Wildlife Management Areas (WMA), and federal Waterfowl Production Areas (WPA).

To aid conservation efforts and decision making in the region, a vegetation map covering all historical RWB wetlands was created based on vegetation communities present in 2012. Specific examples of the uses of this vegetation map include providing information about the location and extent of invasive species such as reed canarygrass (*Phalaris arundinacea*), narrowleaf cattail (*Typha angustifolia*), and river bulrush (*Schoenoplectus fluviatilis*); helping prioritize wetland easement acquisitions; and estimating the amount of forage available for waterfowl and shorebirds. This vegetation map can also be compared to a previous vegetation map created to reflect conditions in 2004 (Bishop and Vrtiska 2008). By comparing the vegetation maps, conservation organizations can better understand how vegetation communities, and therefore availability of plant foods, have changed over time. An analysis of vegetation changes can help land managers determine whether management practices are beneficial. The objective of this article is to detail the process for creating the 2012 RWB wetland vegetation map and general results of the map.

Methods

Imagery Processing

We acquired three aerial imagery sets covering the RWB, including spring color infrared, mid-summer true color, and late-summer color infrared imagery. Color infrared aerial photographs were collected by Cornerstone Mapping (Lincoln, Nebraska) during the spring (1–15 March, 2012) and late-summer (1–10 August, 2012). Cornerstone Mapping supplied the raw images and image acquisition geometry, including the X, Y, Z coordinates and phi, omega, and kappa aircraft orientation at acquisition, to the RWBJV. Images were orthorectified based on acquisition geometry and exterior orientation using ERDAS Leica Photogrammetry Suite 11 (ERDAS, Inc., Norcross, Georgia). We then color balanced images within a season so color tone and hue matched within image sets and mosaicked images into counties using OrthoVista 4 (Inpho GmbH, Stuttgart, Germany). The mid-summer imagery was processed and supplied by

the U.S. Department of Agriculture's Farm Service Agency using imagery collected in July 2012.

To prepare the imagery for segmentation, the individual images for each county were mosaicked together for each image set. We then used the resample tool in ArcMap 10 (ESRI, Redlands, California) because original resolution (0.6x0.6 m for infrared and 1x1 m for true color) was too fine for future analyses. For the spring imagery, we set the resample output cell size to 3x3 m. For the mid- and late-summer imagery, the output cell size was again set to 3x3 m and the Snap Raster in the Environments tab was set to the resampled spring imagery in order to align the pixels in all image sets.

Wetland Segmentation

Once the imagery was processed, we used eCognition Developer 8 (Trimble Germany GmbH, Munich, Germany) to segment all historical RWB wetlands. This program uses image object orientated processing to aggregate pixels that have similar spectral and textural characteristics. The resulting image object polygons generally contain similar vegetation communities. To conduct the segmentation, we loaded all three resampled imagery sets and a shapefile of all historical RWB wetlands as the thematic layer. A chessboard segmentation with an exaggerated scale parameter was performed to create polygons around the historical wetlands. Within the historical wetlands, we conducted a multiresolution image object segmentation for which eCognition 8 segmented by grouping similar pixels together based on imagery pixel values and neighborhood context (Figure 1). The resulting wetland image object polygons served as the basic units for all subsequent classification with the assumption that similar groups of pixels had similar dominant vegetation communities.

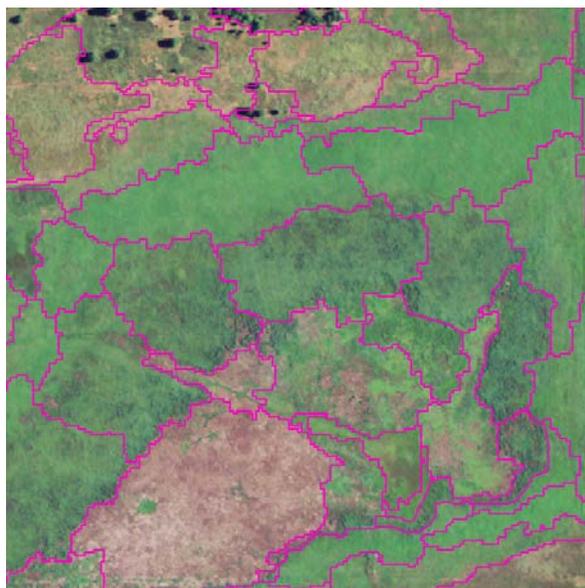


Figure 1. Example of vegetation community segments created in eCognition by grouping imagery pixels of similar values. Pink lines indicate segment outlines.

To make the vegetation map as accurate as possible, the resulting polygons were loaded into ArcMap, where we manually segmented the polygons further when we believed the polygon contained more than one vegetation community based on mid-summer imagery. Polygons were then assigned a unique polygon identifier.

Field Vegetation Surveys

To create the 2012 vegetation map, field data describing the vegetation communities had to be collected. A total of 12,594 points were surveyed on RWB wetlands, of which 2,698 points were on WRP sites, 248 were on other long-term private easements, 2,827 were on WMAs, and 6,821

were on WPAs. Points on WRP and other private easements were created in the center of randomly selected vegetation community polygons created in eCognition, whereas the points on WMA and WPA properties were initially created for a vegetation monitoring project and were located using a combination of transect midpoints through distinct vegetation communities and randomly generated points in underrepresented communities (Figure 2; Nugent et al. 2015).

Surveys were conducted between 27 August and 9 November, 2012. A GPS unit was used to navigate to a point, where we placed a 1-m² sampling frame. We then recorded all vegetation cover types and associated percentage ranges within the frame. Vegetation cover types were a predetermined list of 37 species and groups of species chosen based on their commonness (e.g., ragweed [*Ambrosia* spp.]) and importance to wetland management (e.g., phragmites [*Phragmites australis*]). Percentage ranges included 0–5%, 6–25%, 26–50%, 51–75%, 76–95%, 96–100%.

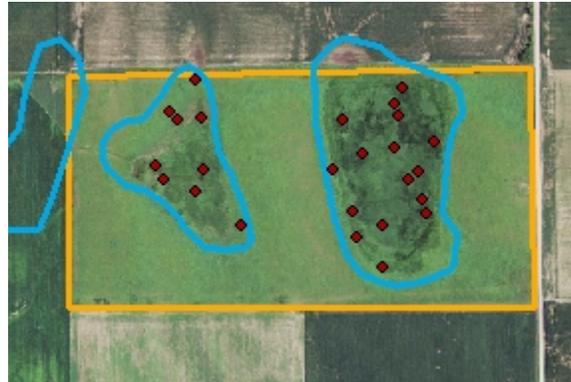


Figure 2. Example of survey points (red points) on Meadowlark Waterfowl Production Area (yellow outline). Blue outlines indicate the wetland areas.

On WRP and other private easement wetlands, if the vegetation within the 1-m² sampling frame did not represent the immediate vegetation community, monitoring assessment area was increased to a 10-m² sample area. We accepted this bias because the vegetation information that was collected was strictly for mapping purposes to describe the polygon. However, we never increased the sample area outside of the sampling frame at monitoring points on WMA or WPA properties because those data were also used for another project evaluating annual change in vegetation as a result of management activities.

Field Data Management

Once surveys were completed, survey data were loaded into Microsoft Access 2007 (Microsoft Corporation, Redmond, Washington). Using a combination of Access and Microsoft Excel 2007 (Microsoft Corporation, Redmond, Washington), we converted the raw data into a usable format. We first converted percentage ranges to their midpoint (e.g., 5–25% became 15%). Our next step was to relativize all midpoints to ensure that each point was equally weighted in the analysis. To do so, we summed the midpoints for all cover types at a point and divided each midpoint by the sum. For example, a plot with 75–95% reed canarygrass, 5–25% annual smartweeds (*Polygonum* spp.), and 5–25% barnyardgrass (*Echinochloa* spp.) would be assigned midpoints of 85%, 15%, and 15%, respectively. These midpoints would total 115%, so the midpoint of each observation would be divided by 115. As a result, the relativized percent covers would equal 74% reed canarygrass, 13% annual smartweeds, and 13% barnyardgrass.

Assigning Training and Testing Data

A shapefile of the field survey points was loaded into ArcMap with the segmented wetlands shapefile. Using a spatial join, we added the unique polygon identifiers to the survey points shapefile. In Access, we opened the survey points shapefile's attribute table and the field survey data. The unique polygon identifiers were joined to the field data based on survey point numbers. The 37 different vegetation cover types used to describe vegetation in the field were aggregated into nine more general categories: Bare Soil/Mudflat, Cattail, Grass, Moist-Soil Species, Reed Canarygrass, River Bulrush, Water, Wet Meadow Species, and Woody Species. We used the relativized field data, including unique polygon identifiers, to determine the map class each polygon represented. In the relativized field data, we assigned each cover type its associated map class. For a unique polygon identifier, the relativized midpoints of each map class were summed. In Excel, we conducted a series of queries to determine the dominant map class of each unique polygon identifier. If two or more map classes were tied, we assigned the polygon "mixed."

The surveyed polygons' map classes were joined to the segmented polygon shapefile in ArcMap based on the unique polygon identifiers. We then specified surveyed polygons as training or testing data. Training polygons were used to teach eCognition the imagery pixel characteristics (i.e., spectral signatures) of each map class. Testing polygons were used to assess the accuracy of the final vegetation map. To determine the number of polygons needed as training data, we used the following equations from Congalton and Green (1999):

$$n = B \times \prod_i \times (1 - \prod_i) / b_i^2$$

and

$$B = \chi^2_{(1,\alpha/k)}$$

where

n = number of samples

\prod_i = percentage of the map area covered by the class, based on field data

b_i = precision

α = confidence level

k = number of classes

For eCognition to have the best possible training data, we used polygons that were dominated by a single map class. For each map class, we first randomly selected n polygons that were $\geq 75\%$ dominated by the map class and assigned them as training data. If fewer than n polygons were $\geq 75\%$ dominated by a class, we then randomly selected additional polygons containing 70–74% of the class in order to have n training polygons. For all of the map classes, we had sufficient polygons with $\geq 70\%$ dominance to use as training data. If possible, we also set the minimum number of testing polygons to equal n . If the number of sampled polygons with $> 50\%$ dominance was $> 2n$, then any extra polygons with $\geq 75\%$ dominance were assigned as training polygons as well. The remainder of the polygons with $> 50\%$ dominance, and not used for training data, was assigned as testing polygons. Polygons with $\leq 50\%$ dominance were used as neither training nor testing polygons.

Classification of Vegetation Communities

Because the spring and late-summer imagery did not extend to the very edges of the RWB region (e.g., Dawson County), segmented polygons had to be classified in two sets. The interior portion of the RWB region (90.2% of the RWB wetland area) contained all three image sets. However, the remaining, exterior region only had mid-summer imagery. To develop the separate datasets, we first created a polygon encompassing the interior region containing all image sets. We clipped the segmented wetlands shapefile by the interior region to generate the interior wetlands. We then erased the surveyed properties from the interior region polygon and used that to erase the interior region from the wetlands shapefile, leaving only the exterior wetlands and surveyed areas. The surveyed interior wetlands were included with the exterior wetlands to have sufficient training data to complete the supervised classification.

Interior wetlands were classified in eCognition, where we loaded the resampled spring, mid-, and late-summer imagery and the segmented interior wetlands shapefile as the thematic layer. We conducted a chessboard segmentation to create polygons of the wetland segments. The assign class tool was used to classify the training polygons based on field data and the classified image objects to samples tool was used to set the training polygons as samples. We edited the standard nearest neighbor feature space to select the mean pixel value of each of our nine imagery bands, standard deviation of each band, maximum difference between imagery bands, and brightness within each polygon. We then applied the standard nearest neighbor feature space to our map classes. A supervised classification was conducted, which assigned a map class to every polygon based on the training data's characteristics of the 20 nearest neighbor feature space parameters.

We followed the same methods to classify the exterior wetlands as the interior wetlands, except we only used mid-summer imagery. First, we loaded the resampled mid-summer imagery and set the exterior wetlands shapefile, including the sampled interior wetlands, as the thematic layer. We then executed the same tools as with the interior wetlands, including chessboard segmentation, assign class, classified image objects to samples, edit standard nearest neighbor feature space and applied it to classes, and supervised classification. The only difference was our standard nearest neighbor feature space only included three imagery bands for a total of eight parameters, including the mean of each band, standard deviation of each band, maximum difference between bands, and brightness. For the exterior wetlands, the interior wetlands training polygons were needed to provide sufficient training data to complete the supervised classification.

Classified interior polygons were exported from eCognition and loaded in ArcMap. We added a text field called "Vegetation" in the corresponding shapefile and populated it with the appropriate map class. We then divided the interior wetlands into three regions: northeast, southeast, and west regions. These regions were developed to decrease drawing time in ArcMap. We imported the three regions as feature classes into a geodatabase we had previously made in ArcCatalog 10 (ESRI, Redlands, California). In the geodatabase, we created a domain of the map classes and applied it to each feature class' Vegetation field, which provided a map class dropdown list and thereby reduced data entry errors. The classified polygons, training data, non-resampled county aerial imagery, and Light Detection and Ranging (LiDAR) elevation data were loaded into ArcMap. We used these datasets to manually verify that every polygon was logically

classified based on the imagery, surrounding vegetation communities, training data, elevation, and knowledge of aerial imagery. The map class “Agriculture” was also created and assigned to all cultivated polygons based on aerial imagery.

The testing polygons were manually verified a second time. The twice-verified testing polygons were then selected and exported as separate shapefiles to be used later for the accuracy assessment.

After the accuracy assessment shapefiles were created, we reclassified all surveyed polygons, including testing polygons, to their field-verified map class. The surveyed polygons assigned “mixed” based on field data (i.e., equally dominated by ≥ 2 map classes) were manually set to one of the tied classes based on imagery and adjacent vegetation communities. All the remaining, non-testing interior polygons were verified a second time using the same procedure as the first round of verification, except we used all the field-surveyed polygons as references to increase the map’s accuracy.

We exported the classified exterior polygons from eCognition. In ArcMap, we erased the sampled interior wetlands used for training data, leaving only the exterior wetlands. We used the same method to verify the exterior wetlands as the interior. First, we added the Vegetation field, in which we assigned the eCognition-produced map class. The file was uploaded into the geodatabase containing interior polygons and the domain was applied to the Vegetation field. We again used the mid-summer imagery, surrounding vegetation communities, training data, and LiDAR elevation to verify the map classes of all polygons. Because of the lack of other 2012 imagery, we referenced the 2010 mid-summer, true color imagery available from the Farm Service Agency when there was cloud cover in the 2012 imagery or as a secondary reference when oddities in the classification were observed. All field-surveyed polygons were assigned their appropriate map class and “mixed” polygons were manually classified based on survey data and surrounding communities. When the second round of verification was complete, we merged all interior and exterior regions into a single shapefile.

To increase our accuracy further, we reclassified the surveyed polygons that were initially classified as Bare Soil/Mudflat but overlapped areas disked for vegetation management after imagery acquisition but prior to field surveys. We reclassified these polygons because the assignment of Bare Soil/Mudflat may have only reflected the recent disking and not the vegetation present at the time of imagery acquisition. We used a shapefile of all RWB wetland disking activities conducted by RWBJV partners and selected by location all polygons intersecting disking activities. A field was created that indicated whether polygons were disked or not. We used the mid-summer imagery to determine if field surveyed Bare Soil/Mudflat polygons should be classified as such, and so were left as Bare Soil/Mudflat, or if actively growing vegetation was present in the imagery and the assignment was only due to disking, for which we changed the map class. When a polygon was reclassified, we based the new classification on other species present in the 2012 field surveys. For example, if a polygon contained 50–75% bare soil and 25–50% cattail, the polygon was reassigned as Cattail. If no other cover types were present in the 2012 field surveys, polygons were reclassified based on field vegetation surveys conducted at the same survey points in 2013.

Incorporation of Irrigation Reuse Pits

Irrigation reuse pits and water concentration pits were excavated in many historical wetlands to facilitate cropping of the wetland. To incorporate irrigation reuse pits into the vegetation map, we used a shapefile containing all irrigation reuse pits in the RWB region (RWBJV 2012) and deleted pits filled with soil as part of the RWBJV Watershed Restoration Initiative. We then performed an identity overlay with the vegetation map as the input and the irrigation reuse pits shapefile as the identity feature. A field labeled “Pit” was created and populated with whether polygons overlapped an irrigation reuse pit or not. To remove slivers caused by the identity, an eliminate was conducted to merge polygons $<40 \text{ m}^2$ with neighboring polygons. We verified that all remaining polygons $<40 \text{ m}^2$ were not topologically adjacent to other polygons and deleted them.

Identification of Cropped Wetlands

Many historical RWB wetlands contain irrigation reuse pits and/or other hydrologic modifications so wetlands can be cropped. Significantly impacted wetlands rarely, if ever, pond water and have little to no wetland functionality. Less impacted wetlands, however, pond water seasonally or every few years, which produces a flush of annual wetland vegetation and can provide important habitat for wetland-dependent birds. These frequently ponded, cultivated wetlands have been termed “cropped wetlands” to distinguish them from cultivated wetlands that rarely exhibit wetlands characteristics.

To identify cropped wetland areas, we used previous shapefiles of ponded areas created for the Annual Habitat Survey (AHS; Bishop et al., RWBJV, in review). The AHS assessments were conducted in 2004 and annually from 2006–2012. For each year of AHS, infrared aerial imagery was collected during peak spring waterfowl migration (e.g., 27 February–14 March, 2006) and covered most (e.g., 92% in 2006) of the RWB wetlands (Bishop et al., RWBJV, in review). Each year’s shapefile identified the historical RWB wetland areas of ponded water, wetland vegetation, and historical nonfunctional wetland (Bishop et al., RWBJV, in review). Cropped wetlands were defined as those cultivated areas that ponded water in $\geq 25\%$ of the AHS assessment years.

Because the extent of AHS data varied slightly between years, we created shapefiles delineating the spatial extent of imagery for each AHS year. These shapefiles were combined with a union overlay. In the attribute table of the resulting shapefile, we added a field detailing the number of years each polygon was surveyed. This shapefile was then converted to a raster file based on the years surveyed field. All “no data” values were converted to one using the reclassify tool to create the final years surveyed raster. “No data” values could not be converted to zero because the raster would be used as the denominator in a division equation.

To determine the number of years an area ponded water, we first added a field to each of the AHS shapefiles (one for each year of analysis) in which we assigned a one to ponded areas and zero to non-ponded areas. Each shapefile was then converted to a raster based on the binary ponded field. We used the raster calculator to match the extent and cell alignment for all rasters. In the raster calculator, we set the function to equal the original raster and both the output extent

and snapping raster to the years surveyed raster. The binary ponded rasters were all summed using the raster calculator to determine the number of years each cell ponded water. The resulting raster was reclassified so all “no data” values became zero to create the final years ponded raster.

We then determined the areas that pond $\geq 25\%$ of the time by first dividing the years ponded raster by the years surveyed raster (Figure 3a). A reclassify was conducted on the resulting raster to convert all values < 0.25 to zero and ≥ 0.25 to one, which created a raster of areas that ponded water at least 25% of the time (Figure 3b). The binary raster was then converted to a shapefile.

To integrate the areas that pond $\geq 25\%$ of the time into the vegetation map, we exported all of the Agriculture polygons from the vegetation map and all of the remaining, wetland vegetation as two separate shapefiles. We performed an identity overlay to combine the ponded areas with the Agriculture polygons by setting the Agriculture polygons shapefile as the input and the ponded $\geq 25\%$ of the time shapefile as the identity feature. In the output, we selected all polygons that ponded $\geq 25\%$ of the time and changed the map class to Cropped Wetland. We then dissolved by the Vegetation, Pit, and unique polygon identifier fields. To remove slivers caused by the identity, we used the eliminate tool to merge all polygons $< 25 \text{ m}^2$ with neighboring polygons. The remaining polygons $< 25 \text{ m}^2$ were selected and manually merged with neighboring polygons. We then merged the Agriculture and Cropped Wetland shapefile with the shapefile of the other wetland vegetation to recombine the vegetation map.

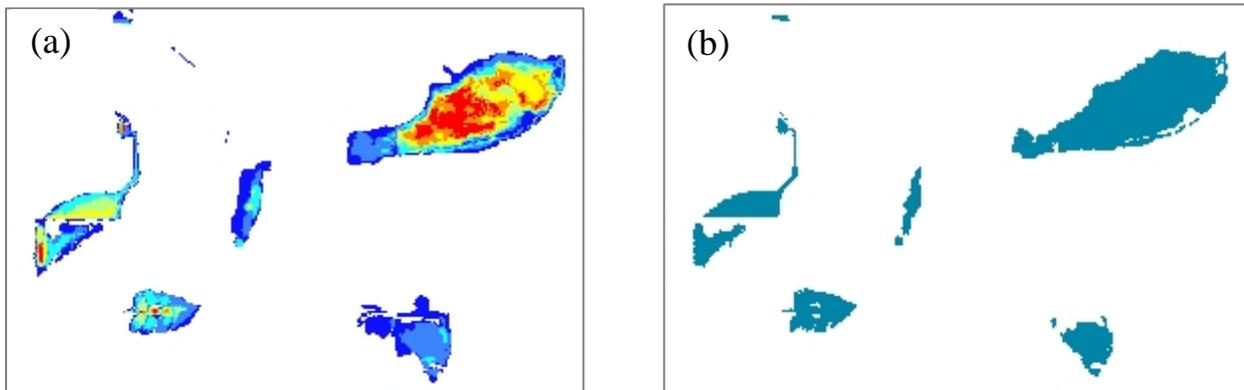


Figure 3. A portion of the 2012 wetland vegetation map, showing (a) the proportion of years areas ponded water, ranging from dark blue (1 out of 8 years) to red (8 out of 8 years), and (b) the areas that pond $\geq 25\%$ of the time, shown in blue.

Topology Maintenance

First, we used the repair geometry tool to delete polygons with null geometry. We then created a topology with the rule polygons must not overlap and corrected all errors. To reduce the number of polygons, we dissolved based on the Vegetation and Pit fields. Finally, we created area fields for acres and square meters and calculated geometry for each area field.

Accuracy Assessment

We based the accuracy of the vegetation map on the previously saved shapefiles of testing polygons. The polygon shapefiles' attribute tables included each polygon's field-verified class, twice verified vegetation map class, and area. The attribute tables of the testing data shapefiles were opened in Excel. The attribute tables were combined into one table, the information from which we used to calculate the overall, producer, and user accuracies. Producer accuracy evaluates errors of omission for each class where the area correctly classified when compared with field-collected reference data was divided by the total reference data area of the class. For example, a high producer accuracy of Water indicates that most of the polygons that should be classified as Water were classified correctly; however, additional polygons that were not Water may be incorrectly classified as Water. User accuracy represents the probability that classification correctly matches field conditions, ignoring errors of omission and only evaluating errors of commission, by calculating the area correctly assigned to a class divided by the total area of that class in the vegetation map. High user accuracy of Water indicates that if a polygon was classified as Water, it was very likely water. However, water areas that were incorrectly classified as something other than Water have no effect on user accuracy.

The accuracy of non-surveyed natural vegetation (i.e., all map classes except Agriculture and Cropped Wetland) polygons was calculated as the area of correctly classified polygons for all classes divided by the total testing polygon area. In the final product, all surveyed polygons, including both training and testing, were recoded to the correct class and, therefore, accuracy for surveyed polygons is 100%. To calculate the overall accuracy of surveyed properties and the overall accuracy for the entire RWB complex, three area values were calculated using the Statistics tool in ArcMap: surveyed polygons, natural vegetation in the entire map, and natural vegetation on surveyed properties. We then calculated the accuracy, by area, of all surveyed and non-surveyed natural vegetation in the overall map and surveyed properties. The surveyed property accuracy and overall accuracy were calculated as $\text{Accuracy} = (\% \text{Surveyed area} \times \% \text{Surveyed accuracy}) + (\% \text{Non-surveyed area} \times \% \text{Non-surveyed accuracy})$.

Results and Discussion

Vegetation Map

The final vegetation map contained 45,777 individual polygons covering 79,575 ha (Figure 4). Long-term WRP sites contained 1,545 ha of wetlands, other long-term private easements 226 ha, WMA properties 2,316 ha, and WPA properties 5,480 ha. The most common map class on conservation lands was Moist-Soil Species, followed distantly by Grass and Reed Canarygrass (Table 1). The predominance of the Moist-Soil Species map class was due to management activities on conservation lands that promote moist-soil species, which are beneficial to waterfowl and other wetland-dependent wildlife.

A total of 6,961 undissolved polygons were surveyed. Training data consisted of 3,424 undissolved surveyed polygons and testing data consisted of 2,459 undissolved polygons. The remaining 1,078 surveyed polygons were not used for testing or training data because each polygon's most common map class did not cover >50% of the polygon's surveyed area, which

was a requirement of training and testing data. Surveyed polygons covered 58.2% of surveyed properties, 32.6% of all the natural vegetation, and 7.7% of the entire vegetation map.

In the entire vegetation map, the Agriculture map class was by far the most common, covering 77% of the historical wetland area (Table 2). The prevalence of agriculture can be attributed to the historical modifications of RWB wetlands to facilitate cropping. Among the natural vegetation types, Moist-Soil Species was the most common due to habitat managers employing techniques to promote these species and privately-owned wetlands often being integrated into farm operations, the disturbance from which promotes moist-soil species. The least common map class was Water because of region-wide drought conditions in 2012 and the ephemeral nature of RWB wetlands. The vegetation map contained 496 ha of irrigation reuse pits, and 925 ha of wetlands on conservation lands that were disked in 2012.

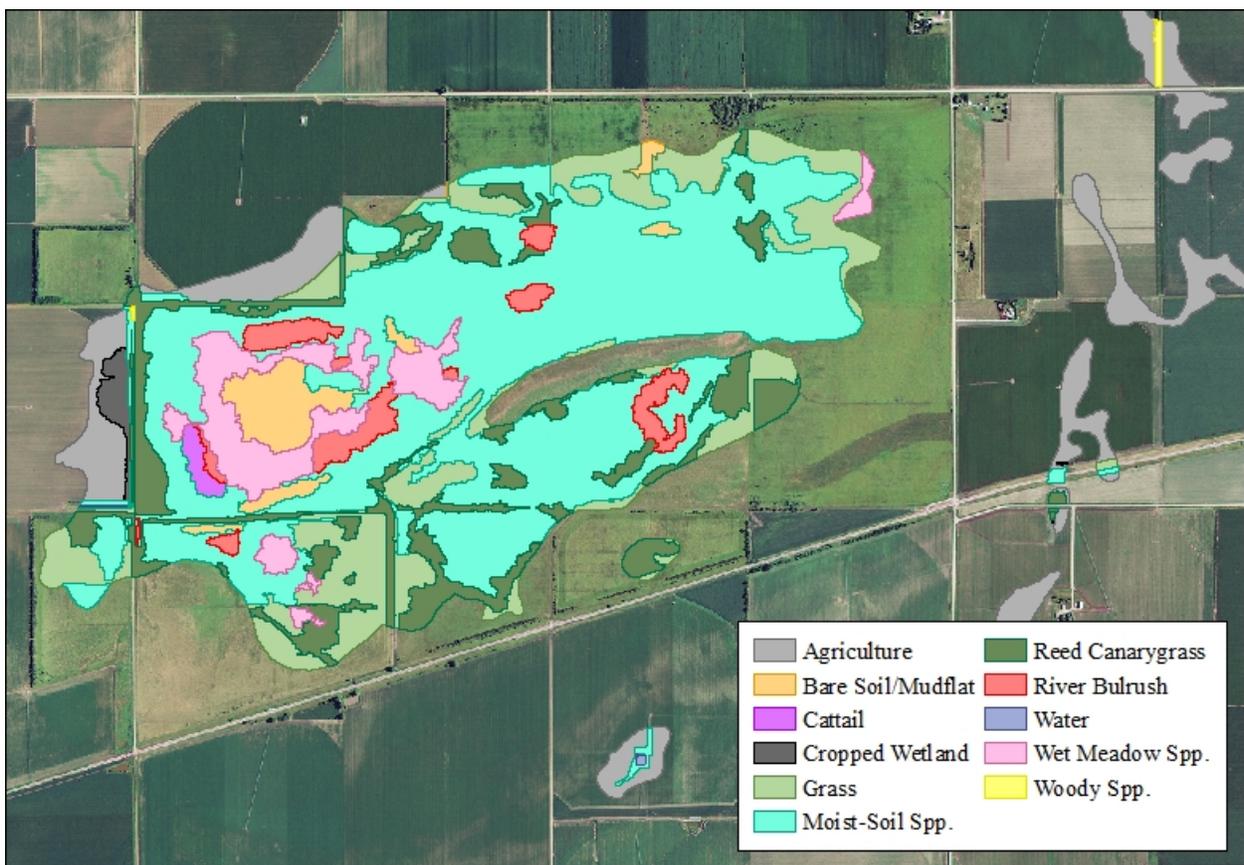


Figure 4. Wetlands in Clay County, Nebraska, representing a portion of the final 2012 vegetation map, including 2012 mid-summer aerial imagery, of the Rainwater Basin.

Table 1. Area (ha) of each vegetation map class and the percentage of the property type's area for long-term Wetlands Reserve Program sites (WRP), other long-term private easements (Other), Wildlife Management Areas (WMA), Waterfowl Production Areas (WPA), and all sites combined in the Rainwater Basin region of Nebraska.

	WRP		Other		WMA		WPA		All	
	ha	%	ha	%	ha	%	ha	%	ha	%
Moist-Soil Spp.	789.0	48.0	95.8	42.3	1,212.8	52.4	1,999.5	36.5	4,097.1	42.4
Wet Meadow Spp.	167.1	10.2	9.5	4.2	152.5	6.6	504.5	9.2	833.6	8.6
Bare Soil/Mudflat	76.2	4.6	13.6	6.0	106.3	4.6	284.0	5.2	480.1	5.0
Water	3.4	0.2	4.1	1.8	43.7	1.9	82.2	1.5	133.3	1.4
Cattail	30.6	1.9	6.8	3.0	59.2	2.6	163.6	3.0	260.2	2.7
Reed Canarygrass	218.3	13.3	40.7	18.0	287.4	12.4	599.3	10.9	1,145.8	11.9
River Bulrush	39.5	2.4	6.6	2.9	65.4	2.8	401.6	7.3	513.0	5.3
Grass	282.3	17.2	39.5	17.5	357.4	15.4	1,403.4	25.6	2,082.6	21.5
Woody Spp.	8.2	0.5	0.7	0.3	25.9	1.1	31.2	0.6	66.1	0.7
Cropped Wetland	0.9	0.1	1.4	0.6	0.1	0.0	1.4	0.0	3.9	0.0
Agriculture	28.5	1.7	7.5	3.3	5.0	0.2	9.6	0.2	50.7	0.5

Table 2. Area of each map class in the final vegetation map of wetlands in the Rainwater Basin, Nebraska. Also included are the percentage of the area of the entire map each map class covers and percentage of the area of natural vegetation (i.e., not Agriculture or Cropped Wetland) each of the non-cultivated classes covers.

Class	Area (ha)	% of Entire Map	% of Natural Vegetation
Moist-Soil Species	7,059.1	8.9	39.5
Wet Meadow Species	1,305.5	1.6	7.3
Bare Soil/Mudflat	686.8	0.9	3.8
Water	468.5	0.6	2.6
Cattail	488.9	0.6	2.7
Reed Canarygrass	2,650.5	3.3	14.8
River Bulrush	678.5	0.9	3.8
Grass	3,974.2	5.0	22.2
Woody Species	575.9	0.7	3.2
Cropped Wetland	709.8	0.9	---
Agriculture	60,977.3	76.6	---

Accuracy Assessment

Non-surveyed natural vegetation polygons were 62.9% accurate. When combined with the 100% accuracy of surveyed polygons, natural vegetation accuracy was 84.5% on surveyed properties, 62.9% on non-surveyed properties, and 75.0% for the overall map. Because we did not survey cultivated wetlands, the accuracy of the Agriculture and Cropped Wetland map classes was not assessed. However, cultivated areas have a distinct, homogeneous appearance on aerial imagery, so their accuracies are likely near 100%. The Agriculture map class' producer and user accuracies in the 2004 RWB wetland vegetation map were 99.9% and 99.2%, respectively (Bishop and Vrtiska 2008). We assumed the 2012 vegetation map had similar accuracies.

Reed canarygrass had the highest producer accuracy, while Bare Soil/Mudflat had the lowest (Table 3). The lower producer accuracy of Bare Soil/Mudflat was due to it being difficult to distinguish when its dominance was near 50%, although it was easily distinguishable when >75% dominant. Water and Woody Species map classes had the highest user accuracies because they were easily distinguishable when >75% dominant. User accuracy was lowest for River Bulrush and Reed Canarygrass. The higher producer but lower user accuracy for Reed Canarygrass was because areas that appeared white in the spring imagery were usually, but not always, Reed Canarygrass. Since the Reed Canarygrass class was most frequently confounded by moist-soil, it's likely that some species within the moist-soil community have similar seasonal growth cycles.

Table 3. The error matrix and producer and user accuracies for each surveyed map class in the 2012 wetland vegetation map in the Rainwater Basin, Nebraska. Producer accuracies represent the probability a testing area was correctly classified. User accuracies represent the probability classification correctly denoted field conditions. Shaded cells are the area (ha) of each class that is classified correctly. Testing data were based on field vegetation surveys conducted in 2012.

		Testing Data Classification (ha)										Accuracy (%)	
		Moist-S.	W. Mead.	B. Soil/Mud.	Water	Cattail	R. Canar.	Riv. Bul.	Grass	Woody	Total	Producer	User
Vegetation Map Classification (ha)	Moist-Soil Spp.	599.4	70.0	52.9	1.8	12.0	13.6	65.1	74.4	13.2	902.5	73.0	66.4
	Wet Meadow Spp.	45.1	103.1	2.4	0.0	0.0	1.9	11.6	21.5	0.3	185.9	45.6	55.5
	Bare Soil/Mudflat	21.3	1.8	43.0	0.0	0.7	1.0	0.9	5.0	2.5	76.2	31.8	56.4
	Water	0.2	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	1.9	40.7	91.8
	Cattail	12.6	0.6	4.4	0.0	32.8	3.7	0.3	0.0	4.9	59.4	58.8	55.2
	Reed Canarygrass	38.0	3.7	5.6	0.3	7.5	74.1	1.0	1.9	3.1	135.1	76.4	54.8
	River Bulrush	54.1	13.6	6.1	0.0	2.8	1.8	132.0	33.8	0.0	244.2	57.4	54.1
	Grass	49.4	33.1	19.6	0.4	0.0	0.5	19.4	257.3	0.0	379.7	65.3	67.8
	Woody Spp.	0.5	0.0	1.2	0.0	0.0	0.3	0.0	0.0	18.5	20.5	43.5	90.2
	Total	820.6	225.9	135.1	4.3	55.8	97.0	230.2	394.0	42.5	2005.3		

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