PROGRESS REPORT

MAPPING THE RIPARIAN VEGETATION USING MULTIPLE HYPERSPECTRAL AIRBORNE IMAGERY OVER THE REPUBLICAN RIVER, NEBRASKA

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PROJECT SUMMARY

As the dependency on rivers for fresh water increases, rivers ecosystem analysis becomes essential for proper water management and riparian vegetation protection. Changes in river water flow pattern have affected the riparian vegetation distribution and encouraged invasive species to replace the native ones. Therefore, mapping the riparian vegetation is very important to quantify the riparian forest and provide information about the areas and locations of the invasive species to help in the invasive species control measures. We used high spectral and spatial resolution imagery to map the riparian vegetation in the Republican River Basin in Nebraska (Neb.). Four flights were conducted during the summer of 2009 using AisaEagle Airborne Hyperspectral Imaging System and FLIR SC640 thermal digital camera. The AisaEagle acquires visible and near infrared images in the waver band over 400 - 970 nm of the electromagnetic spectrum, while the thermal infrared captures images in the range of 800-1200 nm. Early and mid-season images were primarily acquired to classify the overstory cottonwood (*Populus spp*.) vegetation. The late-season images were primarily acquired to classify the understory vegetation and the invasive eastern redcedar (*Juniperus virginiana*) after the senescence of cottonwood leaves. The land use map was developed using a supervised classification technique. The high resolution imagery delineated the riparian vegetation accurately with an overall classification accuracy of 85%. The classification accuracy was assessed using ground truth information obtained through comprehensive field campaigns. Results indicated that high resolution imagery is very useful in mapping both heterogonous forest systems and woody invasive species along the Republican River Basin. The map will eventually help in estimating water use from riparian vegetation in conjunction with evapotranspiration maps. The information will be very useful for water managers in the state in order to decide on how much water could be diverted from the river and how to distribute it while preserving the river ecosystem.

BACKGROUND

Imagery from the LANDSAT Thematic Mapper (TM) and SPOT-HRV (‘‘Syste`me Pour l’Observation de la Terre’’—High Resolution Visible) satellite instruments have proven insufficient for differentiating vegetation types in detailed vegetation studies (Harvey and Hill, 2001; Kalliola and Syrjanen, 1991) mostly due to spatial resolution issues. The use of these images resulted in 40% or less classification accuracy (Czaplewski and Patterson, 2003). Satellite multi-spectral imagery, by virtue of its ability to cover large areas, has also been used to map riparian vegetation (Sugumaran et al., 2004; Williams, 1992). Limitations with satellite imagery are (1) the difficulties faced in distinguishing fine, ecological divisions between certain vegetation classes, (2) the larger pixel sizes with respect to the small scale variability in some riparian systems, and (3) the inability of passive sensors (such as optical multi-spectral imagery) from both satellite and airborne platforms to effectively penetrate the canopy and monitor the understory vegetation. Riparian vegetation classes were observed to share common heterogeneous traits and similar spectral responses while using SPOT and TM data (Williams, 1992). It is important to mention that the term high resolution imagery can relate to spatial and spectral resolution. Spatial resolution is defined as the smallest area on the ground surface for which information is obtained in an image represented by a unit picture element or pixel, while spectral resolution represents the number of spectral bands and the bandwidth that can be detected by the sensor or sensors in the RS system.

Vegetation classification and mapping can be achieved using multi-spectral bands in the red, green and the near infrared wavelengths and high spatial resolution imagery is well suited for riparian systems in semi-arid areas (Neale, 1992, 1997). The objective was to map the riparian vegetation at high resolution and identify the native and invasive vegetation species along Republican River Basin in Nebraska.

AERIAL DATA ACQUISITION

The hyperspectral and thermal infrared airborne data acquisition occurred for two invasive tree sites (Bartley and Benkelman) from late June to early November on Republican River Basin in Nebraska. The center of coordinates for Bartley site is at 40^{o} 15’08.92” N, 100^{o} 16’07.22” W and Benkelman’s two sites (40^{o} 01’54.13” N 101^{o}33’39.54” W for Prairie site) (40^{o} 01’48.38” N 101^{o}35’32.53” W for invasive tree site). The flights were acquired in DOY 173 (June22nd), 196 (July15th), 213 (August 1st), and 311 (November 7th) in 2009. This period spans the pre-green-up and growing season to allow for characterizations in ET, and surface water and ground-water interactions. The imagery acquisition in both the shortwave (Hyperspectral) and thermal band occurred simultaneously (Figure 1). The Aisa Eagle hyperspectral imagery was automatically stored with registration while the thermal imagery collected by FLIR SC640 had to be rectified later on using the shortwave imagery collected on the same day. Figure 2 shows the extent of area covered in Nebraska while figure 3 and 4 show hyperspectral imagery acquired on June 22^{nd}, 2009, and Nov 7^{th}, 2009, respectively.

CLASSIFICATION PROCEDURE

An iterative combination of supervised classification and unsupervised procedure was used in this study. First, the supervised seeding routines in ERDAS Imagine 9.3 were used to extract spectral signatures for the major separable riparian classes. The transformed divergence (TD) method was used to test signature separatability. This method statistically compares all spectral signatures in a signature set among them, assigning a TD index number between 0 and 2000, where the value of 2000 indicates total separability and 0 indicates the opposite. The resulting final signature file contained several dozen signatures, many representing the same type of vegetation. In this way, nuances in the signatures caused by bi-directional reflectance effects or density of the vegetation are accounted for. Finally, the classes representing the same vegetation type is recorded into one class. The recoding process reduces the dozens of classes in the classified image into specific basic classes. After the recoding process completion, a 3 x 3 majority filter was applied to the recoded classified image to eliminate isolated pixels. Manual recoding was performed as well to remove any remaining confusion and obvious misclassifications in the classified images.

This classification was done using (a) hyperspectral images and (b) a Normalized Difference Vegetation Index (NDVI). For hyperspectral classification, we used the individual red, green and NIR bands from the hyperspectral images. For the latter, the NDVI was first calculated in order to run the classification.

PRELIMINARY RESULTS

Riparian classification

The assessment of classification accuracy consisted of determining the efficiency of extracting relevant information derived from remotely sensed imagery. The procedure is done on the classified images using ground truth field data that was set aside for this purpose. The accuracy assessment was conducted on the major vegetation classes including Cottonwood, Red cedar, Riparian Grass and Red Willow at the site. Initial assessment of overall accuracy was 89 % with Kappa index of 85% for Hyperspectral imagery. Accuracy was 72% with 69 % Kappa index for NDVI based classification. NDVI classification was not able pick up shadow. In addition, water was confused with wet sand when NDVI based classification was used.

Data on Table 1 shows the areas (hectare) for each riparian class at Bartley. Results showed that overstory vegetation was mainly Red willow and Cottonwood on Bartley site. Once the leaves dropped during fall, the understory on the image was mostly Redcedar trees.

Detailed mapping of the riparian vegetation at high spatial resolution described in this paper will result in a better estimation of the water use by each vegetation type and potentially leading to a more efficient water resources management in the Republican River, Nebraska.

Table 1. Areas (hectares) for each riparian vegetation at Bartley, Neb., on June 22 and November 7, 2009. The riparian vegetation is classified with Hyperspectral (Hyper) and NDVI data.

Class	Hyper June 22nd	Hyper Nov 7th	NDVI June 22nd	NDVI Nov 7th
Shadow	22.5	7.3	0	0
Water	5	7.5	9.7	6.8
Shaded Tree(Redcedar)	22.8	7.3	0	0
Redcedar	47.5	81.2	26.1	72.0
Cottonwood	78.2	0	132.8	0
Red Willow	0	0	6.7	0
Bare Soil, Sand	39.2	70	72.4	108.6
Short Grass, Soil	37.3	70.2	16.5	36.9
Riparian Grass, Crops	89.7	114.9	77.7	95.7
Cottonwood (dropped)	0	90.4	0	93.5

Figure 1. AISA-Eagle Hyperspectral and FLIR SC640 system used for aerial flight campaign.

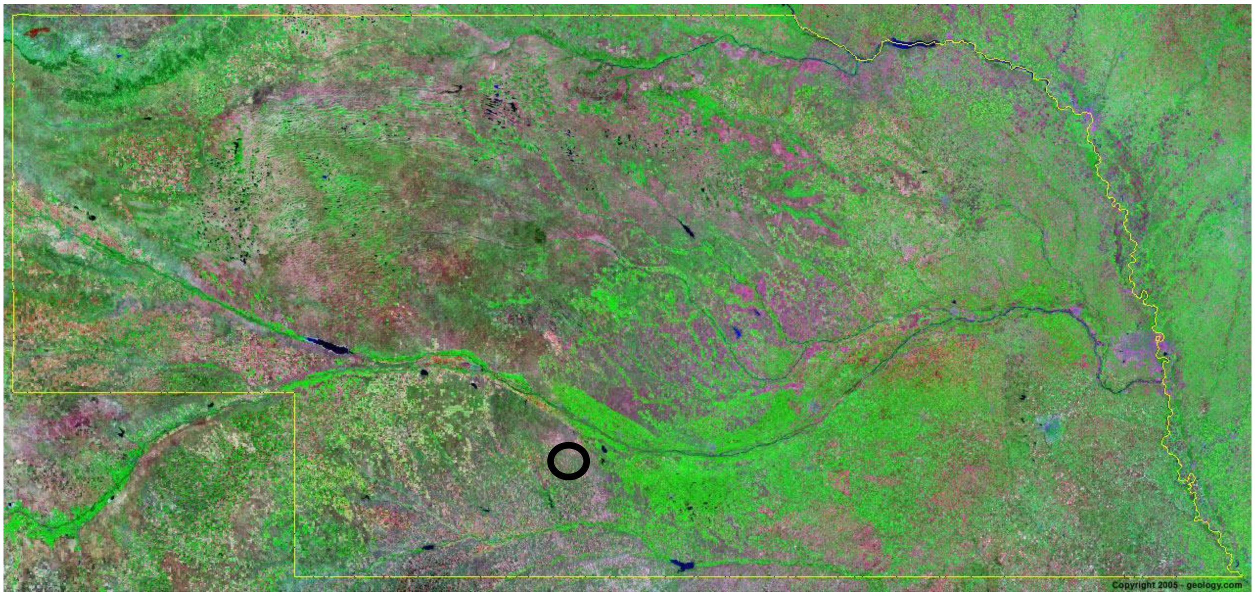

Figure 2. Location of study area (Bartley) is shown with a black circle along Republican Basin, Neb.

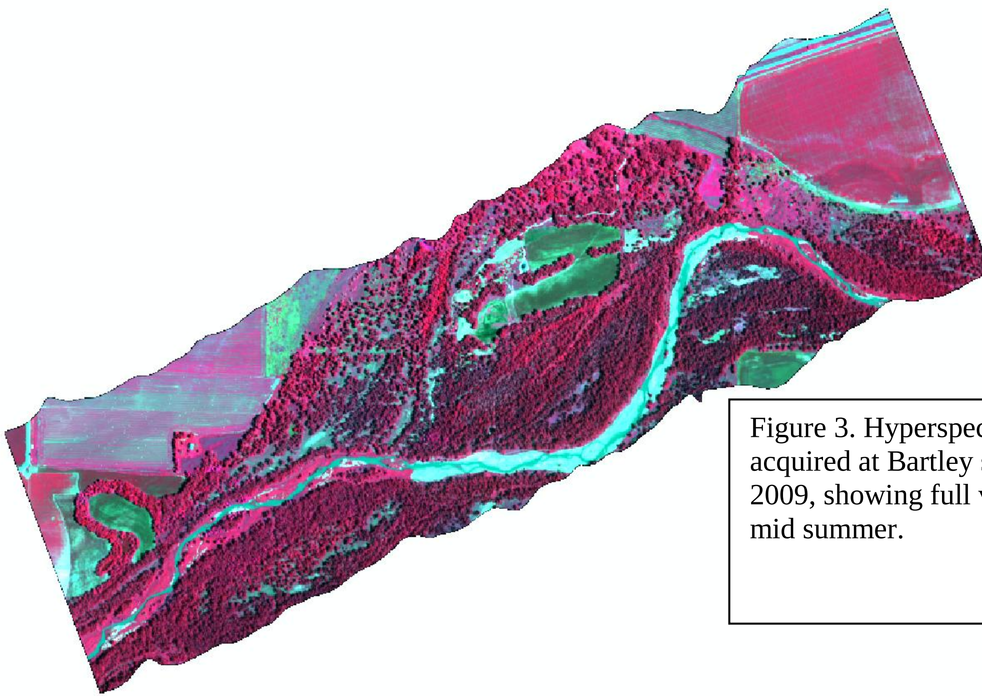

Figure 3. Hyperspectral imagery acquired at Bartley site on June 22, 2009, showing full vegetation cover in mid summer.

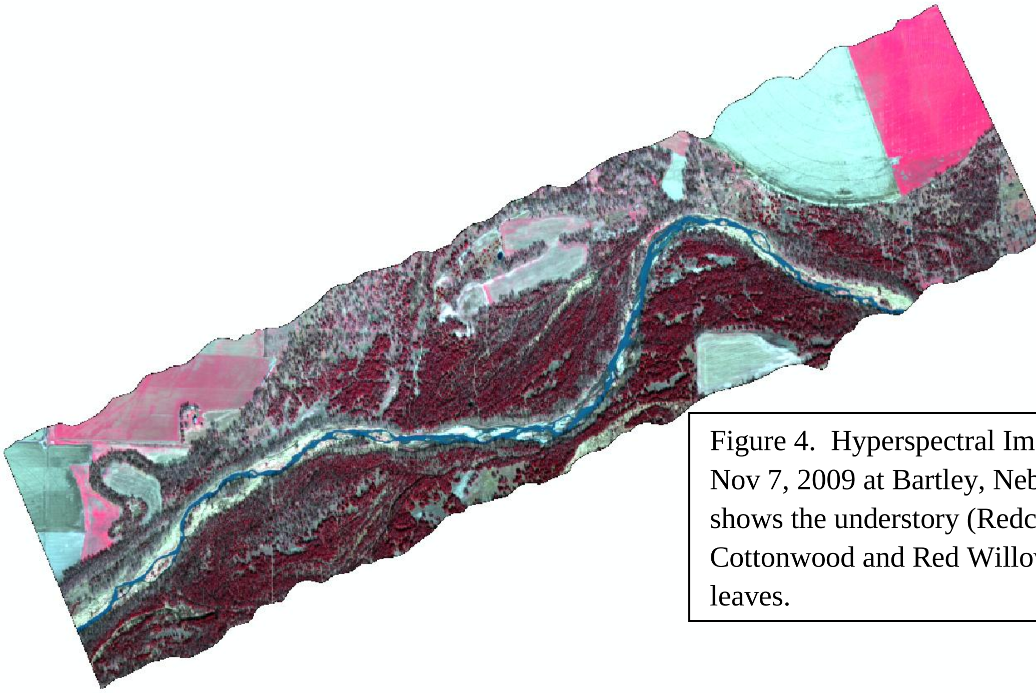

Figure 4. Hyperspectral Imagery acquired on Nov 7, 2009 at Bartley, Neb... The image shows the understory (Redcedar) after the Cottonwood and Red Willow dropped their leaves.

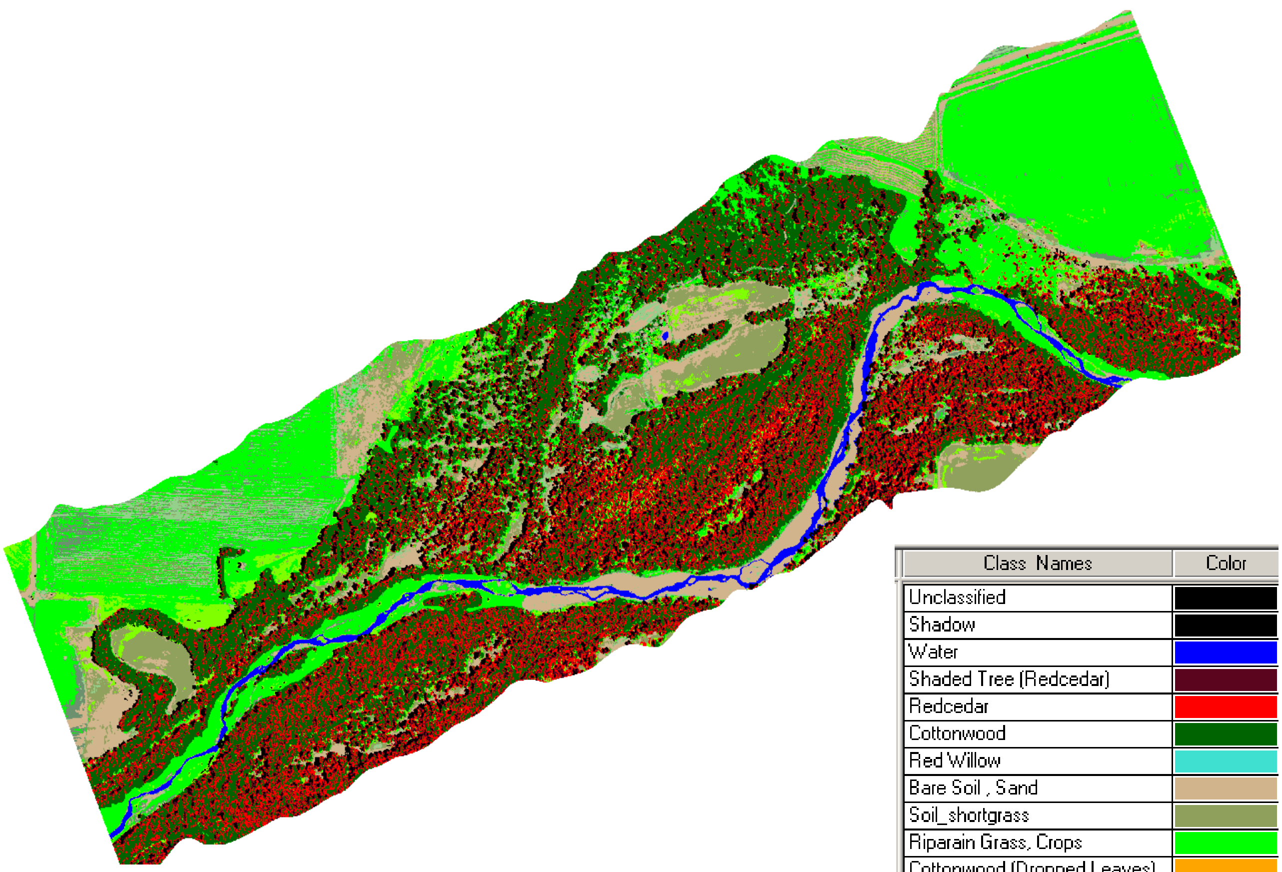

Figure 5. Riparian vegetation classification at Bartley using Hyperspectral data on June 22, 2009.

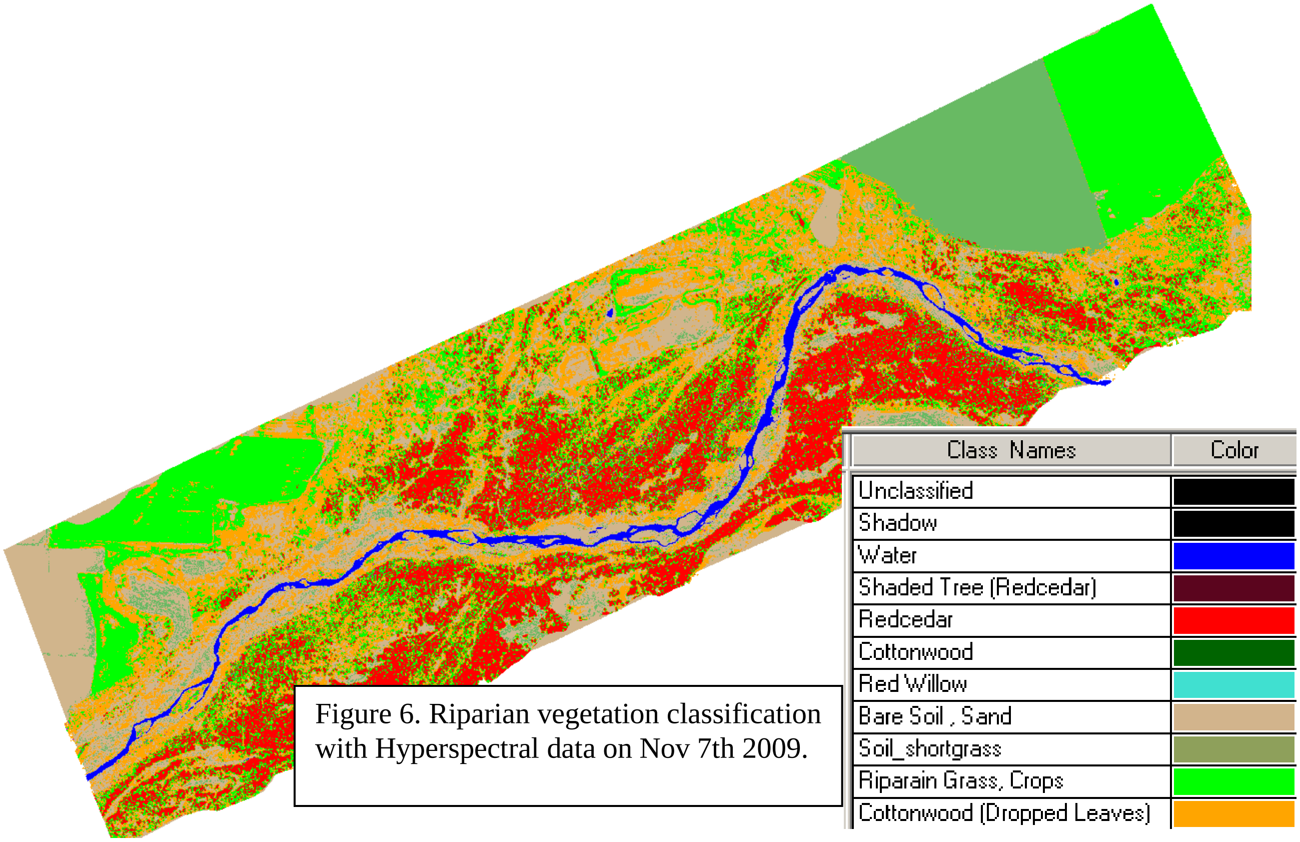

Figure 6. Riparian vegetation classification with Hyperspectral data on Nov 7th 2009.

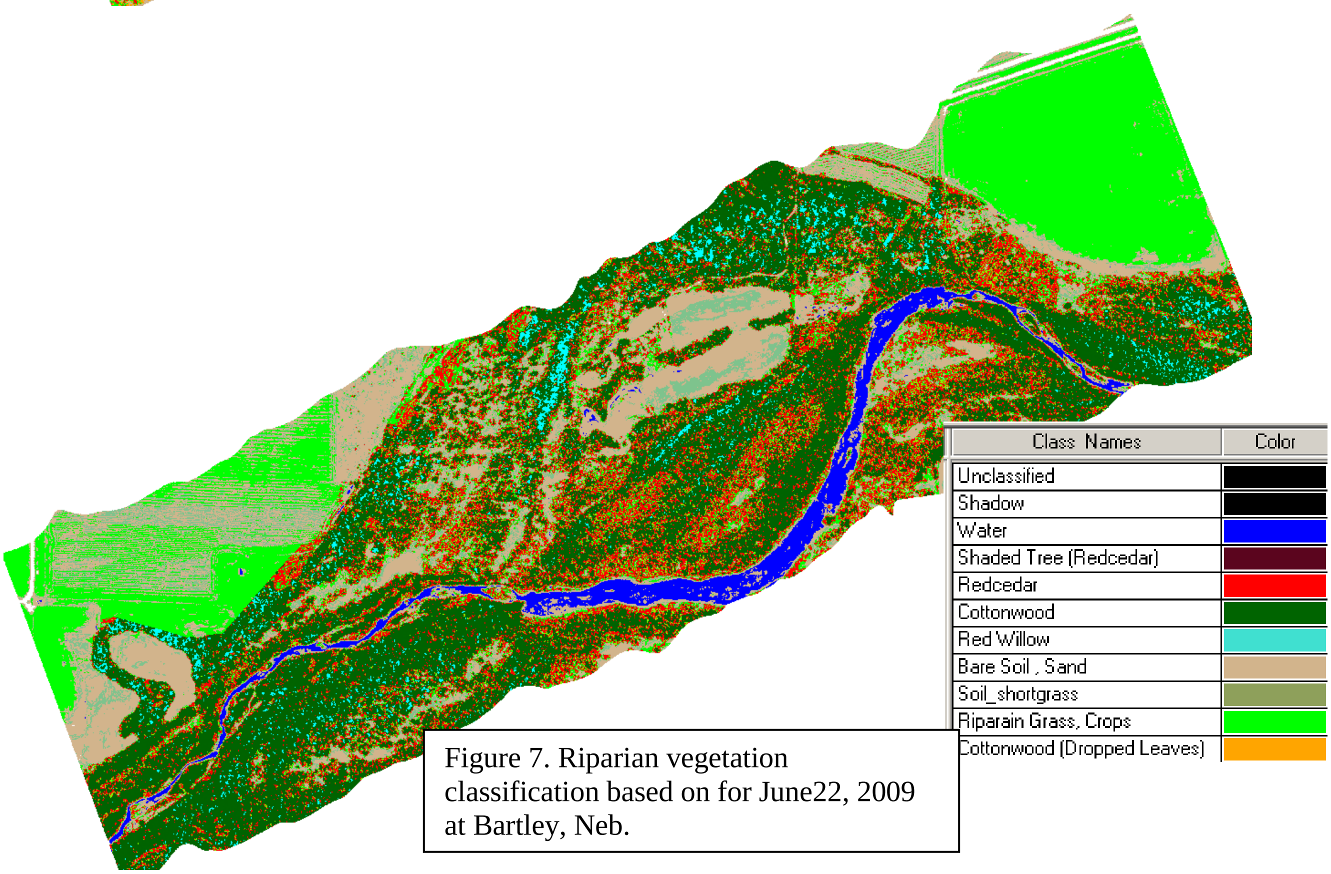

Figure 7. Riparian vegetation classification based on for June22, 2009 at Bartley, Neb.

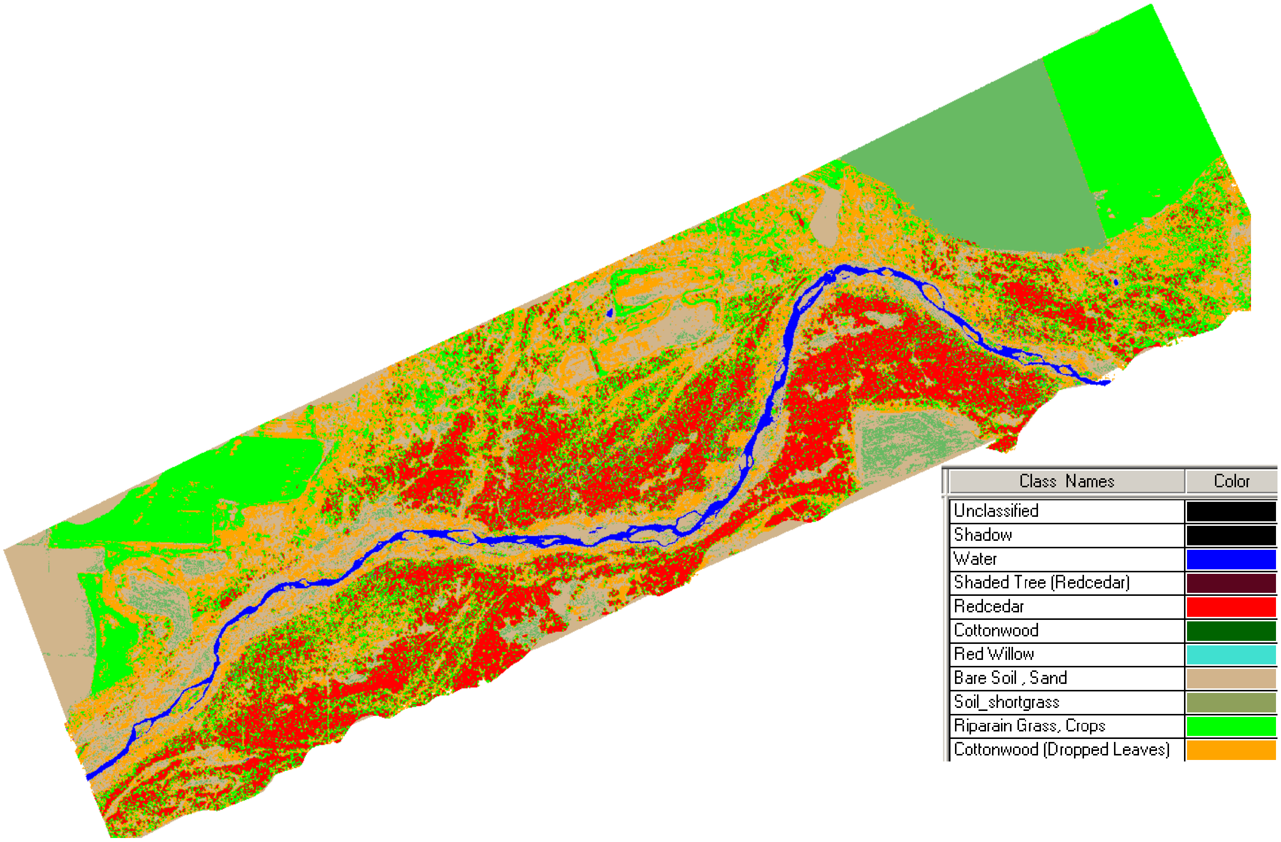

Figure 8. Riparian vegetation classification using NDVI data, Nov 7, 2009**.**

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