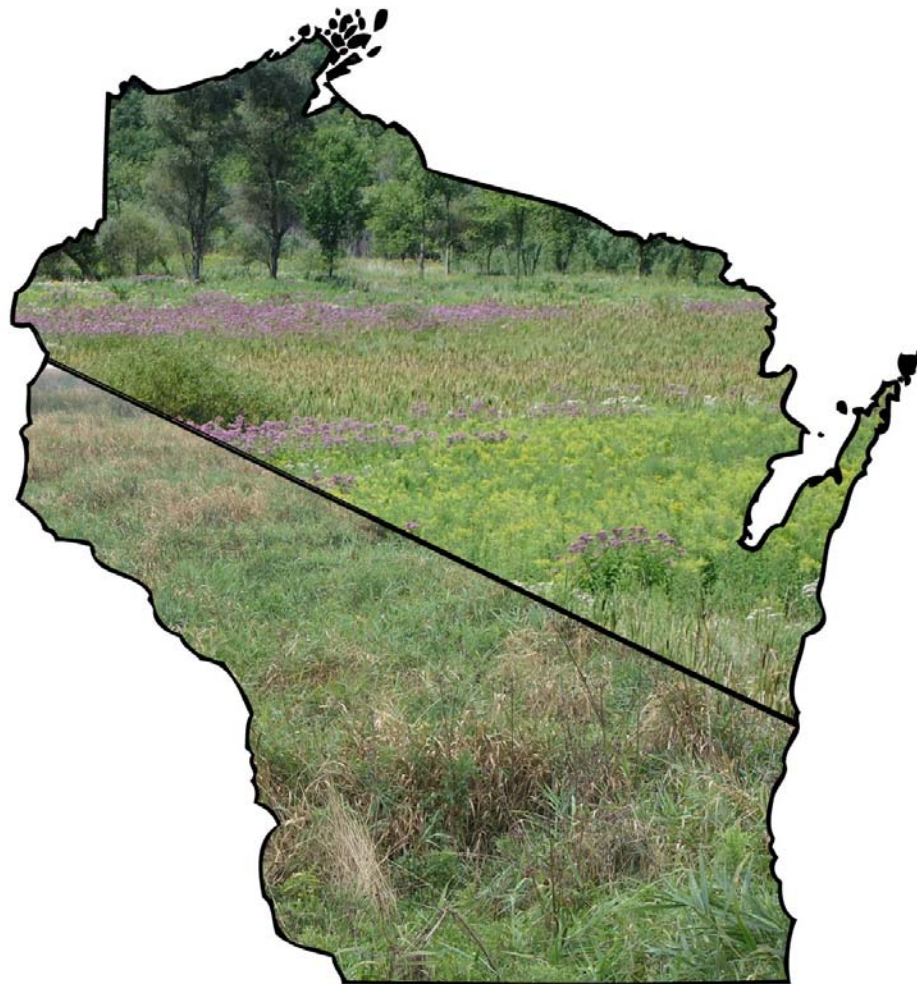


Mapping Wisconsin Wetlands Dominated by Reed Canary
Grass, *Phalaris arundinacea* L.: A landscape level
assessment



Final Report to the U.S. Environmental
Protection Agency, Region V
Wetland Grant # 96544501-0

October 2008

**MAPPING WISCONSIN WETLANDS
DOMINATED BY REED CANARY GRASS,
PHALARIS ARUNDINACEA L.: A landscape level
assessment**

Final Report to the U.S. Environmental
Protection Agency, Region V
Wetland Grant # 96544501-0

October 2008

Authors:
Brynda K. Hatch
Thomas W. Bernthal

This report was prepared by the Wisconsin Department of Natural Resources under Grant No. 96544501-0 from the U. S. Environmental Protection Agency, Region 5. Points of view expressed in this report do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.

Contact for Further Information

Brynda Hatch

Bureau of Watershed Management

Wisconsin Department of Natural Resources

101 S. Webster Street

P.O. Box 7921

Madison, WI 53707-7921

Phone: (608) 261-6446

Email: Brynda.Hatch@Wisconsin.gov

CONTENTS

1. EXECUTIVE SUMMARY	2
2. INTRODUCTION	3
3. PROJECT GOALS AND OBJECTIVES.....	3
4. THE CLASSIFICATION METHODOLOGY AND RES	4
4.1 METHODS	4
4.1.1 Acquiring the Remote Sensing Data Source – Landsat-7 (etm+) and Landsat-5 (tm)	4
4.1.2 Setting Mapping Objectives	6
4.1.3 Fieldwork and Computing Procedures.....	6
4.2 RESULTS	11
4.2.1. The Classification	11
4.2.2 Accuracy of the Classification	11
4.2.3 Calculating Statistics of Reed Canary Grass Cover Statewide	16
4.2.4 Some observations on the pattern of Reed Canary Dominance	19
4.2.5 Reed Canary Grass Dominance by Watershed.....	20
4.2.6 Limitations of the Classification Methodology	23
4.2.7 Cost Considerations	24
4.3 CONCLUSIONS	25
4.4 RECOMMENDATIONS FOR FUTURE CLASSIFICATION EFFORTS	26
5. LITERATURE CITED	27

Tables

1. ERROR MATRIX FOR PATH 23 ROW 29	12
2. ERROR MATRIX FOR PATH 23 ROW 30	12
3. ERROR MATRIX FOR PATH 24 ROW 29	13
4. ERROR MATRIX FOR PATH 25 ROW 29	13
5. ERROR MATRIX FOR PATH 25 ROW 29	13
6. ERROR MATRIX FOR PATH 25 ROW 30	14
7. ERROR MATRIX FOR PATH 26 ROW 29	14
8. REED CANARY GRASS STATISTICS WITHIN WISCONSIN	18
9. REED CANARY GRASS STATISTICS – TOTAL ACRES WITHIN THE WISCLAND CLASSES AND PERCENT OF CLASS DOMINATED	18
10. REED CANARY GRASS STATISTICS – PERCENT OF RCG IN WI FOUND WITHIN THE WISCLAND CLASSES OF WETLANDS	18
11. EXPENSE SUMMARY	25

Maps

1. THE EXTENT FOR THE LANDSAT SCENES WITH WISCONSIN COUNTIES	5
2. AN EXAMPLE OF A PAPER FIELD MAP	9
3. MOSAIC SOLUTION BASED ON OVERALL ACCURACY STATISTIC FOR EACH SCENE	16
4. WISCONSIN WETLANDS, AGRICULTURE, AND REED CANARY GRASS DOMINATION	19
5. PERCENT AREA OF WATERSHEDS DOMINATED BY REED CANARY GRASS	21
6. PERCENT AREA OF WETLANDS DOMINATED BY REED CANARY GRASS, PER WATERSHED	22
7. PERCENT OF OPEN CANOPY WETLANDS DOMINATED BY REED CANARY GRASS, PER WATERSHED	23

Figures

1. FLOWCHART FOR WATERSHED ANALYSIS	17
---	----

1. Executive Summary

Using satellite imagery we analyzed 5,065,419 of Wisconsin's approximately 5,300,000 acres of wetlands and mapped 498,250 acres that are dominated by invasive reed canary grass (*Phalaris arundinacea*). Our results indicate that this species is Wisconsin's most extensive wetland plant invader. The GIS (geographic information system) data layer we produced has many uses, such as wetland assessment, wetland restoration, watershed planning, research into control of reed canary grass and outreach programs on invasive species.

We found classification of Landsat satellite imagery to be the most cost-effective method to broadly capture the impact reed canary grass has on our native wetland plant communities. An earlier pilot project demonstrated the feasibility of mapping reed canary grass using 30m resolution Landsat-7 imagery in a single 185 km x 185 km scene in south-central Wisconsin (Bernthal and Willis 2004). We applied their methodology to map wetlands dominated by reed canary grass across the entire state.

Twelve scenes from both the Landsat 7 and Landsat 5 satellites were required to build the mosaic from which the final raster (grid) dataset could be made. Each of the scenes were processed to prepare them for classification by georeferencing, masking out clouds and uplands, and subsetting. Field sites were selected to ground truth the satellite data based on two criteria: easy access and homogenous landcover. Skilled volunteers were recruited and trained to perform fieldwork to reduce the number of field visits per person. Unsupervised and supervised classification algorithms were run on the satellite images to create the individual maps of reed canary grass for each scene. The ground-truth data was used in both the training (assigning spectral ranges to mapping classes) and the testing (accuracy assessment) of the data.

Emergent, open canopy wetland is the community type that has been most extensively invaded, with 307,056 acres, or 26% of this type dominated by reed canary grass. "Domination" is defined as "occupying greater than 50% of the vegetative cover in a sample area." The areas most heavily impacted are in the west-central, central, south-central and southeast regions of Wisconsin. Wetlands in the north-central and northeast regions of the state are currently relatively unaffected by reed canary grass. By re-doing the classification in five to ten years, we could detect the change in extent and pattern of reed canary domination.

The final statewide, seamless dataset is now viewable online on the Surface Water Data Viewer (<http://dnrmaps.wisconsin.gov/imf/imf.jsp?site=SurfaceWaterViewer>) and is also available for download from the WDNR's ftp site: ftp://dnrftp01.wi.gov/geodata/landcover/reed_canary_grass.zip. The accuracy assessment we performed revealed a range of 61-83% overall accuracy and 72-92% user's accuracy for the reliability of areas mapped as reed canary grass dominated wetlands in the individual Landsat scenes.

2. Introduction

Invasive species can be the first easily detectable sign of declining health in wetlands. Reed canary grass (*Phalaris arundinacea*) is a particularly aggressive invasive species. In many areas of the state, reed canary grass was originally introduced to farmers as a cover crop for their fields. It was recommended for use as forage and erosion control. Even though its invasive nature has since been recognized as a problem, some farmers still choose to plant it as marsh hay.

Reed canary grass is a cool-season, perennial wetland grass native to temperate regions of Europe, Asia, and North America. Within Wisconsin, it is commonly found in disturbed wetland sites, particularly along roadside ditches and drainage ditches. Once it is established, it can create large monotypic stands, choking out all the native species in the area. It not only grows in wetland areas, but can also be found in adjacent upland areas too.

Reed canary grass is one of the first plants to sprout in spring, and remains green well into the fall. Since reed canary grass has a wide distribution across Wisconsin and creates large mats, it was recognized as a prime choice for remote sensing. It is easily classified by satellite imagery because of its late senescence period, growing long past other wetland species.

Bernthal and Willis (2004) established the protocol for mapping reed canary grass using Landsat satellite imagery in a pilot area in South Central Wisconsin. As a result of their research, a fairly cost-effective methodology was developed. They recommended expanding the mapped area to cover the state in a future project. Through a new grant from EPA, the WDNR has carried their work forward to widen the area where reed canary grass dominance can be mapped.

3. Project Goals and Objectives

Our goal was to take the methodology outlined in Bernthal and Willis (2004) and apply it statewide. A map showing reed canary grass dominance across the whole state could provide a clear picture of the spreading patterns of the species. Statistics could then be drawn for each watershed, illustrating where the species has been the most invasive.

There were three main objectives to this project. The first objective was to repeat the process done with the first Landsat scene (Path 24 Row 30) by Bernthal and Willis on all the scenes covering the state. The second objective was to develop a methodology to merge all the scenes together into one seamless mosaic. And the last objective was to create statewide-level and watershed-level statistics to describe the dominance of reed canary grass in wetlands.

4. The Classification Methodology and Results

The classification process for this project was modeled after the methodology developed by Bernthal and Willis, 2004. Because their project only used one satellite image covering a 185km x 185km area, some of the methods had to be adapted for use on multiple satellite images covering the larger area of Wisconsin as a whole. Steps were also taken to improve the time spent on the process so as to complete the whole state in one year.

4.1 Methods

4.1.1 Acquiring the Remote Sensing Data Source – Landsat-7 (etm+) and Landsat-5 (tm)

Bernthal and Willis (2004) used a scene from the Landsat 7 satellite. It was intended that the same satellite would provide all of the imagery used for the entire state, but there was a system malfunction in the Scan Line Corrector in May of 2003. Therefore, all imagery for dates after July of 2003 had to be taken from the Landsat 5 satellite. The slight differences between Landsat 5 imagery and Landsat 7 imagery were not an issue for this project because only bands common to both satellites were used: bands 1, 2, 3, 4, 5 and 7. We left out band 6, the thermal band, as it was taken at a lower resolution than the other six bands. The pixel sizes for each are 30m x 30m and the scenes for each are 185 km x 185 km.

As determined by Bernthal and Willis (2004), mid-October is the best for distinguishing reed canary grass from other vegetation because of its late senescence. They concluded that multiple dates and use of Normalized Difference Vegetation Index (NDVI) are not needed to classify reed canary grass in Wisconsin. The scenes acquired were selected using three criteria: 1) as close to mid-October as possible, 2) 10% or less of cloud cover, and 3) within a small range of years, none being older than 1999. The range of dates for the imagery acquired was Oct 09-Oct 31, 1999-2003. The scenes with clouds at 10% cover mainly had their clouds outside the Wisconsin state line, but when that was not the case, they almost all fell in an area of overlap with another scene.

The classified scene (Path 24 Row 30) produced by Bernthal and Willis (2004) and the neighboring scene (Path 23 Row 30) produced by Willis for the Milwaukee River Basin Wetland Assessment Project (Kline et al 2006) were used when creating the statewide coverage. Using the two Landsat scenes from the pilot project, ten of the twelve scenes needed still had to be obtained. The additional ten needed to cover the entire state were purchased, through a Memorandum of Understanding between WDNR and WisconsinView, at discounted rates. Total expenses are listed in Table 11 on page 25. Map 1 shows the twelve Landsat scenes, how much area is overlapped, and their array across Wisconsin.

Map 1: The Extent for the Landsat Scenes with Wisconsin Counties



4.1.2 Setting Mapping Objectives

Bernthal and Willis (2004) used three classes of wetland vegetation for the pilot classification scheme: 1) “heavily dominant” – defined as >80% cover of reed canary grass by visual estimate, 2) “co-dominant” – defined as 50-79% cover of reed canary grass by visual estimate, and 3) “absent to subdominant” – defined as 0–49% cover of reed canary grass by visual estimate. However, their accuracy assessment revealed that the “co-dominant” class had an unacceptably low user’s accuracy of 41%. Further, eighteen of the accuracy assessment plots classified as “co-dominant” were actually field verified as belonging in the “heavily dominant” class, while only four were field verified as actually belonging in the “absent to sub-dominant” class. They concluded that the “co-dominant” class was not reliable and recommended that the “co-dominant” and “heavily dominant” classes be combined in further work.

Following the suggestion given by Bernthal and Willis for the statewide classification, we used only two categories of vegetation cover, known as A and B.

A – defined as areas with < 50% cover of reed canary grass, by visual estimate

B – defined as areas with \geq 50% cover of reed canary grass, by visual estimate

Our reasons for this choice of category break are two-fold. The first is due to the recommendation made by Bernthal and Willis (2004) above. The second is that field experience in these two projects indicated that even in a situation with 50% reed canary grass cover, the 50% “other vegetation” was made up of multiple species with no other single species attaining close to 50% cover. Thus reed canary grass would still be considered the most dominant species. One exception to this is some wetter sites where reed canary grass and cattails (often a mix of *Typha latifolia*, *T. angustifolia* and *Typha X glauca*) are both near 50% cover.

4.1.3 Fieldwork and Computing Procedures

Preparing the Satellite Images – Utilizing ERDAS Imagine v9.0

All the satellite images arrived with separate files for each band layer. The bands were combined into one file through a process called layer stacking. Some of the images came in the National Land Archive Processing System Data Format (NLAPS) and others came in Geostationary Earth Orbit Tagged Image File Format (GEOTIFF). The NLAPS were already projected in Universal Transverse Mercator (UTM) coordinates, so a simple transformation changed it to Wisconsin Transverse Mercator (WTM) coordinates. The GEOTIFFS had to be resampled in a process called geo-referencing. Through this iterative process, control points were manually defined using a previously referenced WTM image. Once this was completed, some of the images needed to be clipped. Sometimes at the very edge of the images, the bands begin to separate, causing colored strips to appear on the east and west edges. These needed to be removed through a process called subsetting before moving to the next step. Then, the upland areas were removed from each image, in a process called masking. As was done by Willis, the wetland pixels from WISCLAND were used in the masking process (2004). When this was completed, the only pixels visible in each image are those of wetlands.

For scenes with some cloud cover, a masking process had to be performed to remove the clouded areas. This process, occurring after the subsetting step described above, involved using the classification procedure defined in detail below, in the section titled “Conducting the Classification”, to create two information classes: 1) clouds and their shadows, as both are a potential for errors, and 2) no clouds. Band 2, or the green band (0.52-0.60 μm), showed the greatest spectral separation when sorting out the clouds from non-clouds. Once the clouds were removed, then the wetland mask was performed. Later, when the scenes were mosaiced together, the areas where clouds were removed were replaced with cloud-free areas from the overlapping scenes.

Selection of Field Sites

Using the masked scenes, sites were chosen to represent the full range of spectral signatures, and to ensure good geographic distribution. The scenes overlap by a measure of 38% on each side to the east and west with a potential for 76% overlap total, so field sites within those areas could be used to classify both of the overlapping scenes. The scenes overlap by only 10% on the north and south sides; so field sites in those areas, although not as common, would still work to classify the two overlapping scenes. Scenes overlapping North-South, can be from the same day (as in Path 24, Rows 28 and 29, and Path 25, Rows 28 and 29). Scenes overlapping East-West, are at least eight days apart.

It was preferred that for each site, the spectral signature was homogenous within the site area. It was assumed that once in the field, relationships could be inferred between the spectral signatures and the different vegetation types they represented. This would make it easier to find the spectral signature(s) that represented reed canary grass and separate them out from those representing other wetland vegetation.

At the start of the project, there was no preference for public lands over private lands. Maps were studied to find sites that were relatively easy to access from roads. For private lands, permission was acquired through phone calls and house visits. As the project progressed, the trend shifted towards only using public lands for sites in order to alleviate the step of contacting landowners.

There were originally 315 sites selected for field visits. Due to various reasons such as denied access, or too far from the road, or the site was completely inaccessible, the list was narrowed down to 269. From those 269 sites visited, 1,388 polygons were catalogued.

Setting and Refining the Field Sampling Protocol

The Trimble GeoXM, a global positioning system (GPS), was purchased for this project. We set its parameters to reject a GPS fix with a Position Dilution of Precision (PDOP) higher than 6.0, to average 20 GPS fixes together when capturing a vertex, and to only accept GPS fixes with real-time differential corrections from Satellite Based Augmentation Systems. With these parameters set, the accuracy for the GPS coordinates recorded was one to three meters. ESRI’s ArcPad software was installed on the GeoXM to make the data collection more efficient. Using the software program, the user could see their location displayed on an aerial photo. The most current digital orthophotos

available in the WTM projection were downloaded to the units, referenced to the North American Datum of 1983, 1991 adjustment (also known as HARN). Typically, they were grayscale with one-meter resolution and were at least three to six years old. Once the position of the user was determined by the satellites, polygons were drawn using the GPS positions as vertices, and attributes were recorded. The user then saved the edits directly to an ArcGIS feature class that was later directly synced with the computer.

The paper field maps consisted of a horizontal WTM-HARN coordinate grid superimposed on top of the 2005 digital orthophoto (DOP) overlaid with the masked satellite image. The grid was marked at 90m intervals, with ticks every 30m. The 2005 DOPs are true color, leaf-on, and have a resolution of 12in. The maps also were labeled with property owners, road and street names, and Public Land Survey System (PLSS) locational information. Map 2 shows a field map used for site visits. The green dot is the point directing the field staff where to start.

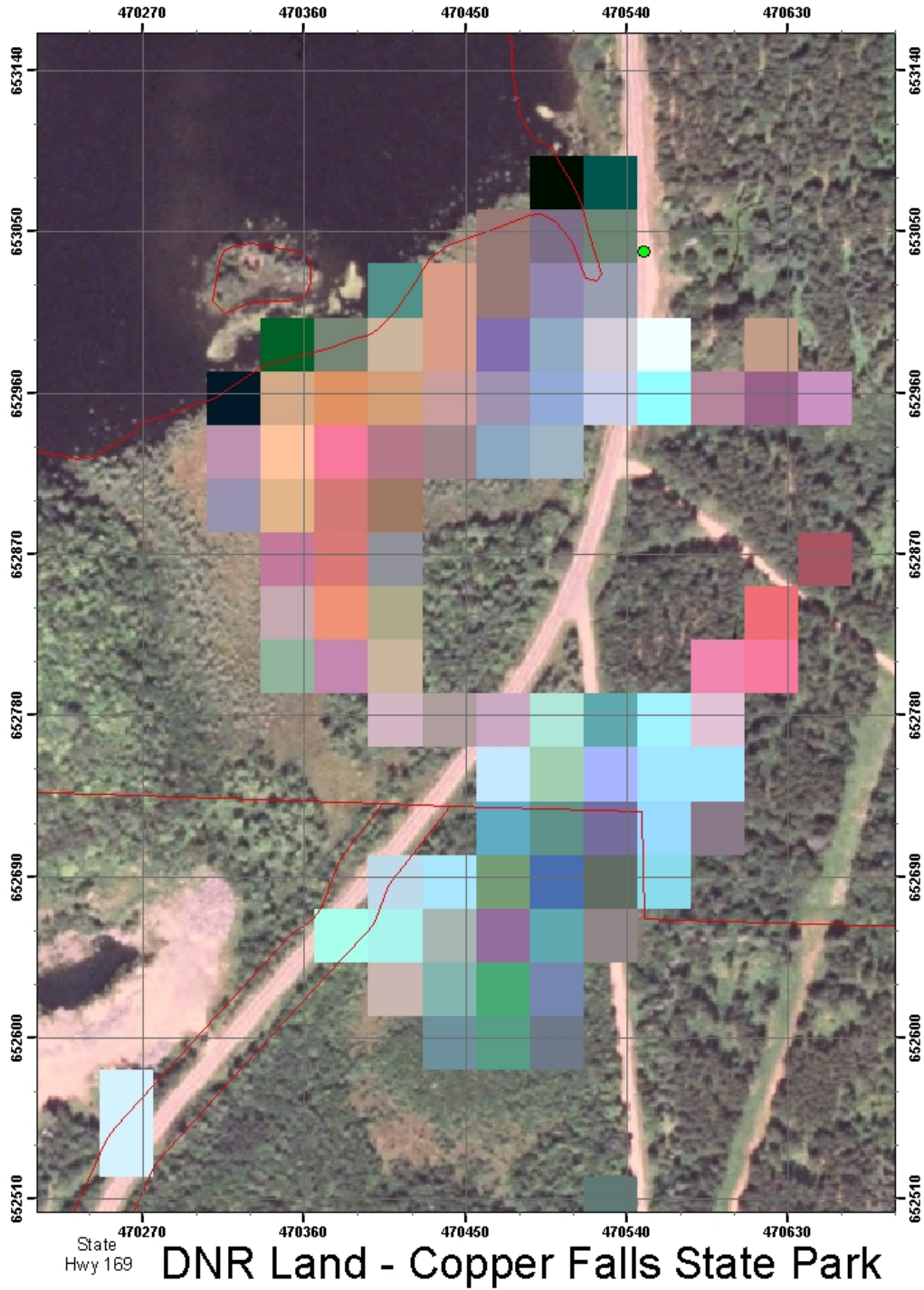
Three volunteers helped the project coordinator with the fieldwork. They were Jon Motquin from the East Central Wisconsin Regional Planning Commission, Shirley Griffin of the Glacial Lakes Conservancy, and Dan Pubanz from Wolf River Forestry, LLC. Once they were trained by project staff, each volunteer worked independently on their own assigned sites. Doug Cox from the Menominee Indian Tribe of Wisconsin accompanied the project coordinator when she visited protected tribal lands.

Field staff used the horizontal grids on the paper maps to find the coordinates for the corners of each pixel. Then, using the GPS, they walked to the starting corner of a pixel and began recording vertices within the ArcPad software on the GPS. They walked around the pixel, marking each vertex in the GPS, closed the polygon, and then visually estimated percent cover of the reed canary grass. The classification of the vegetation (A or B), the name of the observer, the property information, and an overall vegetative cover description was recorded in the attribute table of the feature class on the GPS unit. Any additional comments that did not fit within the attribute table were made on the paper maps. Only the project coordinator used the Trimble GeoXM with ArcPad software for her fieldwork. She, however, visited 90% of the 269 field sites. The volunteers used GPS units not equipped to hold imagery as basemaps or have the capability for real-time feature class editing. Their methods were slightly altered, so that they only used the GPS to navigate to pixel corners. All of their drawings and vegetation descriptions were written on the paper field maps. The volunteers visited 10% of the field sites.

Seeing the entire 30m x 30m area could be difficult at times. Where necessary, halfway points (at 15m) along pixel lines were established to break the pixel into halves or quarters. By contrast, in other areas, a much larger area was visible to the field person, allowing them to record vegetation cover for an entire site without having to walk each pixel's perimeter. In those cases, a freehand polygon was drawn using the DOP on the GPS screen as a guide. More often than not, these situations occurred where there was an obvious dominance of a wetland community, such as an open bog, that did not have any reed canary grass present at all. Notations were made to distinguish the GPS drawn polygons from the freehand polygons in the attribute table.

Map 2: An Example of a Paper Field Map

Ashland Co. T45NR2WS29 Town of Morse



Photos were taken in the field with a digital camera. These photos were available for referencing during the classification process. The paper field maps were used to organize the order of sites visited and to keep a small scale view of the area on hand.

Conducting the Classification

All of the following procedures had to be done on each scene individually.

Initial classification was done using the ISODATA (Iterative Self-Organizing Data Analysis Technique) program. ISODATA is an unsupervised clustering algorithm that takes an image and groups the pixels by similar reflectance values into a specified number of clusters. The clusters are defined by a set of means and variances in each spectral band, and their distribution is optimized so as to maximize the variance between clusters while minimizing the variance within clusters. The method is unsupervised in the sense that the algorithm automatically determines the statistically optimal set of spectral classes in the image (Trochlell, 2001). Willis specified that 75 spectral clusters be used for the ISODATA unsupervised classification. One of the outputs from ISODATA is a signature file that defines the 75 spectral clusters. The analyst took the signature file and used it as an input for the Maximum Likelihood supervised classification. This algorithm assigns all the pixels in the raster image to the spectral cluster to which it has the highest probability of belonging. The two algorithms were run using ERDAS Imagine v9.0 software.

Notations made in the field on the paper maps, by the volunteers, were digitized on screen at the office using ESRI's ArcGIS software v9.1. For each Landsat scene, the number of polygons in each category (A or B) was tallied and then divided into two sets: one for training the computer and one for testing the accuracy of the classification process. This was done to make sure that there was an equal number of A polygons and an equal number of B polygons in both the training set and the testing set.

Using the ground truth data assigned to the training set as reference, the analyst assigned each spectral class to one of the two information classes using color assignments: **green** = less than 50% reed canary grass and **red** = greater than 50% reed canary grass. This is a lengthy, iterative process requiring much patience and attention to detail. To help discern the correct class for some of the borderline clusters, the analyst studied the signature mean plots and signature statistics with ERDAS Imagine v9.0 software. Band 5, the midIR band (1.55-1.75 μm), showed the greatest spectral separation between the mean signature values and was the most useful when separating the **red** from the **green**. When the analyst was satisfied that all 75 spectral classes had been correctly assigned, she recoded the image so that each pixel had a nominal value of either 1 (less than 50% reed canary grass) or 2 (greater than 50% reed canary grass).

Finally, the accuracy assessment was performed. A program, written by Jonathon Chipman, then of the University of Wisconsin –Space Science and Engineering Center, was used to automate this process. The polygons in the testing set were used as the input. The program looks at the total area of the pixels that fall within the polygons. It calculates the average value of all the pixels in the polygon and then rounds the number to assign it the nominal value of 1 or 2. The result was compared to the nominal value of the original input polygon. In other words, the category on the screen was compared to the recorded category on the ground.

Once each Landsat scene was classified and the accuracy assessment was completed, a statewide mosaic of all the scenes was made. The scenes were overlapped and in the area of overlap the more accurate scenes were chosen over the lesser accurate scenes. Then the scenes were merged together to make a seamless statewide raster grid. Where there were clouds that were masked out in the more accurate scene, the area was filled in with the pixels from the less accurate scene.

4.2 Results

4.2.1. The Classification

The end product of this classification process is a seamless statewide raster grid with pixels having three possible values: 0 = unclassified (upland or clouds), 1 = <50% reed canary grass cover, 2 = > 50% reed canary grass cover. The minimum mapping unit is 0.5 acre. This is roughly equivalent to two adjacent 30m pixels in the raster grid. This grid is now available on the Wisconsin Department of Natural Resources' Surface Water Data Viewer. Instructions for viewing are at <http://dnr.wi.gov/wetlands/reports.html>. The dataset and accompanying metadata are also available for download at the WDNR ftp site at ftp://dnrftp01.wi.gov/geodata/landcover/reed_canary_grass.zip. It is planned that the dataset will be a part of the DNR's Water Assessment, Tracking, and Electronic Reporting System (WATERS) as a new wetland component of watershed planning.

4.2.2 Accuracy of the Classification

An error matrix was made for each scene to evaluate its accuracy. As stated above, the categories on the screen were compared to the recorded categories on the ground using the polygons in the testing set. Noting how often the classification agreed with the training set and how often it disagreed gives errors of commission and errors of omission. Looking at the error matrix as a whole can give the user's and producer's accuracies for each category as well as the overall accuracy for each scene (Lillesand, 2000).

Next to Table 1 an example of how the accuracy statistics are calculated is shown. The overall accuracy is an average of the accuracies for each class weighted by the proportion of test samples in the total training or testing sets. Overall accuracy equals the total number of correctly classified pixels (on diagonal) divided by the total number of reference pixels (on ground).

User's accuracies tell the user how likely it will be that a pixel identified as reed canary grass on the map will actually be reed canary grass on the ground. User's accuracy equals the number of correctly classified pixels in each category (on diagonal) divided by the total number of pixels that were classified in that category (sum of each row).

Producer's accuracies show the analyst the likelihood that the original groundtruth data matches what is on the map. Producer's accuracy equals the number of correctly classified pixels in each category (on diagonal) divided by the number of training set pixels used for that category (sum of each column).

Tables 1-7 show the error matrix for each of the Landsat scenes that were able to have the accuracy assessment performed.

Table 1. Error Matrix for Path 23 Row 29

		On Ground		
		RCG	Other	Sum
On Screen	RCG	8	1	9
	Other	13	61	74
	Sum	21	62	83
Overall Accuracy		83%		
User's Accuracy		RCG	Other	
Producer's Accuracy		89%	82%	
		38%	98%	

Overall Accuracy = 83%
 $(8 + 61) / 83 = 0.83$

User's Accuracy = 89% and 82%
 $8 / 9 = 0.89$ for RCG and
 $61 / 74 = 0.82$ for Other

Producer's Accuracy = 38% and 98%
 $8 / 21 = 0.38$ for RCG and
 $61 / 62 = 0.98$ for Other

Table 2. Error Matrix for Path 23 Row 30

		On Ground		
		RCG	Other	Sum
On Screen	RCG	21	7	28
	Other	7	47	54
	Sum	28	54	82
Overall Accuracy		83%		
User's Accuracy		RCG	Other	
Producer's Accuracy		75%	87%	
		75%	87%	

Table 3. Error Matrix for Path 24 Row 29

		On Ground		
		RCG	Other	Sum
On Screen	RCG	42	16	58
	Other	37	63	100
	Sum	79	79	146
Overall Accuracy		66%		
		RCG	Other	
User's Accuracy		72%	63%	
Producer's Accuracy		53%	80%	

Table 4. Error Matrix for Path 24 Row 30

		On Ground		
		RCG	Other	Sum
On Screen	RCG	130	11	141
	Other	34	74	108
	Sum	164	85	249
Overall Accuracy		82%		
		RCG	Other	
User's Accuracy		92%	69%	
Producer's Accuracy		79%	87%	

Table 5. Error Matrix for Path 25 Row 29

		On Ground		
		RCG	Other	Sum
On Screen	RCG	86	19	105
	Other	18	47	65
	Sum	104	66	170
Overall Accuracy		78%		
		RCG	Other	
User's Accuracy		82%	72%	
Producer's Accuracy		83%	71%	

Table 6. Error Matrix for Path 25 Row 30

		On Ground		
		RCG	Other	Sum
On Screen	RCG	36	7	43
	Other	45	67	112
	Sum	81	74	155
Overall Accuracy		66%		
		RCG	Other	
User's Accuracy		84%	60%	
Producer's Accuracy		44%	91%	

Table 7. Error Matrix for Path 26 Row 29

		On Ground		
		RCG	Other	Sum
On Screen	RCG	53	10	63
	Other	52	44	96
	Sum	105	54	159
Overall Accuracy		61%		
		RCG	Other	
User's Accuracy		84%	46%	
Producer's Accuracy		50%	81%	

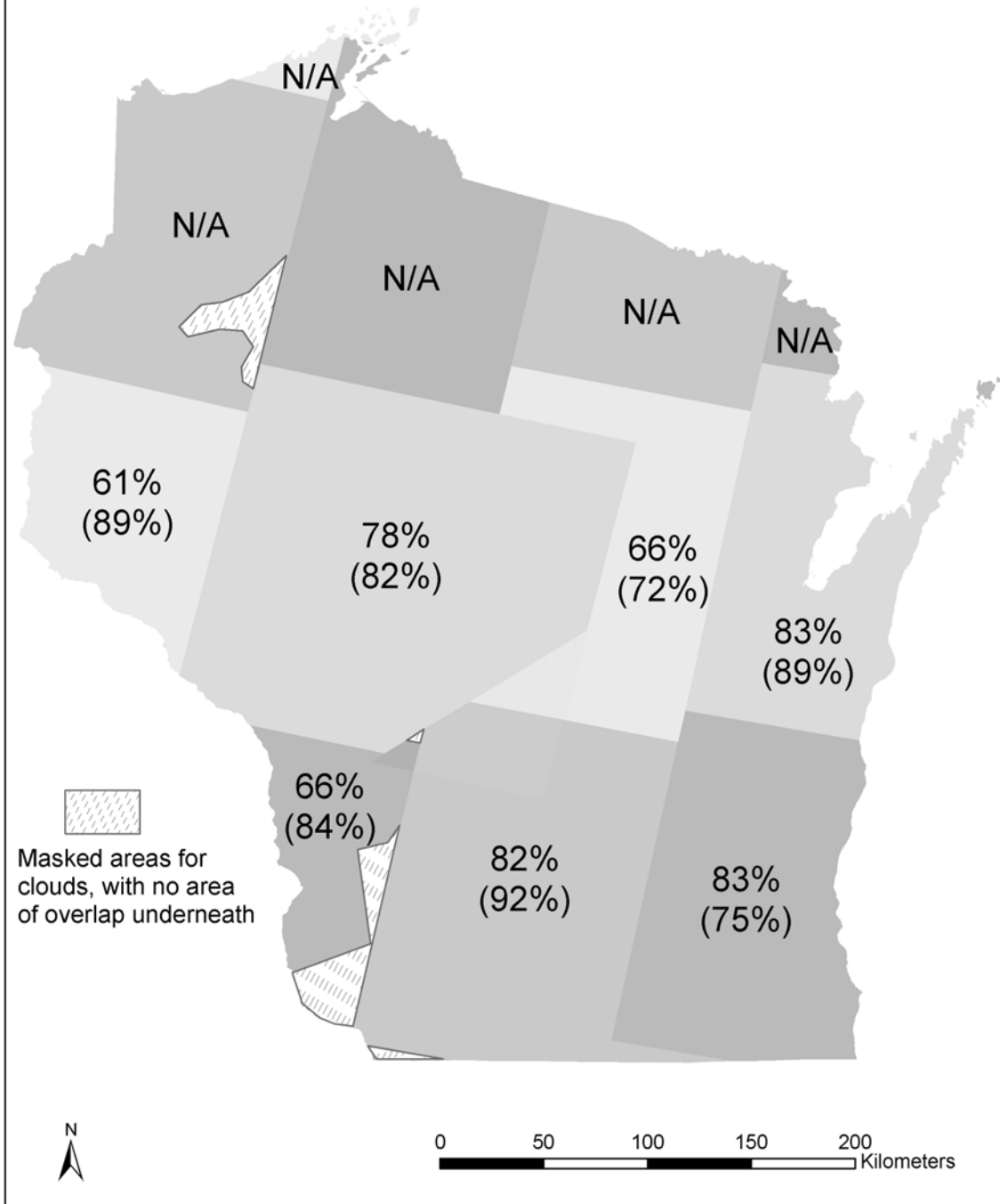
Map 3 illustrates the mosaic solution of the twelve scenes based on the overall accuracy statistic for each. The top two rows (28 and 27) of the Landsat scenes are labeled as N/A. This means Not Applicable; the designation was used because an accuracy assessment could not be performed due to the negligible amounts of reed canary grass present. For these scenes, all of the ground truth data was used for training the computer; leaving none for testing the accuracy of the classification. In the case of Path 24 Row 28 however (Refer to Map 1 for location), there were no areas of reed canary grass located at all during the field visits.

Even though the classification for Path 23 Row 30 had already been performed by Willis, a formal quantitative accuracy assessment had not been completed. Instead, field staff working on the Milwaukee River Basin Wetlands Assessment project gave feedback on the reed canary information as they conducted field checks. Using ground truth data the project coordinator collected, in overlapping areas of other scenes, she performed her own accuracy assessment. The accuracy statistics for Path 24 Row 30 from Bernthal and

Willis (2004) were recalculated, combining the heavily dominant class with the co-dominant class.

A close-up analysis of the output raster grid revealed some possible sources for errors of commission. These errors occur when something other than reed canary grass is classified in that category. It appears that heavily grazed pasture fields were classified as reed canary grass. They are noticeable on the grid by their distinct geometric shapes. In some cases, a pasture might be reed canary grass, but it was hard to tell during the site visits because of how short the grass blades were cropped. Another point of confusion was cranberry bogs. As they are not harvested until late fall (after mid-October), the satellite would have picked up the green leaves on the bushes. Sources of errors of omission were not discovered. They would be a lot more difficult to identify. Those would be areas of reed canary grass that were not classified correctly.

Map 3: Mosaic Solution Based on Overall Accuracy Statistic for Each Scene
(RCG User's Accuracies in parentheses below the Overall Accuracies)



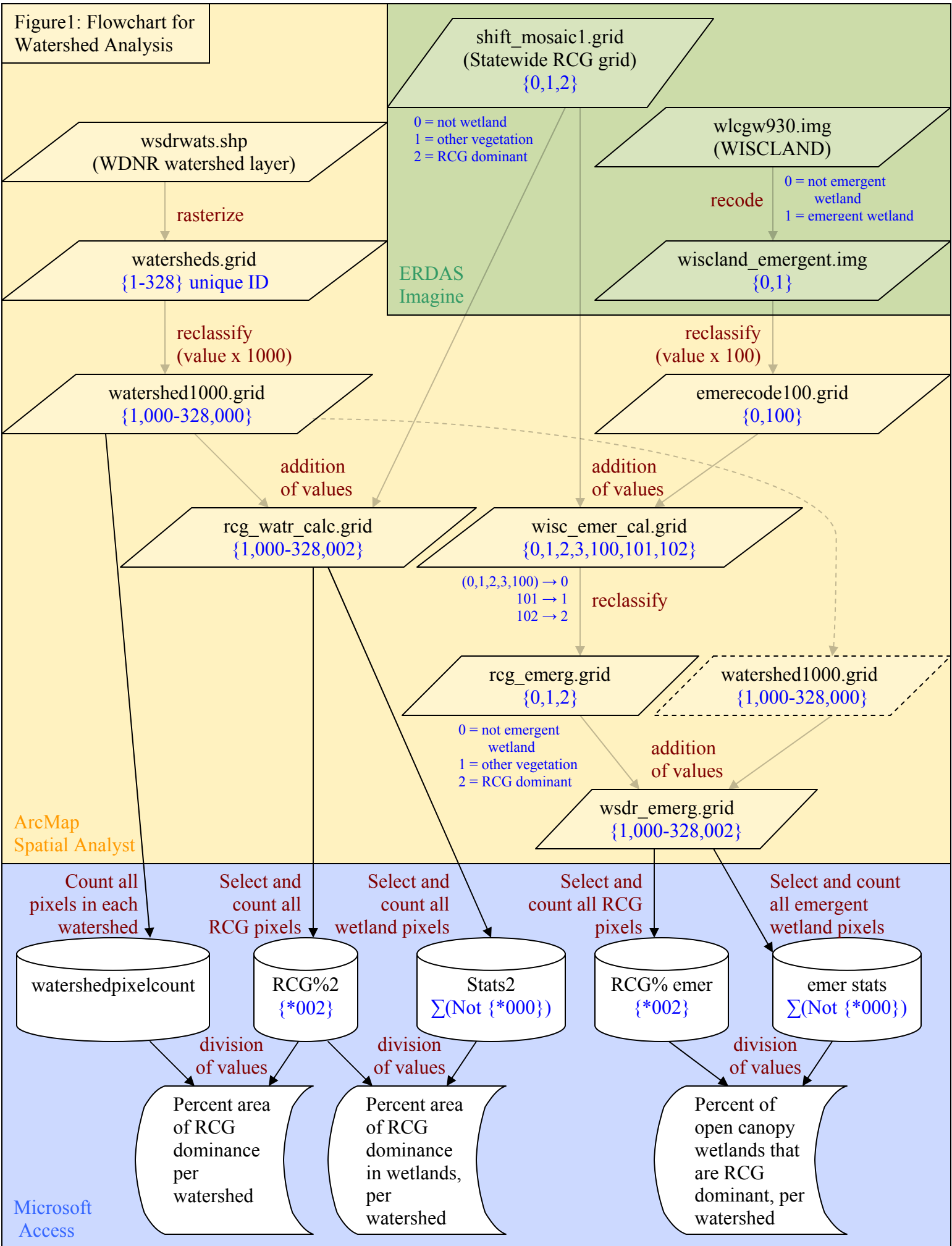
4.2.3 Statistics of Reed Canary Grass Cover Statewide

Map 4 shows the statewide distribution of reed canary grass dominated wetlands, along with the land cover as mapped by WISCLAND. We calculated statistics for the entire state reporting the amount and percentage of reed canary dominance by wetland type. After those statistics were calculated, a series of steps was taken to find three different statistics describing the reed canary grass cover for each watershed:

- 1) Percent Area of Watersheds Dominated by Reed Canary Grass
- 2) Percent Area of Wetlands Dominated by Reed Canary Grass, per Watershed
- 3) Percent of Open Canopy Wetlands Dominated by Reed Canary Grass, per Watershed

The steps taken for the entire process are illustrated in Figure 1.

Figure1: Flowchart for Watershed Analysis



The first set of statistics calculated gives a big picture look at the state of Wisconsin.

Table 8. Reed Canary Grass Statistics within Wisconsin

Total Number of Acres of RCG Dominated Wetlands in WI	498,250
Total Number of Acres of Classified Wetlands in WI	5,065,419
Percent of Wetlands in Wisconsin that are RCG Dominated	9.84%

Using the different wetland cover type classes from WISCLAND in Wisconsin, some simple statistics were calculated to describe reed canary grass-dominant acreage and how much is in each wetland type. There were 17,188 acres of wetlands that could not be classified because of cloud cover in the Landsat scenes. All percents calculated in Tables 8, 9, and 10 take into consideration only the classified wetlands, and not the clouded areas.

Table 9. Reed Canary Grass Statistics – Total Acres within the WISCLAND classes and Percent of Class Dominated.

WISCLAND class	Total # of RCG Acres	% Dominated by RCG
Emergent Wetlands	305,878	26.64%
Floating Aquatic Herbaceous Vegetation Wetlands	1,178	9.15%
Forested Wetlands	82,218	3.36%
Lowland Shrub Wetlands	109,976	7.40%

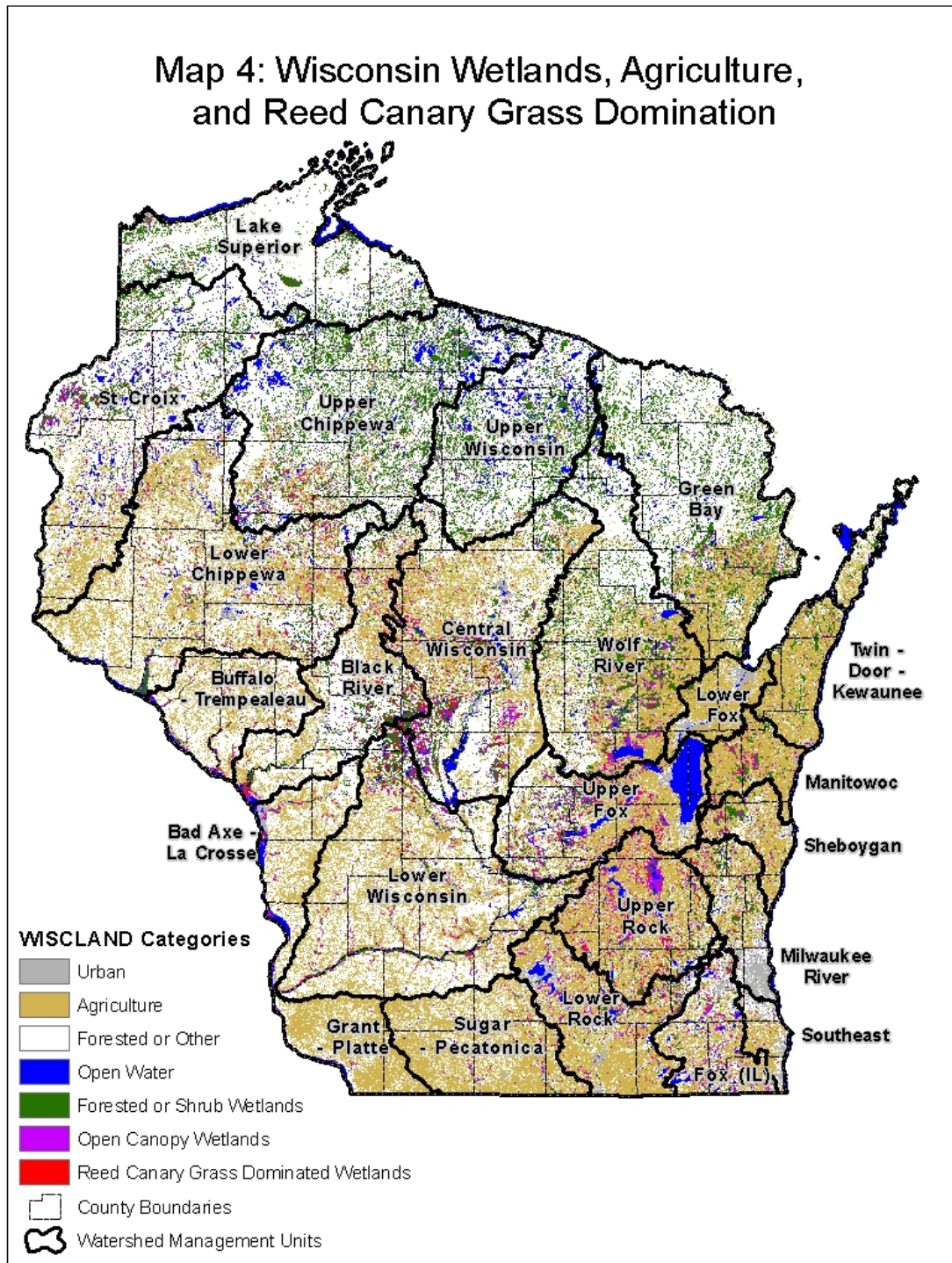
The total number of acres dominated by reed canary grass in what is considered to be open canopy wetlands is 307,056. Open canopy includes both emergent wetlands and floating aquatic herbaceous vegetation wetlands. The next set of calculations reveal how the reed canary grass wetlands are distributed among the four WISCLAND classes of wetlands.

Table 10. Reed Canary Grass Statistics – Percent of RCG in WI found within the WISCLAND classes of Wetlands

RCG in WI that is in Emergent Wetlands	61.39%
RCG in WI that is in Floating Aquatic Herbaceous Vegetation Wetlands	0.24%
RCG in WI that is in Forested Wetlands	16.30%
RCG in WI that is in Lowland Shrub Wetlands	22.07%

The amount of reed canary grass dominated acres found in forested and in lowland shrub wetlands was larger than expected, since reed canary grass under forest and shrub canopy is less detectable than in an open canopy. There are several factors that may explain this. Some shrubs are shorter than reed canary grass, and some deciduous shrubs that are not as woody could have lost their leaves by the second half of October at the time of the Landsat scene capture. In either of these instances the reed canary grass could have been the dominant feature detected by the satellite sensor and these areas would have been classified as reed canary grass dominated shrubland. Another factor could be that areas mapped as lowland shrub by WISCLAND can contain patches of emergent vegetation mixed in with shrubs. Where these patches are larger than the 30m pixel size of Landsat and dominated by reed canary grass they would also have been mapped in our classification.

4.2.4 Some observations on the pattern of Reed Canary Dominance



Examining the extent of reed canary grass wetlands across the state together with WISCLAND land cover data, some patterns start to emerge. Map 4 shows agricultural land use, forested/shrub, open canopy and reed canary dominated wetlands across the major river basins of the state, using water management units delineated by WDNR.

Reed canary grass dominated wetlands occur throughout the state, but most extensively in areas where agricultural land use is predominant. For instance, the southeastern quarter of the state has a high amount of both reed canary dominated wetlands and agricultural land use. There are extensive reed canary grass stands in some large marsh and meadow complexes throughout this area, particularly in the Upper Fox River Basin and the Upper Rock River Basin. The southeast quarter of Wisconsin also has a pattern of smaller reed canary grass wetlands surrounded by a matrix of agricultural land.

Conversely the lake- and forest-rich areas of northern Wisconsin have almost no agricultural land use and also the least amount of reed canary grass dominated wetlands. With the exception of the northwestern corner of the state, the northern-most tier of Basins all have low amounts of reed canary dominated wetlands. Part of the explanation is that these wetlands have predominantly forest and shrub vegetation, in which reed canary grass is not as reliably mapped by our method. Also, reed canary grass occurs in these areas but does not yet dominate areas larger than our one-half acre minimum mapping unit. The increase in shoreland housing and road construction in the north country may bring increased sediment and nutrient loading to wetlands, conditions which are known to accelerate the spread of reed canary grass (Zedler et al., 2005).

A concentration of large wetlands is found west of the Petenwell Flowage at the borders of the Lower Wisconsin River Basin, Central Wisconsin River Basin and the Black River Basin. Many of these have become extensive reed canary grass stands. This area does not have a large amount of agriculture, with the exception of cranberry operations, but an extensive network of drainage ditches has greatly modified hydrology in these basins.

The upper reaches of the Central Wisconsin River Basin, the Black River Basin and the western part of the Lower Chippewa River Basin show a pattern of relatively small reed canary dominated wetlands occurring within a matrix of agricultural land.

In the unglaciated area of western and southwestern Wisconsin wetlands are scarce and primarily confined to stream valleys. Reed canary grass dominates these wetlands, likely as a result of deposition of sediment and delivery of nutrients from upslope agricultural fields. Where larger rivers enter the Wisconsin River and the Mississippi River there are large areas dominated by reed canary grass. For instance the La Crosse River and the Trempealeau River have a considerable amount of reed canary grass dominance in their floodplains and at their confluence with the Mississippi River.

4.2.5 Reed Canary Grass Dominance by Watershed

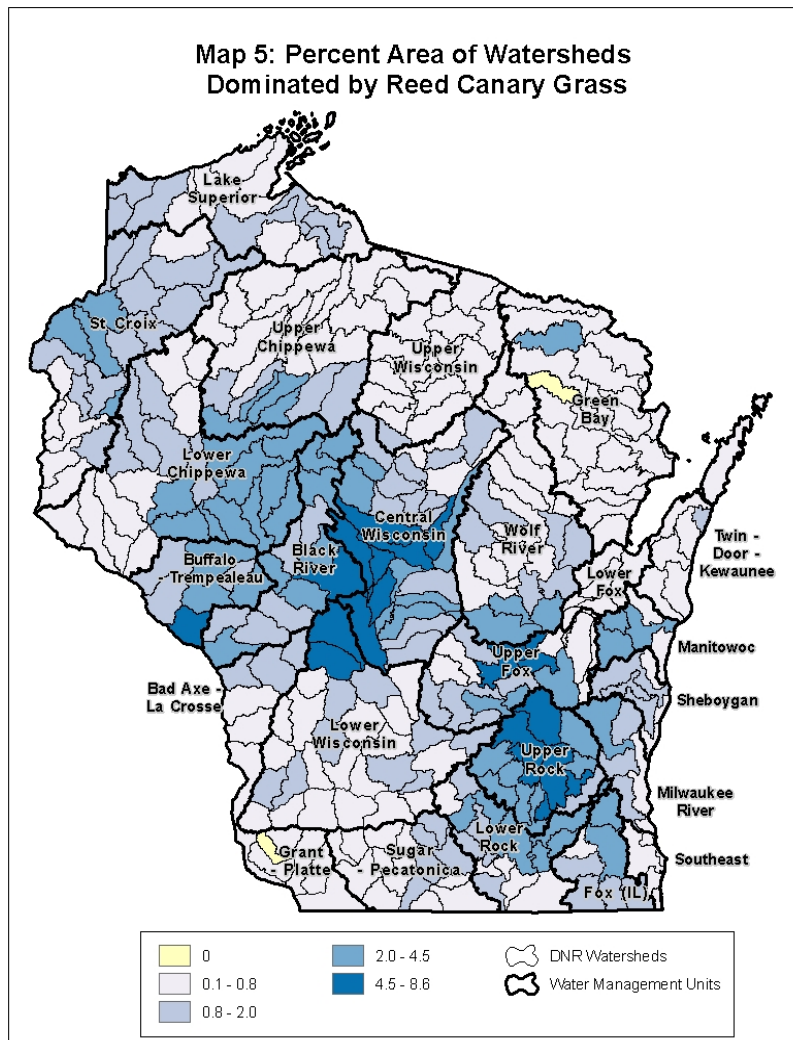
The statewide results were broken down for each of the 323 watersheds delineated by WDNR for these three areal percentages.

- Percent Area of Watersheds Dominated by Reed Canary Grass (Map 5)
- Percent Area of Wetlands Dominated by Reed Canary Grass, per Watershed (Map 6)
- Percent of Open Canopy Wetlands Dominated by Reed Canary Grass, per Watershed (Map 7)

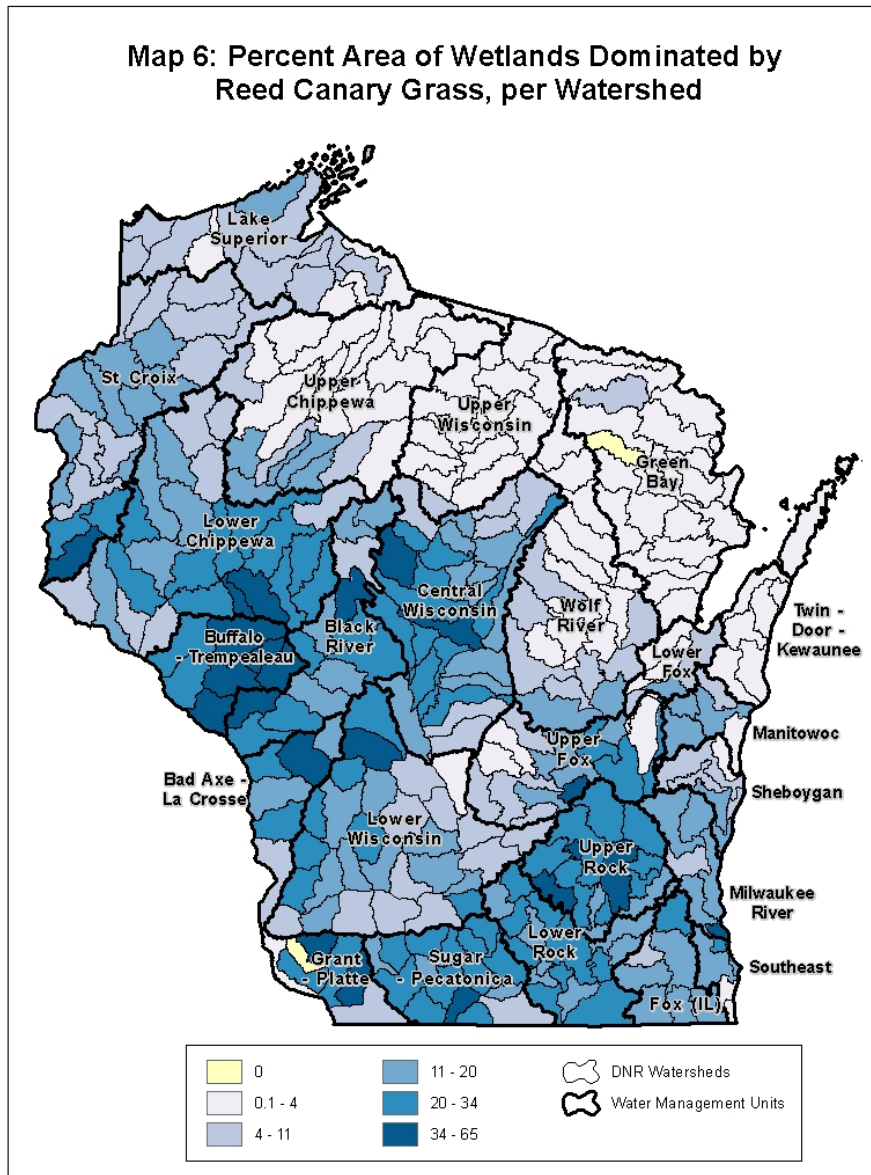
Each of these thematic maps shows a slightly different aspect of the extent of reed canary grass domination. The appropriate set of statistics to use will depend on individual need.

Map 5 shows the watersheds where, taken as a distinct land cover type, reed canary grass dominated wetlands make up the largest portion of a watershed's total area. This kind of analysis is useful in comparing reed canary grass wetlands with all other land cover and water resource types in a watershed. Because it is taken as a percent of the total watershed this number will always be relatively low.

On Map 5 there are two noticeable hot spots of reed canary domination, where watersheds with the highest concentration (4.5% - 8.6%) are surrounded by watersheds in the second highest concentration category (2.0% - 4.5%). The first is centered on the Upper Rock River Basin, and parts of its surrounding Basins. The second straddles the middle and western portion of the Central Wisconsin River Basin, the western portion of the Black River Basin, and the northern portion of the Lower Wisconsin River Basin. There is a third concentration of watersheds in the second highest category covering the western portion of the Upper Chippewa and Buffalo-Trempealeau Basins.

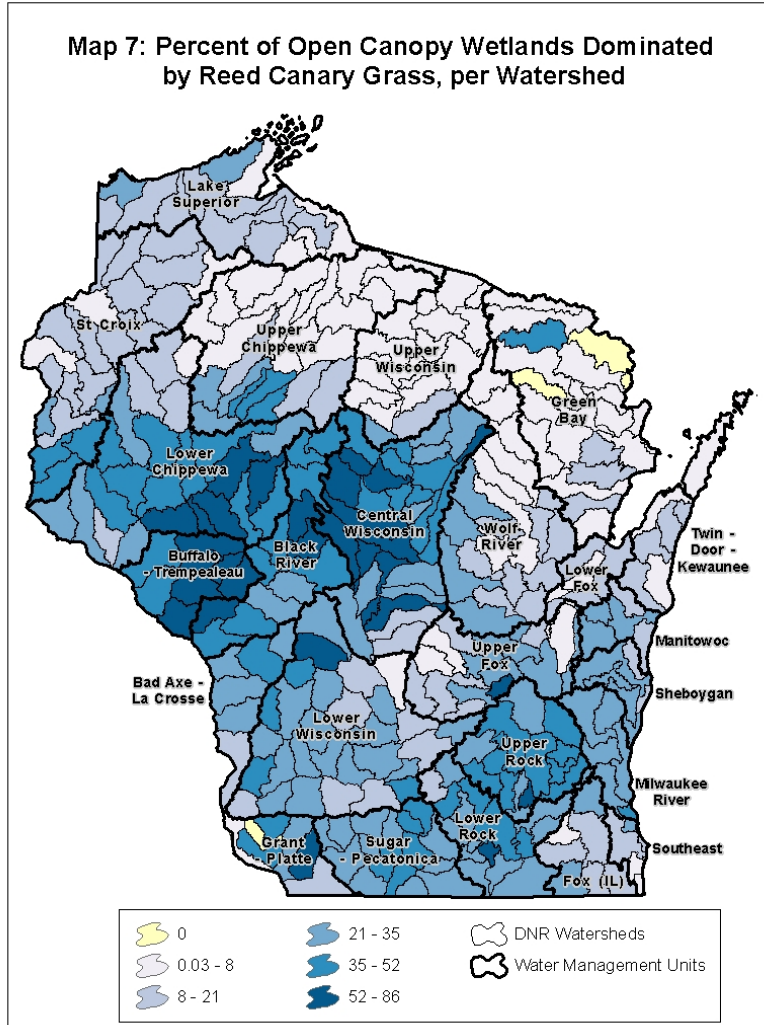


Narrowing the focus, Map 6 shows a characterization of just the wetland resource in each watershed. The percentages are much higher numbers, because total wetland area is the denominator rather than total watershed area.



The same three hotspots appear. The Lower Wisconsin, Bad Axe – La Crosse, Grant – Platte and the parts of other river basins in the unglaciated Driftless Area have several watersheds with high concentrations of reed canary grass. Yet Map 5 showed these same watersheds in the lowest categories when calculated as a percent of the total watershed area. In the Driftless Area, wetlands are relatively scarce, and found almost exclusively along stream courses and valleys. Where reed canary grass dominates these landscape settings, relatively small amounts can still make up a large percentage of the scarce wetlands in these watersheds. Closely examine all three maps to understand the reason for the distribution pattern of reed canary grass across the state.

Map 7 shows the type of wetlands we can most reliably assess. We choose to describe them as “open canopy,” rather than “emergent,” “herbaceous” or “non-forested” in order to highlight the relevant characteristic as it applies to remote sensing. Landsat satellite reflectance band values are affected by woody vegetation, such that they cannot be used to reliably distinguish reed canary grass when it is under a canopy of trees or shrubs.



Map 7 shows the same general pattern as Map 5, with three hot spots embedded within surrounding watersheds at the next lowest category. This time the Buffalo-Trempealeau and the Central Wisconsin hot spot watersheds are in the highest category for extent of domination, while the Upper Rock hotspot watersheds are in the second highest category. This is probably due to the larger amount of open wetlands in the Upper Rock Basin.

4.2.6 Limitations of the Classification Methodology

A very comprehensive disclaimer was written to accompany the grid for users to be aware of its limitations and intended uses. Upon viewing the layer on the Surface Water Data Viewer, as described in Section 4.2.1 above, one can click on the layer name to see the disclaimer online.

Disclaimer for Map Product

This map is a comprehensive state-wide map of reed canary grass infestations in wetlands only. For this reason, only wetlands are visible on this map. All other land cover types were masked out prior to analysis. We recognize that reed canary grass can grow outside of wetland areas; therefore, this map does not depict reed canary grass present in non-wetlands.

The pilot study revealed that reed canary grass growing as an understory in a wooded area is not accurately picked up by the satellites. Trees and woody shrubs tend to block the satellite from “seeing” the groundcover. Therefore this map is only believed to be accurate for open-canopy wetland types such as emergent or wet meadow, but not reliable for assessing the understory of forested wetlands.

The wetland mask used was developed from the WISCLAND land cover wetland boundaries. WISCLAND used data from 1986, and was completed in 1991, making the data currency at present over 20 years old. The vector data from the Wisconsin Wetland Inventory (WWI) was used to create the WISCLAND wetland boundaries. The WWI was not orthorectified at the time, creating the need to manually warp the arcs to fit the imagery. Although WISCLAND employed the WWI for its wetland boundaries, the scale of recommended use decreased from 1:24,000 for WWI to 1:40,000 for WISCLAND. In addition to the effects caused by rasterization, the scale change is also due to the fact that WISCLAND, although started with 30m pixels, was generalized to areas no smaller than four contiguous pixels; making their minimum mapping unit five acres. Only individual wetlands less than one acre were not generalized.

The data shown on this map have been obtained from various sources, and are of varying age, reliability and resolution. This map is not intended to be used for navigation, nor is this map an authoritative source of information about legal land ownership or public access. Users of this map should confirm the ownership of land through other means in order to avoid trespassing. No warranty, expressed or implied, is made regarding accuracy, applicability for a particular use, completeness, or legality of the information depicted on this map.

4.2.7 Cost Considerations

Table 11 is a breakdown of the costs incurred for this project. In addition to the expenses covered in the table, there is the salary for the full-time project employee who performed the work for this project. Staff costs are based on a rough estimate that from May through October 80% of her time was spent on this project, and from November through February 60% of her time was spent on the project. The volunteers who helped with the fieldwork were not compensated in any way. They covered their own expenses including mileage and gas for their own personal vehicles.

Table 11. Expense Summary

Category	Cost
Lodging (eleven hotel stays)	\$556.31
Food (reimbursements for meals on the road)	\$306.44
Vehicle Rental (from 05/09/06 – 10/31/06)	\$3,540.94
Landsat Imagery (seven scenes)	\$2,800.00
Trimble GeoXM with ArcPad Application Builder and Trimble GPSCorrect	\$3,995.00
Trimble GPSCorrect extension enhancement	\$195.00/yr
ArcGIS ArcInfo License Maintenance (incl. extensions and technical support)	\$1,409.27/yr
ERDAS Imagine License Maintenance	\$1,155.00/yr
Salary plus fringe	\$63,336.00
Total Cost	\$77,293.96

4.3 Conclusions

The finished layer is now available, and it has proven to be a great tool in planning wetland restorations and/or enhancements. It could be a helpful warning flag for a wetland restorationist. Knowing where reed canary grass areas are can help determine the most effective long term remediation tactics. Restoring wetlands downstream of a reed canary grass area can compromise the long term success of the restoration site. Or if there is a stand of reed canary grass near a restoration site, it could signal that more long-term monitoring needs to be considered, or more effort needs to be made to establish native plants that can withstand the pressure of encroaching reed canary grass.

There are many organizations working with invasive species, in particular reed canary grass, that are focused on education, outreach, and research. Invasive Plants Association of Wisconsin (IPAW) is working to promote better stewardship of natural resources by increasing the understanding of invasive species and encouraging control efforts. Maps made using the data layer created in this project can be useful tools for such organizations.

The resulting layer has been incorporated into watershed planning and wetland monitoring. The WDNR tracks gains and losses of acres of wetlands, but does not yet track the health of wetlands or the loss of specific functional values. If the mapping process is repeated every five years, an analysis of the two layers could produce maps that would help to better understand the rate of infestation.

The final output of this project should be considered a landscape-level analysis of the wetlands in Wisconsin. It should not replace on-the-ground site analysis. Using the layer as a starting point, research can be done to study the characteristics of sensitive areas vulnerable to an invasion of reed canary grass. In addition, the maps could show where reed canary grass is an imminent threat to the species diversity of nearby wetlands.

4.4 Recommendations for Future Classification Efforts

If this process is repeated in 2011, certain issues need to be addressed, especially data currency for the wetland boundaries. The Wisconsin Wetland Inventory is constantly being improved; currently they are orthorectifying their polygons. An orthorectified version of the WWI would be a great improvement over WISCLAND. Unfortunately, the progress of the WWI updates is slow and will not be complete in time to use when this process is next repeated.

Another issue to consider prior to an update is the condition of the Landsat 5 satellite. The Scan Line Corrector on Landsat 7 will not be fixed and the Landsat 5 satellite was not expected to continue functioning even this long. If it does stop working before the process is repeated, we will need another satellite option.

When selecting imagery for any future classification efforts, it would be ideal to have the time between the field season and the image capture be as small as possible, in addition to having a very small range of dates from which the imagery is gathered. Further research into the differences in reed canary grass growing seasons in the northern part of the state as compared to the southern part of the state might also be warranted.

And lastly, we would recommend that if this process were to be repeated, a larger crew be assembled to carry out the ground truthing in the field and digital image processing on the computer. It is a great advantage to accomplish all of the work in one field season for a more accurate classification. Even adding one more person to the crew would make the process run more smoothly and efficiently.

5. Literature Cited

Bernthal, T.W. and K.G Willis. 2004. *Using Landsat 7 Imagery to Map Invasive Reed Canary Grass (Phalaris Arundinacea): A Landscape Level Wetland Monitoring Methodology*. Wisconsin Department of Natural Resources, Madison. [PUB-SS-992 2004].

Kline, J., T. Bernthal, M. Burzynski, and K. Barrett. 2006. *Milwaukee River Basin Wetland Assessment Project: Developing Decision Support Tools for Effective Planning*. Wisconsin Department of Natural Resources, Madison.

Lillesand, T.M. and Kiefer, R.W. 2000. *Remote Sensing and Image Interpretation*, 4th ed., John Wiley & Sons, Inc., New York.

Trochlell, P.A. 2001. *Development of a Landscape Level Monitoring Methodology Based on Mapping Invasive Species and Disturbance Indicators (ISDI)*. Wisconsin Department of Natural Resources, Madison.

Zedler, J.B. Kercher, S.K. and A. Herr-Turoff. 2005. *What accelerates reed canary grass invasions?* Arboretum Leaflet 5

“Reed Canary Grass (*Phalaris arundinacea*).” Invasive Species. 3 Sept. 2004. Wisconsin Department of Natural Resources. 5 Aug. 2008.
http://dnr.wi.gov/invasives/fact/reed_canary.htm



Wisconsin Department of Natural Resources
P.O. Box 7921, Madison, WI 53707 • (608) 267-7694
DNR PUB WT-900-2008



The Wisconsin Department of Natural Resources provides equal opportunity in its employment, programs, services, and functions under an Affirmative Action Plan. If you have any questions, please write to Equal Opportunity Office, Department of Interior, Washington, D.C. 20240.

This publication is available in alternative format (large print, Braille, audio tape. etc.) upon request. Please call (608) 267-7694 for more information.