Stand Delineation of Floodplain Forest in Nelson-Trevino Research Natural Area in the Upper Mississippi River National Wildlife and Fish Refuge, Winona District

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Abstract

This study examined baseline forest inventory data collected through the forest stand delineation process within the Nelson-Trevino Research and Natural Area (RNA) in Buffalo County located in western Wisconsin. The Nelson-Trevino RNA consists of a unique floodplain ecosystem along the Upper Mississippi River System. Little research and minimal management has been undertaken in the RNA and it recognized that some level of management and data collection is necessary to maintain and monitor the integrity of this unique ecosystem (USFWS, 2006). Completing baseline forest inventory and stand delineation are the first steps towards addressing threats and concerns for the long term health of the floodplain forests within the RNA (USFWS, 2006). This research delineated forest stands and provides information on key parameters relating to the primary dominant over-story. Parameters included the forest stands dominant over-story species, diameter at breast height (DBH) and tree height. The research delivers an accurate interpretation of the forest stands by summarizing, analyzing and organizing collected forest inventory field data.

Introduction

A forest stand is defined as a common grouping of trees relatively similar in species composition, age classes, site quality and condition to be a distinguishable unit (Smith, Larson, Kelty and Ashton, 1997). Forest stand delineation plays a critical role in determining better conservation practices by land managers. The delineation of forest stands gives land mangers a foundational component of inventory and distinguishes specific focal areas for prescribing and implementing management practices (Sullivan, 2008). For example, analysis of forest stands over time can show multiple trends and change occurring within each forest unit. This is a common practice used by many silviculturists to aid in determining strategies and alternatives for forest stands.

Common characteristics generally considered during the forest stand delineation process include trees per acre, basal area, canopy cover, percent cover, average height, age and over-story species composition (Smith and Anson, 1968; Smelser and Patterson, 1975; Avery, 1978).

The forest stand delineation process is most commonly conducted through the use of aerial photographs as a

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way to reduce costs when compared to stand delineation determined from field survey results (Avery and Berlin, 1992). It is recognized that there are significant limitations to this practice. The use of aerial photographs allows a high level of interpretation of features throughout the landscape although obstructions and inadequate resolution can result in inaccuracy.

As technology has progressed the use of Light Detection and Ranging (LIDAR) Data for forestry applications has become a widely accepted practice. LIDAR data has been a reliable source for stand delineation but limitations exist due to the lack of a clear signal resulting in the inability to accurately identify tree species (Leppänen, Tokola, Maltamo, Mehtatalo, Pusa, and Mustonen, 2008).

This research utilized a combination of forest inventory plot data, LIDAR data and aerial imagery to accurately delineate forest stands within the Nelson-Trevino RNA. A basic overview of the process consisted of several steps (Figure 1).

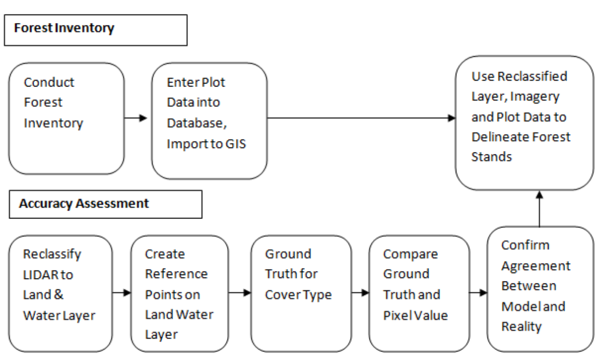


Figure 1. Flow chart describing the research process for forest stand delineation.

First, LIDAR data was reclassified to develop a land and water data layer to assist in the delineation of natural breaks, such as sloughs, streams, islands and other features that can be obstructed by vegetation and the forest canopy in aerial imagery. To determine that adequate agreement existed between the land and water layer and the actual ground cover an accuracy assessment was conducted. Following a successful accuracy assessment, the land and water layer was used along with aerial imagery and the forest inventory plot data to delineate forest stands.

This project delivers an accurate interpretation of forest stands and provides a repeatable method for forest stand delineation.

Study Area

The Nelson-Trevino RNA features 3,740 acres of virtually undisturbed delta floodplain forest created where the Chippewa River empties into the Mississippi River (USFWS, 2006). The RNA is located southwest of the town of Nelson in Buffalo County in Wisconsin (Figure 2).

Figure 2. Locator Map Displaying Nelson-Trevino Research Natural Area.

The RNA is a primary example of a significant and natural floodplain forest ecosystem and can be used as a basis for the comparison of similar ecosystems with greater human influence. The RNA has been deemed a National Landmark by the

National Park Service, a Scientific and Natural Area by the state of Wisconsin and is a federally declared Research Natural Area. The floodplain forest along this area of the Mississippi River System provides critical habitat for a diverse array of flora and fauna and also provide flood effect buffering during periods of severe flooding (Yin, 1999; Romano, 2010).

The Nelson-Trevino RNA is considered a home to various species of birds, fish and mammals such as the great egret (*Ardea alba*), red-shouldered hawk (*Buteo lineatus*), northern harrier (*Circus cyaneus*), cerulean warbler (*Dendroica cerulea*), and prothonotory warbler (*Protonotaria citrea*), largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), river otter (*Lontra Canadensis*) and white-tail deer (*Odocoileus virginianus*). The RNA provides critical nesting habitat for several species of birds and is also home to a small population of the endangered eastern massasauga rattlesnake (*Sistrurus c. catenatus*).

The Nelson-Trevino RNA is frequently used by recreationalist for fishing, hunting, kayak, canoeing, and wildlife viewing. A canoe and kayaking trail that winds through a portion of Nelson-Trevino was recent designated by the Secretary of the Interior as a National Recreational Trail (Figure 3). Numerous changes have occurred throughout the floodplain forest of the Upper Mississippi River since the establishment of the Refuge in 1924.

The forests face an extensive spread of invasive tree, shrub and plant species and a decreasing diversity in native species (Romano, 2010). The diversity that once existed has been reduced to almost a monotypic forest dominated by shade tolerant, even-aged silver maples, with little sign of native regeneration possibly due to the dense understory of the invasive species such as reed canary grass (USFWS, 2006).

Figure 3. A view of the canoe and kayak trail meandering through the floodplain forests of the Nelson-Trevino RNA from Highway 25 area.

There is a great need to document the current characteristics of the individual forest stands to assist in monitoring changes and trends occurring within this important ecosystem.

Methods

Needed Data

The necessary datasets were aquiried from several sources. The Pool 4 forest inventory plot data, 1 meter LIDAR raster data, 2009 aerial imagery,and the Land Use Allocation Plan (LUAP) were aquired from the Upper Mississippi River National Wildlife and Fish Refuge. River gauge CP-4 tabular water elevation data were attained from the Army Corps of Engineers website.

ESRI’s version of ArcMap and ArcCatalog 9.3.1 and 10 were used for data management and analysis. The North American Datum (NAD) 1983 Universal Transverse Mercator (UTM) Zone 15N was the projection used.

Creating Land and Water Layer and Accuracy Assessment

River gauge data were used to determine the water elevation in the study area. Since no gauge was located within the Nelson-Trevino RNA, water elevation data were obtained from the river gauge CP-4, located directly south of the Nelson-Trevino RNA in Wabasha, Minnesota. Annual data were acquired from 2006 until 2011. The mean water elevation was 667.8 feet. The mean elevation was used to reclassify the 1 m Bare Earth LiDAR dataset to define a raster layer consisting of a land and water class. Elevations 667.8 feet and greater were considered land and elevation below 667.8 feet as water. This layer was converted to a polygon shapefile and acreage was calculated. Polygons representing areas less than 3 square meters were eliminated. To verify agreement existed between the land and water layer and the actual ground cover, an accuracy assessment was conducted. The land and water class were each assigned 50 random points using a simple random sample design with ArcToolbox's "Create Random Points" tool. Next, the identify tool was used to extract the ground cover attribute from the land and water layer to the random point shapefile. Random point coordinates were loaded into a WAAS enabled Garmin Global Positioning System (GPS) and ground truthed during time periods when the water level was roughly at 667.8 feet elevation. Specific ground cover type, either land or water was documented with a visual estimate at each GPS coordinate. Field data were recorded and entered into an Excel database then spatially joined to the random points in ArcMap. The symbology was classified to show visual comparison of the agreement between the pixel value from the land and water layer and the ground truthed results (Figure 4). The land cover type recorded from each pixel value on the land and water layer and actual ground truthed survey was used to create an Error Matrix. The Error Matrix summarized the relationship between the land cover of the reclassified layer and the ground truthed reference points. The output of the Error Matrix included the user and producer accuracy to show the accuracy of individual classes and total accuracy to show the percentage of correctly mapped samples. The user, producer and total accuracy were the foundational units used to determine the Kappa Statistic as noted below.

$$kappa = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i.} \cdot x_{.i})}{N^2 - \sum_{i=1}^{r}(x_{i.} \cdot x_{.i})}$$

Where:

- r is the number of rows in the error matrix
- x_{ii} is the number of observations in row and column i
- x_{i} is the total number of observations in row i
- $x_{.i}$ is the total number of observations in column i
- N is the total number of observations

The Kappa Statistic is commonly used as a measure of agreement between reality and model predictions (Congalton, 1991).

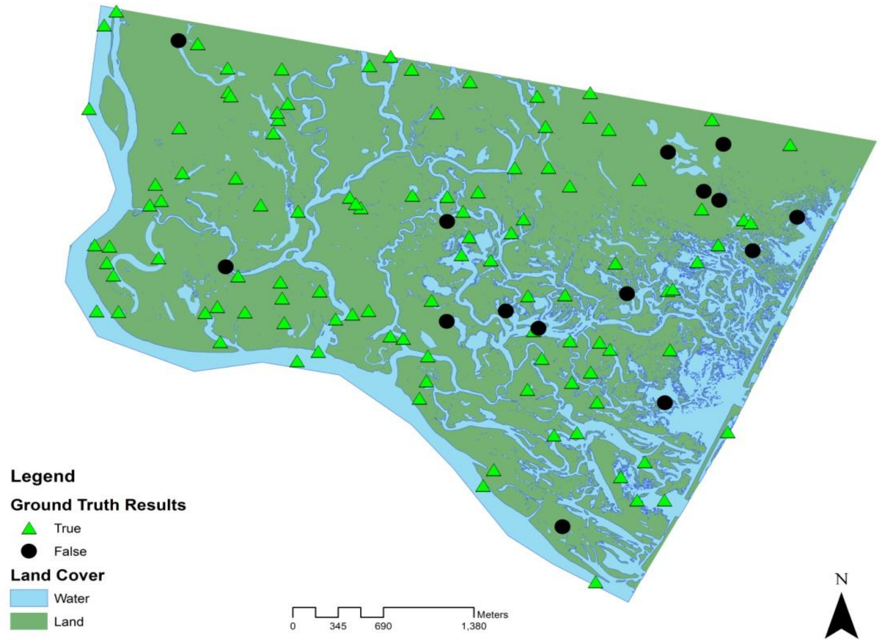
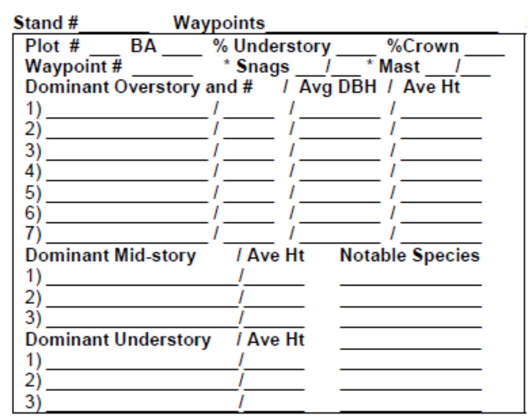


Figure 2. Displays agreement of pixel values and land cover between ground truth and reclassified data layer.

The importance of the Kappa analysis is that it is possible to test if a land cover map/layer is significantly better than if the map/layer had been generated by randomly assigning labels to areas (Congalton, 1996). The Kappa result was then rated using a commonly used statistical scale to verify if there was substantial agreement or better between the land and water layer and actual land cover.

Forest Stand Summary

Forest inventory surveys were conducted throughout the summer field season from 2006 through 2010. Plot field data were collected at 1,039 sites sysematically distributed throughout the Nelson-Trevino area by trained U.S. Fish and Wildlife Service biological technicians. Forest inventory attributes collected at each plot included the information needed to assist in the development of management strategies for the floodplain forest (Figure 5). Also, 'XY' coordinates were recorded to identify the spatial location of the


Stand # ______ Waypoints ____________________

Plot # ___ BA ____ % Understory ____ %Crown ____
Waypoint # ______ * Snags ___/___ * Mast ___/___
Dominant Overstory and # / Avg DBH / Ave Ht
1) ____________ / _____ / _______ / _______
2) ____________ / _____ / _______ / _______
3) ____________ / _____ / _______ / _______
4) ____________ / _____ / _______ / _______
5) ____________ / _____ / _______ / _______
6) ____________ / _____ / _______ / _______
7) ____________ / _____ / _______ / _______
Dominant Mid-story / Ave Ht Notable Species
1) ______________ / ______ ____________
2) ______________ / ______ ____________
3) ______________ / ______ ____________
Dominant Understory / Ave Ht ____________
1) ______________ / ______ ____________
2) ______________ / ______ ____________
3) ______________ / ______ ____________

Figure 5. Forest inventory data sheet displaying the attributes collected at each forest plot in the Nelson-Trevino RNA.

survey plots. After the completion of field surveys within the Nelson-Trevino area, the plot data were entered into an Excel database. A Plot Data shapefile was created using the 'XY' coordinates in ArcMap to display where a forest inventory survey occured. The symbology of the Plot Data shapefile was changed to categories with unique values to represent the different dominant over-story tree species (Figure 6) then the plots were labeled with the average DBH. This allowed ease of visualization during the digitizing of forest plots.

Next, a stand summary polygon shapefile was created. This shapefile was used to delineate boundaries with on-screen digitizing by grouping plot data points with the same dominant over-story and similar DBH. Aerial imagery and the land water layer assisted in delineating natural breaks such as sloughs and streams between forest stands. If no natural breaks were located between plots with different over-stories the boundaries were digitized at the midpoint to separate the two plots. After completing the delineation of forest stands, each polygon was assigned an unique identifier and attributes from the plot data were summarized to show unique characteristics of each forest stand. Due to the scope of the research this project will only discuss the primary dominant over-story. The dominant over-story species within the stands were ranked according to the total numbers of each species. The average diameter and height of the over-story species was determined by multiplying the total number of trees by the average DBH/height of that species for each plot in the stand. The numbers were then added in all plots and divided

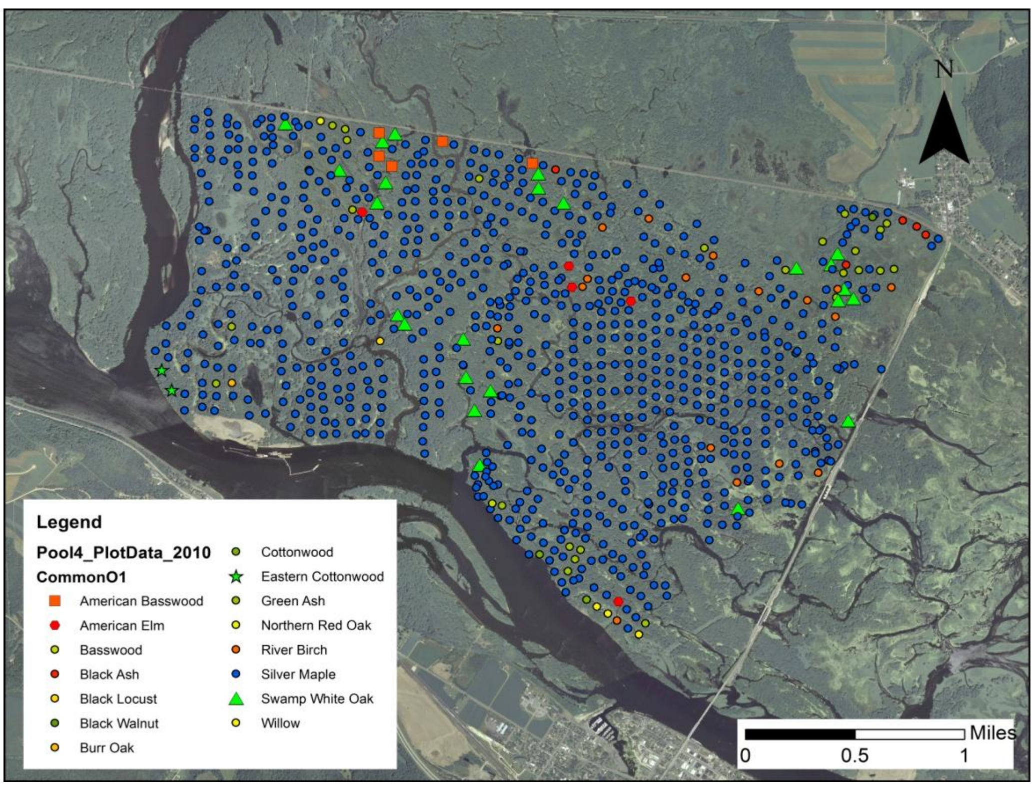


Figure 6. Aerial imagery displaying forest inventory plot sites classified by dominant over-story tree species.

by the number of trees in the stand. An example of the calculations is given in Appendix A.

Results/Discussion

Creating Land and Water Layer and Accuracy Assessment

The results of the analysis conducted in the accuracy assessment validated that a suitable land and water data layer was developed for use in the forest stand delineation process (Table 1). The resulting kappa statistic of 70% showed substantial strength of agreement between the land and water data layer and the actual land cover.

An Error Matrix was used to calculate the user, producer and total accuracy (Table 2). The user and producer accuracy showed minimal distribution of error between the two classes. The total accuracy or the magnitude of pixels in agreement with the ground truthing result was 85%. The user accuracy, or the percentage of map-derived samples that are correctly mapped was 86% for the land class and 84% for the water class. The producer accuracy, or the percentage of field-derived samples that were correctly mapped was 95% for the land class and 71% for the water class.

Forest Stand Summary

Within the Nelson-Trevino RNA 249 forest stands were delineated according to two parameters, the dominant over-story tree species and their DBH (Figure 7). The results were not surprising, nearly 97% of the forest stand acreage was comprised of a dominant over-story consisting of silver maple. The remaining 3% consisted of small stands of swamp white oak, green ash, river birch, willow, black ash and American basswood (Figure 8). The average stand size was 10.7 acres with a mean age of 70.1 years.

Table 1. Interpretation of Kappa Statistic (Landis and Koch, 1997).

Interpretation of Kappa
Poor Slight Fair Moderate Substantial Almost Perfect
Kappa 0.0 .20 .40 .60 .80 1.0
Kappa Agreement
< 0 Less than chance agreement
0.01-0.20 Slight agreement
0.21-0.40 Fair agreement
0.41-0.60 Moderate agreement
0.61-0.80 Substantial agreement
0.81-0.99 Almost perfect agreement

The average DBH for the stands was subdivided using a 5 inch increment for each species. Silver maple was dominant in 232 forest stands having a median value of 73 stands with the DBH between 21-25 inches. The average tree height for the stands was subsetted using a 10 foot increment for each species.

Table 2. Error Matrix displaying the Producer, User and Total Accuracy between land and water layer and ground-truthed results.

Class determined from Land & Water Layer	Class Determined from Ground Truth				
		Land	**Water**	**Total**	**User Accuracy**
	Land	43	7	50	86%
	Water	8	42	50	84%
	Total	51	49	100	
	Product Accuracy	84%	86%		
Total Accuracy					85%

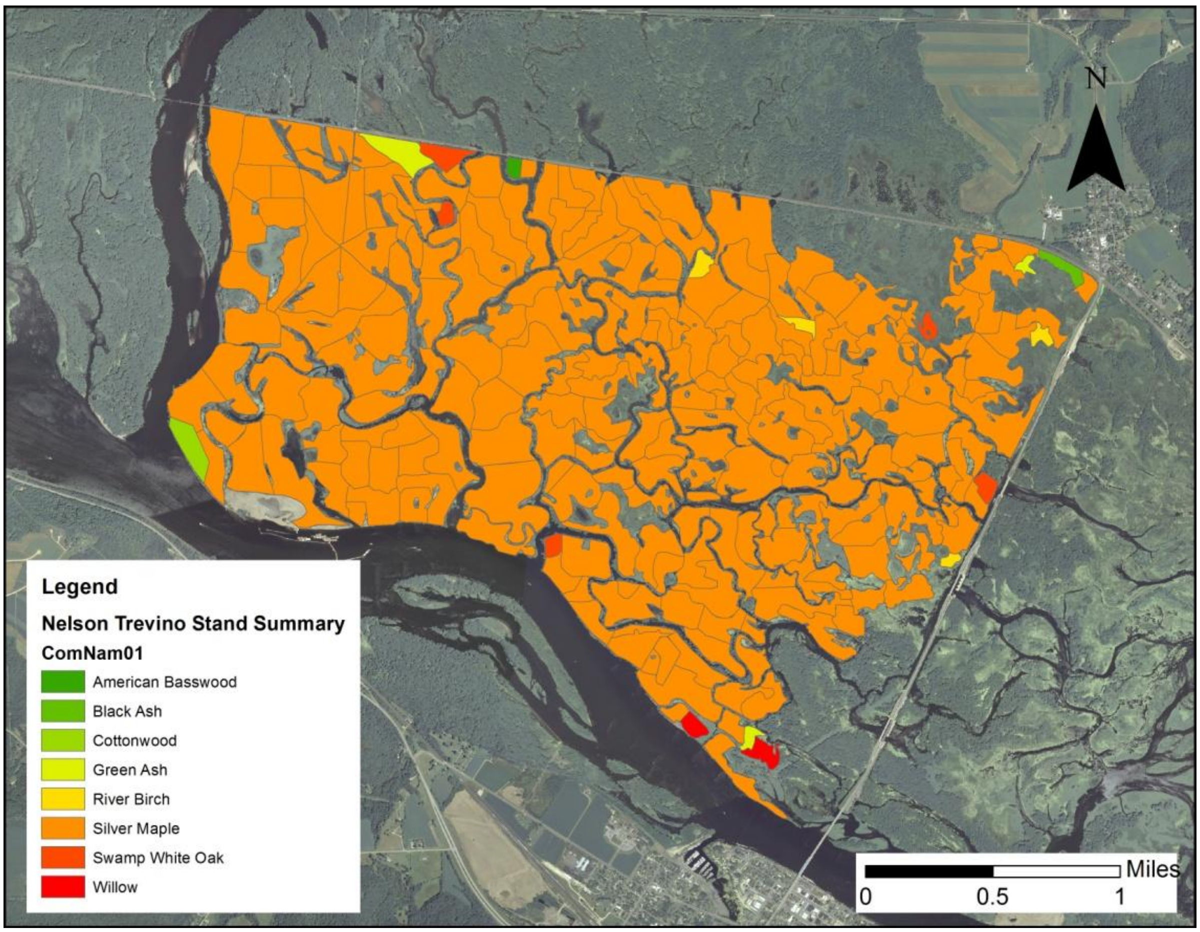


Figure 7. Map displaying delineated forest stands classified by dominant over-story tree species in Nelson-Trevino RNA.

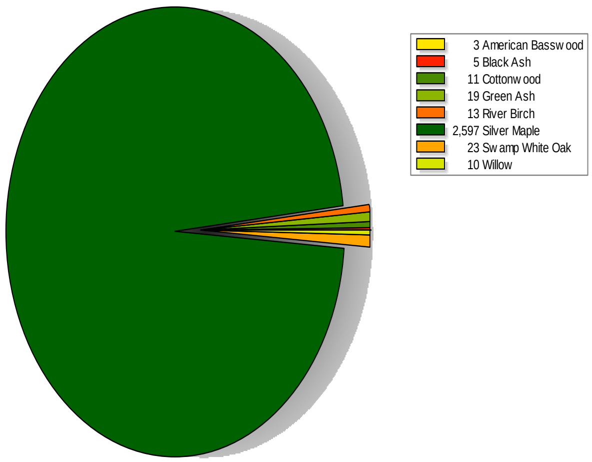


Figure 8. Graph displaying the forest stand dominant over-story tree species composition by percent total acreage.

Silver maple had a median value of 88 stands in the 71-80 foot range.
A table displaying the range of average DBH and tree height for all forest stands within the Nelson-Trevino RNA is listed in section Appendix B. The results show that the forest stands are dominated by an over-story primarily comprised of silver maple.

Limitations/Future Studies

With the baseline data collected and the forest stands delineated, future forest inventory field surveys followed by analysis could display trends and changes occurring within the RNA. During the delineation of forest stands other parameters were summarized from the forest inventory plot data that could be useful for future studies. These parameters attributed in the stand summary shapefile include: Stand ID, Acreage, XY coordinates, percent canopy, dominant mid-story, dominant understory, basal area, notable species, snags, mast trees and the tree age.

Assumptions were made during the accuracy assessment's classification of the water elevation at 667.8 feet. In reality the elevation would decrease as the water progresses through the watershed. Since the RNA is located in a delta area the elevation is relatively flat and use of the data was considered acceptable for this study.

This process of forest inventory and stand delineation was effective but there is the possibility to reduce expenses with the use of remote sensing techniques to minimize costs of transportation and wages for field surveys.

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Great appreciation goes out to everyone at the Upper Mississippi River National Wildlife and Fish Refuge for providing me knowledge and skills to continue on my career path into the natural resource management field.

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Appendix A. Three tables displaying the process of determining the dominant over-story from forest inventory plot data.

Plot 1:	**Species**	**# Trees**	**Average DBH**	**Average Height**
	Silver Maple	13	18"	80
	E. Cottonwood	3	30"	92
	American Elm	3	12"	33
Plot 2	**Species**	**# Trees**	**Average DBH**	**Average Height**
	Silver Maple	12	15"	85
	E. Cottonwood	3	29"	92
	American Elm	4	15"	66

Species	**# Trees**	**Average DBH**	**Average Height**
Silver Maple	13 + 12 = 12.5 2 Plots	13 x 18" = 234 12 x 15" = 180 414 / 25 = 16.6"	13 x 80 = 1040 12 x 85 = 1020 2060 / 25 = 82.4
E. Cottonwood	3 + 3 = 3 2	3 x 30 = 90 3 x 29 = 87 177 / 6 = 29.5"	3 x 92 = 276 3 x 92 = 276 552 / 6 = 92
American Elm	3 + 4 = 3.5 2	3 x 12 = 36 4 x 15 = 60 96 / 7 = 13.7	3 x 80 = 240 4 x 66 = 264 504 / 7 = 72

ComNam01	Silver Maple	**ComNam02**	American Elm	**ComNam03**	E. Cottonwood
Oavg1	12.6	**Oavg1**	3.5	**Oavg1**	3
ODBH1	16.6	**ODBH1**	13.7	**ODBH1**	29.5
Oheight1	82.4	**Oheight1**	72	**Oheight1**	92

Appendix B. Breakdown of dominant over-story average dbh and height by species.

		DBH		Height	
Dominant Over-story	**Total Stand #**	**# in Stand**	**Size Range**	**# in Stand**	**Height Range (ft)**
Silver Maple	232	3	5-10	2	31-40
		24	11-15	7	41-50
		41	16-20	25	51-60
		73	21-25	77	61-70
		51	26-30	88	71-80
		30	31-35	29	80-90
		4	36-40	3	90-100
		5	41-45	1	104
		1	66		

		DBH		Height	
Dominant Overstory	**Total Stand #**	**# in Stand**	**Size Range**	**# in Stand**	**Height Range (ft)**
Swamp White Oak	5		5-10	1	31-40
		3	11-15	1	51-60
		1	16-20	1	61-70
		1	41-45	2	71-80

		DBH		Height	
Dominant Overstory	**Total Stand #**	**# in Stand**	**Size Range**	**# in Stand**	**Height Range (ft)**
Willow	2	1	5-10	1	31-40
		1	11-15	1	41-50

		DBH		Height	
Dominant Overstory	**Total Stand #**	**# in Stand**	**Size Range**	**# in Stand**	**Height Range (ft)**
Green Ash	3	1	5-10	2	31-40
		2	11-15	1	51-60

American Basswood	1	11	71
Black Ash	1	6	48
Cottonwood	1	14	68