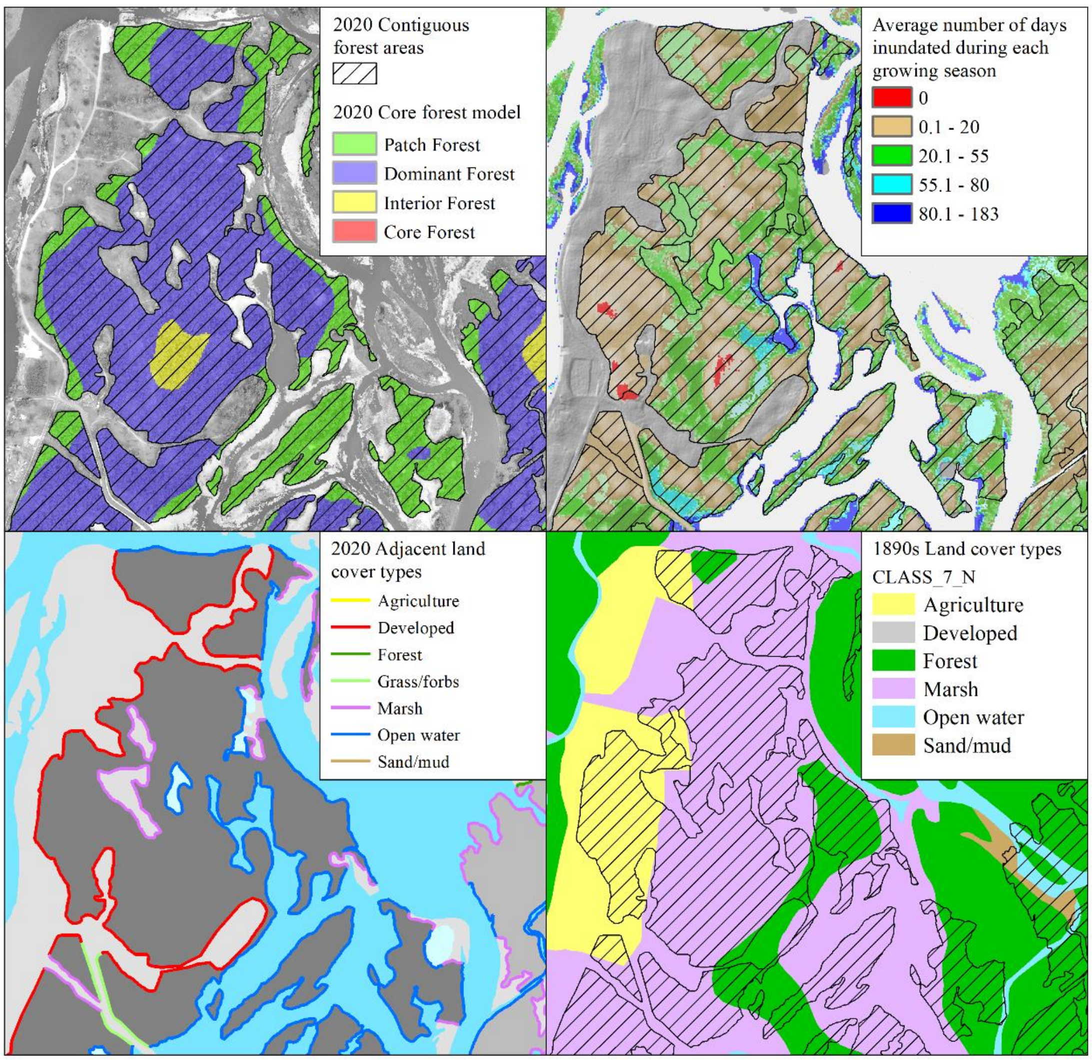
Attributes of Upper Mississippi River System contiguous forest areas



U.S. Department of the Interior
U.S. Geological Survey

Suggested citation:

Rohweder, J., De Jager, N., 2023, Attributes of Upper Mississippi River System contiguous forest areas. Cooperator report prepared for the U.S. Army Corps of Engineers' Upper Mississippi River Restoration – Long Term Resource Monitoring element. 29 p. https://www.usgs.gov/centers/upper-midwest-environmental-sciences-center/science/attributes-upper-mississippi-river

Attributes of Upper Mississippi River System contiguous forest areas

By

Jason J. Rohweder
U.S. Geological Survey
Upper Midwest Environmental Sciences Center
2630 Fanta Reed Road
La Crosse, WI 54603
jrohweder@usgs.gov

and

Nathan R. De Jager
U.S. Geological Survey
Upper Midwest Environmental Sciences Center
2630 Fanta Reed Road
La Crosse, WI 54603
ndejager@usgs.gov

This study was funded as part of the U.S. Army Corps of Engineers' Upper Mississippi River Restoration, Long Term Resource Monitoring element

January 2023

Cover image is a depiction of contiguous forest area development and metric calculation examples related to core forest models (upper left panel), flood inundation models (upper right panel), adjacent land cover types (lower left panel), and historic land cover classifications (lower right panel).

Contents

CONTENTS I

FIGURES II

TABLES II

INTRODUCTION 1

METHODS 1

CONTIGUOUS FOREST AREA DEVELOPMENT AND METRIC CALCULATION 3
Forest unit shape/size/proximity metrics 5
Core forest area metrics 7
Adjacent land cover metrics 9
Floodplain inundation model metrics 11
Forest type metrics 13
Forest cover density metrics 15
Tree height metrics 17
Standing dead tree metric 19
Historic land cover metrics 21

RESULTS AND DISCUSSION 23

LITERATURE CITED 26

SPATIAL DATA SETS USED IN ANALYSIS 28

2020 LAND COVER/LAND USE DATA FOR THE UPPER MISSISSIPPI RIVER SYSTEM 28
Citation 28
Summary 28
1890S MISSISSIPPI RIVER COMMISSION SURVEYS LAND COVER DATA: MISSISSIPPI RIVER 28
Citation 28
Summary 28
FLOODPLAIN INUNDATION ATTRIBUTE RASTERS: MISSISSIPPI & ILLINOIS RIVERS 28
Citation 28
Summary 28

Figures

FIGURE 1. LOCATION OF UPPER MISSISSIPPI RIVER SYSTEM POOLS THAT WERE USED IN ANALYSES DESCRIBED WITHIN THIS REPORT. 3
FIGURE 2. MAP SHOWING LOCATIONS OF 2020 CONTIGUOUS FOREST AREAS FOR POOLS 4, 8, 13 AND 26. 4
FIGURE 3. MAP DEPICTING CONTIGUOUS FOREST AREAS DEVELOPED FOR A SECTION OF POOL 8. SEVERAL METRIC SCORES ARE LISTED RELATED TO THE SHAPE, SIZE, AND PROXIMITY OF THE CONTIGUOUS FOREST AREA WITH THE UNIQUE IDENTIFIER "P08F_0269" AND "P08F_0182". 6
FIGURE 4. MAP DEPICTING THE OUTPUTS OF THE CORE FOREST MODEL DEVELOPED USING THE 2020 UMRR-LTRM LAND COVER DATA SET. SEVERAL METRIC SCORES ARE LISTED RELATED TO THE AMOUNT OF EACH CORE FOREST MODEL CLASS FOR THE CONTIGUOUS FOREST AREA WITH THE UNIQUE IDENTIFIER "P08F_0269" AND "P08F_0182". 8
FIGURE 5. MAP DEPICTING THE OUTPUTS OF THE ADJACENT LAND COVER MODEL DEVELOPED USING THE 2020 UMRR-LTRM LAND COVER DATA SET. SEVERAL METRIC SCORES ARE LISTED RELATED TO THE AMOUNT OF SHARED BOUNDARY TO DIFFERENT LAND COVER CLASSES AND THE CONTIGUOUS FOREST AREA WITH THE UNIQUE IDENTIFIER "P08F_0269" AND "P08F_0182". 10
FIGURE 6. MAP DEPICTING THE OUTPUTS OF THE FLOOD INUNDATION MODEL. SEVERAL METRIC SCORES ARE LISTED SUMMARIZING THE AVERAGE NUMBER OF DAYS THAT WERE INUNDATED DURING EACH GROWING SEASON FROM 1972-2011 THAT OVERLAP THE CONTIGUOUS FOREST AREA WITH THE UNIQUE IDENTIFIER "P08F_0269" AND "P08F_0182". DARKER SHADING WITHIN EACH FLOOD DURATION BIN REPRESENTS A LARGER AVERAGE NUMBER OF DAYS INUNDATED. 12
FIGURE 7. MAP DEPICTING THE 31-CLASS LAND USE TYPE USING THE 2020 UMRR-LTRM LAND COVER DATA SET. METRIC SCORES ARE LISTED RELATED TO COMPOSITION OF EACH DIFFERENT FORESTED LAND COVER CLASS WITHIN CONTIGUOUS FOREST AREA "P08F_0269" AND "P08F_0182". 14
FIGURE 8. MAP DEPICTING THE COVER DENSITY VALUES USING THE 2020 UMRR-LTRM LAND COVER DATA SET. METRIC SCORES ARE LISTED RELATED TO AREA OF EACH COVER DENSITY CLASS WITHIN CONTIGUOUS FOREST AREA "P08F_0269" AND "P08F_0182". 16
FIGURE 9. MAP DEPICTING THE TREE HEIGHT VALUES USING THE 2020 UMRR-LTRM LAND COVER DATA SET. METRIC SCORES ARE LISTED RELATED TO AREA OF EACH TREE HEIGHT CLASS WITHIN CONTIGUOUS FOREST AREA "P08F_0269" AND "P08F_0182". 18
FIGURE 10. MAP DEPICTING THE STANDING DEAD TREE PRESENCE VALUES USING THE 2020 UMRR-LTRM LAND COVER DATA SET. THE METRIC SCORE IS LISTED RELATED TO AREA OF THE STANDING DEAD TREE CLASS WITHIN CONTIGUOUS FOREST AREA "P08F_0269" AND "P08F_0182". 20
FIGURE 11. MAP DEPICTING THE OVERLAP OF THE 1890S HISTORIC LAND COVER CLASS WITH EACH CONTIGUOUS FOREST AREA. METRIC SCORES ARE LISTED RELATED TO THE AREA OF EACH HISTORIC LAND COVER CLASS WITHIN CONTIGUOUS FOREST AREA "P08F_0269" AND "P08F_0182". 22

Tables

TABLE 1. CROSSWALK TABLE DESCRIBING POSSIBLE ATTRIBUTES GIVEN TO POLYGONS WITHIN THE 2020 UMRR-LTRM LAND COVER DATA SETS. 2
TABLE 2. SUMMARY OF METRIC SCORES BY POOL. 25

Introduction

Floodplain forests are important features of river systems as they create habitat for a variety of wildlife species as well as influence water quality by sequestering nutrients. The ecological conditions found within forested areas can vary greatly from place to place, contributing to spatial variability in species diversity, animal use of the floodplain, and other ecological functions. For this reason, it is important for managers and researchers to identify and map existing forest conditions for use in restoration practices or research studies.

A number of forest attributes have been identified as useful in predicting the local ecological conditions found within forested areas. For example, attributes related to the size, shape and configuration of forest patches have been linked to susceptibility to invasion by exotic species, animal and plant dispersal patterns, population distributions, and species diversity (Zuidema and others, 1996; Laurance and others, 2001; Weathers and others, 2001; Lindenmayer and Franklin 2002; Harper and others, 2005; Ramaharitra 2006). In floodplain forests, patterns of inundation have been shown to influence local soil conditions as well as plant species composition and diversity (De Jager and others, 2012). Knowing the land-use history of forest areas has also been shown to be important in understanding present day ecological conditions of forested areas (Turner and others, 2004).

To support floodplain forest research and management actions on the Upper Mississippi River System (UMRS), we identified contiguous forested areas (i.e., areas of forest cover that were separated from each other by other land or water cover types) in the floodplain and calculated a wide range of attributes that define basic ecosystem conditions within such forested areas. The data allows users to query on a set of attributes (e.g., size, shape, inundation characteristics, etc.) to visualize the distribution of various ecological conditions. In addition, the data allows for future data analyses of relationships among different ecological conditions and other data, such as animal and plant population distributions.

Methods

The base spatial data set used to develop the contiguous forest areas was the 2020 land cover data set developed by the Upper Mississippi River Restoration (UMRR) program, Long Term Resource Monitoring (LTRM) element (Hop and others, 2021). This data set was developed to assess and evaluate vegetation components and long-term vegetation trends of navigable pools on the UMRS. For forest polygons to be included as part of a contiguous forest area they would need to belong to the seasonally flooded forest classifications, “Floodplain forest” or “Salix community”, or the temporarily flooded forest classifications, “Lowland forest” or “Populus community”. The [CLASS_31_N] forest classification “Upland forest” was also included, but only if that forest occurred on land classified as islands within the river floodplain. Additionally, only forests with the cover density modifiers identifying that forest as having at least 33% cover density were included for all the forest classes.

Table 1 depicts the 31 individual classes mapped for the 2020 land cover data set and the additional classes and modifiers attributed to each polygon (Dieck and others 2015).

Table 1. Crosswalk table describing possible attributes given to polygons within the 2020 UMRR-LTRM land cover data sets.

CLASS_31_N 31-Class LCU name	CLASS_15_N 15-Class LCU name	CLASS_7_N 7-Class LCU name	LAND_WATER Description of a 2-class land/water system.	HYD_REG_N Description of the Hydrologic Regime.	COVER_N Density-cover modifier name.	HEIGHT_N Description of the tree-height modifier code.
Agriculture	Agriculture	Agriculture	Land	Infrequently flooded	n/a	n/a
Developed	Developed	Developed	Land		n/a	n/a
Conifers	Upland forest	Forest	Land		Y	Y
Plantation					Y	Y
Upland forest					Y	Y
Shrub/scrub	Shrub/scrub				Y	n/a
Lowland forest	Wet forest	Forest	Land	Temporarily flooded	Y	Y
Populus community					Y	Y
Wet meadow shrub	Wet shrub				Y	n/a
Floodplain forest	Wet forest	Forest	Land	Seasonally flooded	Y	Y
Salix community					Y	Y
Shallow marsh shrub	Wet shrub				Y	n/a
Wooded swamp	Wet forest	Forest	Water	Semipermanently flooded	Y	Y
Deep marsh shrub	Wet shrub				Y	n/a
Pasture	Grass/forbs	Grass/forbs	Land	Infrequently flooded	n/a	n/a
Grassland					Y	n/a
Levee	Road/levee				Y	n/a
Roadside					Y	n/a
Sedge meadow	Wet meadow	Marsh	Land	Temporarily flooded	Y	n/a
Shallow marsh annual	Shallow marsh	Marsh	Land	Seasonally flooded	Y	n/a
Shallow marsh perennial					Y	n/a
Wet meadow	Wet meadow				Y	n/a
Deep marsh annual	Deep marsh	Marsh	Water	Semipermanently flooded	Y	n/a
Deep marsh perennial					Y	n/a
Open water	Open water	Open water	Water	Permanently flooded	n/a	n/a
Rooted floating aquatics	Rooted floating aquatics				Y	n/a
Submersed aquatic vegetation	Submersed aquatic vegetation				Y	n/a
Sand	Sand/mud	Sand/mud	Land	Infrequently flooded	n/a	n/a
Sand bar	Sand/mud	Sand/mud	Land	Temporarily flooded	n/a	n/a
Mud	Sand/mud	Sand/mud	Land	Seasonally flooded	n/a	n/a
No coverage	No coverage	No coverage	n/a	n/a	n/a	n/a

The specific classes to include in the derived contiguous forest units were identified by scientists, resource managers, and other stakeholders from the U.S. Geological Survey, U.S. Army Corps of Engineers, and the U.S. Fish and Wildlife Service. The reason the forest polygons belonging to this subset of forest type classes and density modifiers were chosen was to best create contiguous forest areas for floodplain forest areas containing overstory trees across a range of species compositions.

At the time of analysis, 2020 land cover data sets were available for pools 4, 8, 13, and 26 on the UMRS (Figure 1). The entire UMRS including pools 1 through 26, and the open river reach on the Mississippi River, the entire navigable portion of the Illinois River, and the navigable portions of the Minnesota, St. Croix, and Kaskaskia Rivers are slated to be completed by 2025. As these additional pools are completed, the contiguous forest area delineation can be performed, and metrics calculated.

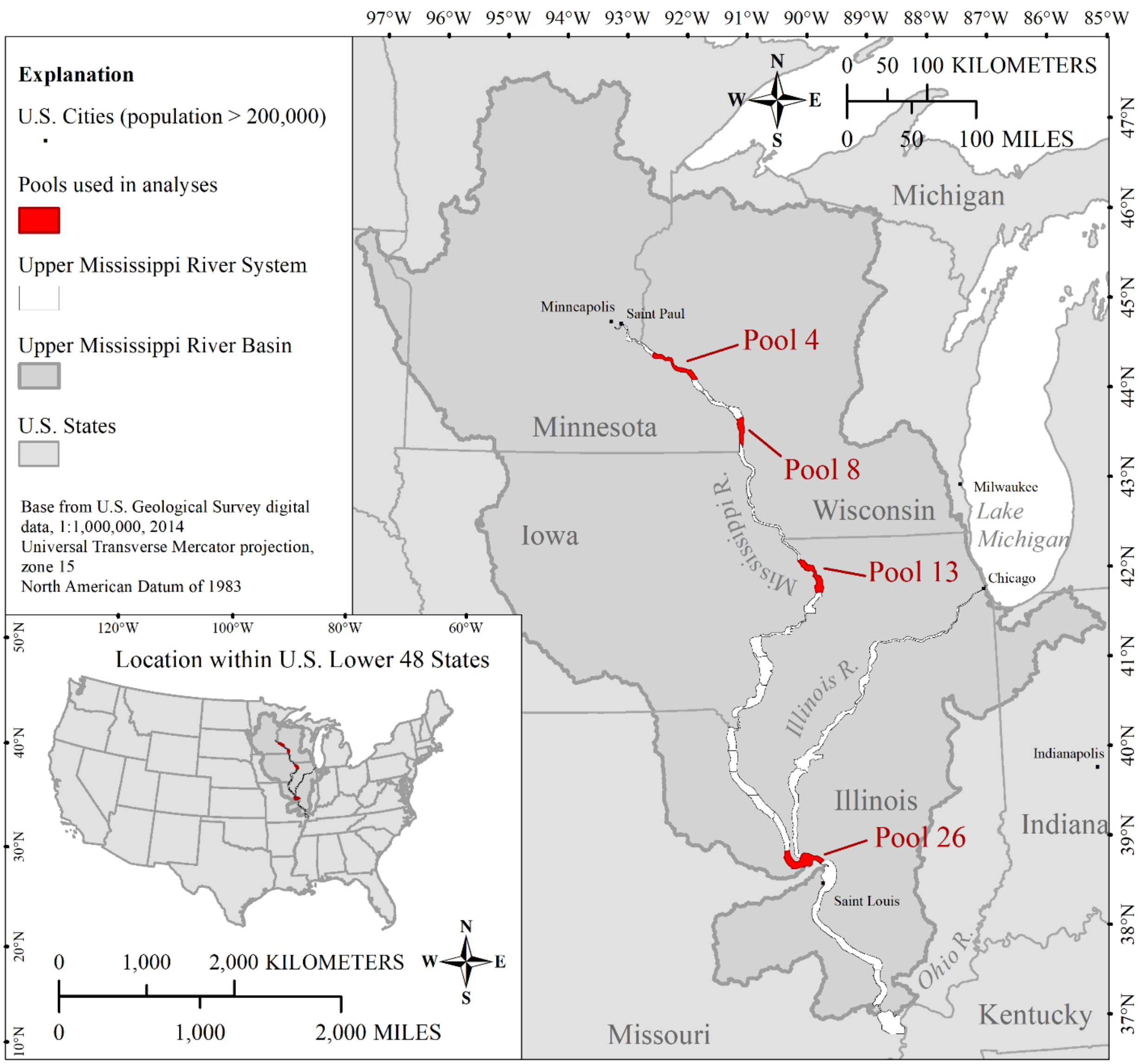


Figure 1. Location of Upper Mississippi River System pools that were used in analyses described within this report.

Contiguous forest area development and metric calculation

Python scripts were developed to take the input data layers (2020 land cover, 1890s land cover, flood inundation model, and continuous river mile raster (unpublished data)) for each pool and perform several operations. First, queries were made of the 2020 land cover data set to identify those forest areas that met the criteria outlined previously related to forest type and cover density. Next, a process was run to remove upland forest polygons that did not overlap those areas defined as islands. The remaining selected forest areas were then merged to create forest areas that were completely contiguous with each other, but isolated from other forest areas by other land cover types. Each contiguous forest area is comprised of one or more smaller forest polygons delineated by the photo interpreter. Figure 2 displays the contiguous forest areas derived for pools 4, 8, 13 and 26.

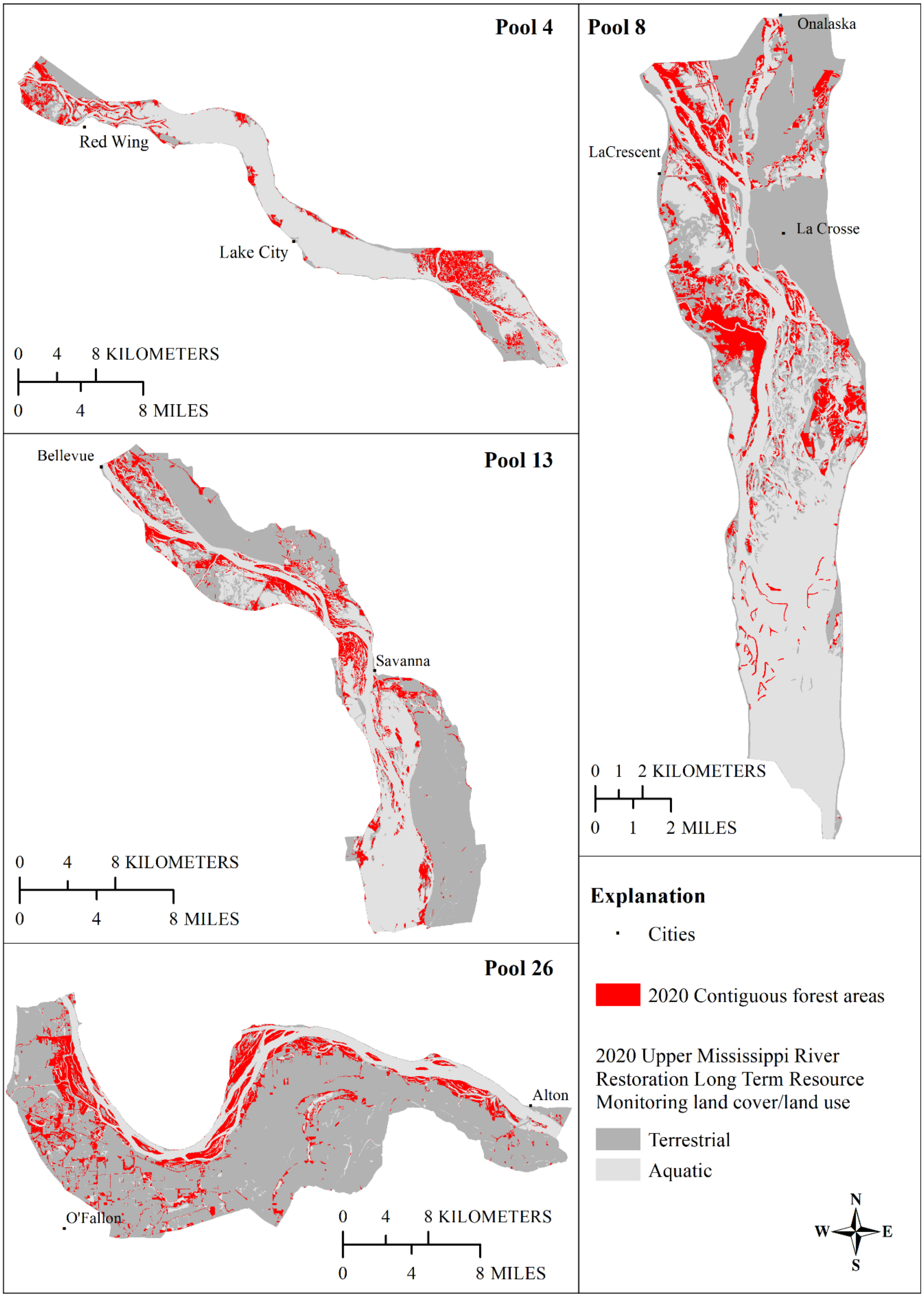


Figure 2. Map showing locations of 2020 contiguous forest areas for pools 4, 8, 13 and 26.

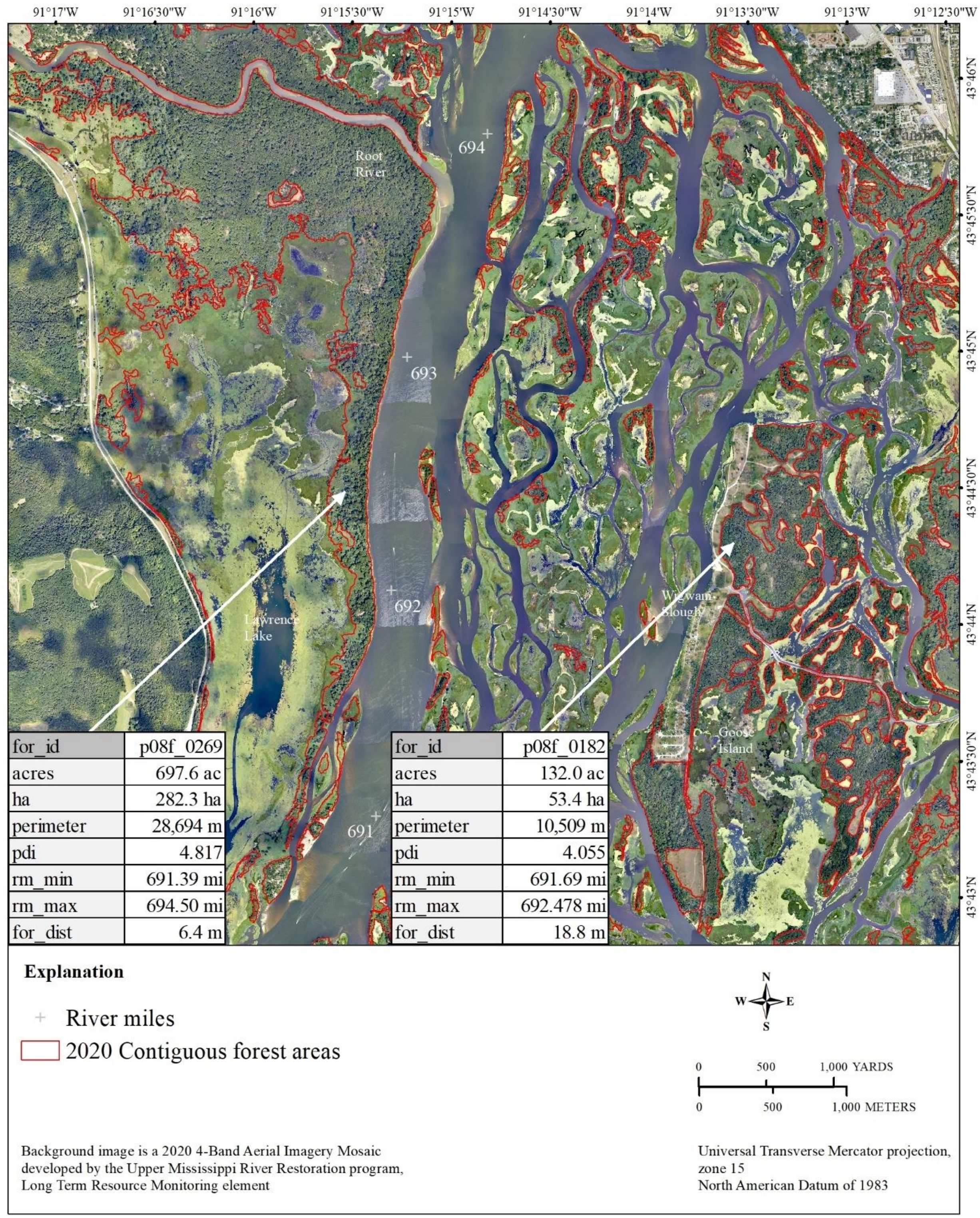
A unique identifier "for_id" was created for each contiguous forest area to be able to easily identify them.

Next, the scripts generated several metrics for each contiguous forest area based upon the shape, proximity, or underlying geomorphic characteristics. While it is relatively easy to delineate the boundaries of forest areas, it is much more difficult to identify species composition within those areas using remote sensing techniques. We therefore calculated more generalized (average) conditions among different contiguous forest areas as an indication of habitat, geomorphic, ecosystem conditions/processes. These metrics are described in detail in the following sections and an example figure is given using a section of pool 8. The derived metrics for two contiguous forest area polygons possessing often differing attributes are displayed on each map.

Forest unit shape/size/proximity metrics

Several metrics were developed for each contiguous forest area related to shape, size, and proximity (Figure 3).

acres	-	Area of the contiguous forest area in acres
ha	-	Area of the contiguous forest area in hectares
perimeter	-	Perimeter length of the contiguous forest area in meters
pdi	-	Polygon Development Index defined as the ratio of the contiguous forest area's perimeter length to the perimeter length of a circle of the same area. Larger values represent a more complex contiguous forest area boundary
rm_min	-	Furthest reach of the contiguous forest area downstream (measured in river miles)
rm_max	-	Furthest reach of the contiguous forest area upstream (measured in river miles)
for_dist	-	Distance in meters from the contiguous forest area to the nearest contiguous forest area



for_id	p08f_0269
acres	697.6 ac
ha	282.3 ha
perimeter	28,694 m
pdi	4.817
rm_min	691.39 mi
rm_max	694.50 mi
for_dist	6.4 m

for_id	p08f_0182
acres	132.0 ac
ha	53.4 ha
perimeter	10,509 m
pdi	4.055
rm_min	691.69 mi
rm_max	692.478 mi
for_dist	18.8 m

Figure 3. Map depicting contiguous forest areas developed for a section of pool 8. Several metric scores are listed related to the shape, size, and proximity of the contiguous forest area with the unique identifier "p08f_0269" and "p08f_0182".

Core forest area metrics

Several metrics related to the density of forest surrounding each contiguous forest area were developed using a moving window analysis (see De Jager and Rohweder 2011) (Figure 4). Using the contiguous forest area as a source, the percentage of contiguous forested area surrounding each 1-meter forested pixel was calculated using a 10-ha circular window. Thresholds used in these analyses were adopted to classify forested pixels based on the percentage of forest cover in the surrounding neighborhood (10-ha circular window). Core forest pixels were those that were nested in a 100-percent forested neighborhood, which is relevant for species or processes that require extremely dense forest cover. Interior forest pixels were surrounded by greater than 90-percent but less than 100-percent forest cover and represent slightly fragmented forest. Dominant forest pixels were those surrounded by greater than 50-percent forest cover but less than 90-percent and were therefore more fragmented than interior forest. Finally, patch forest pixels were those surrounded by less than 50-percent forest cover and were therefore most fragmented (De Jager and Rohweder 2011).

for_core	-	Area in hectares of forest polygon classified as "Core forest - 100% forest coverage" using a 10-ha circular analysis window
for_inte	-	Area in hectares of forest polygon classified as "Interior forest - >90% < 100% forest coverage" using a 10-ha circular analysis window
for_domi	-	Area in hectares of forest polygon classified as "Dominant forest - >50% < 90% forest coverage" using a 10-ha circular analysis window
for_patc	-	Area in hectares of forest polygon classified as "Patch forest - <50% forest coverage" using a 10-ha circular analysis window

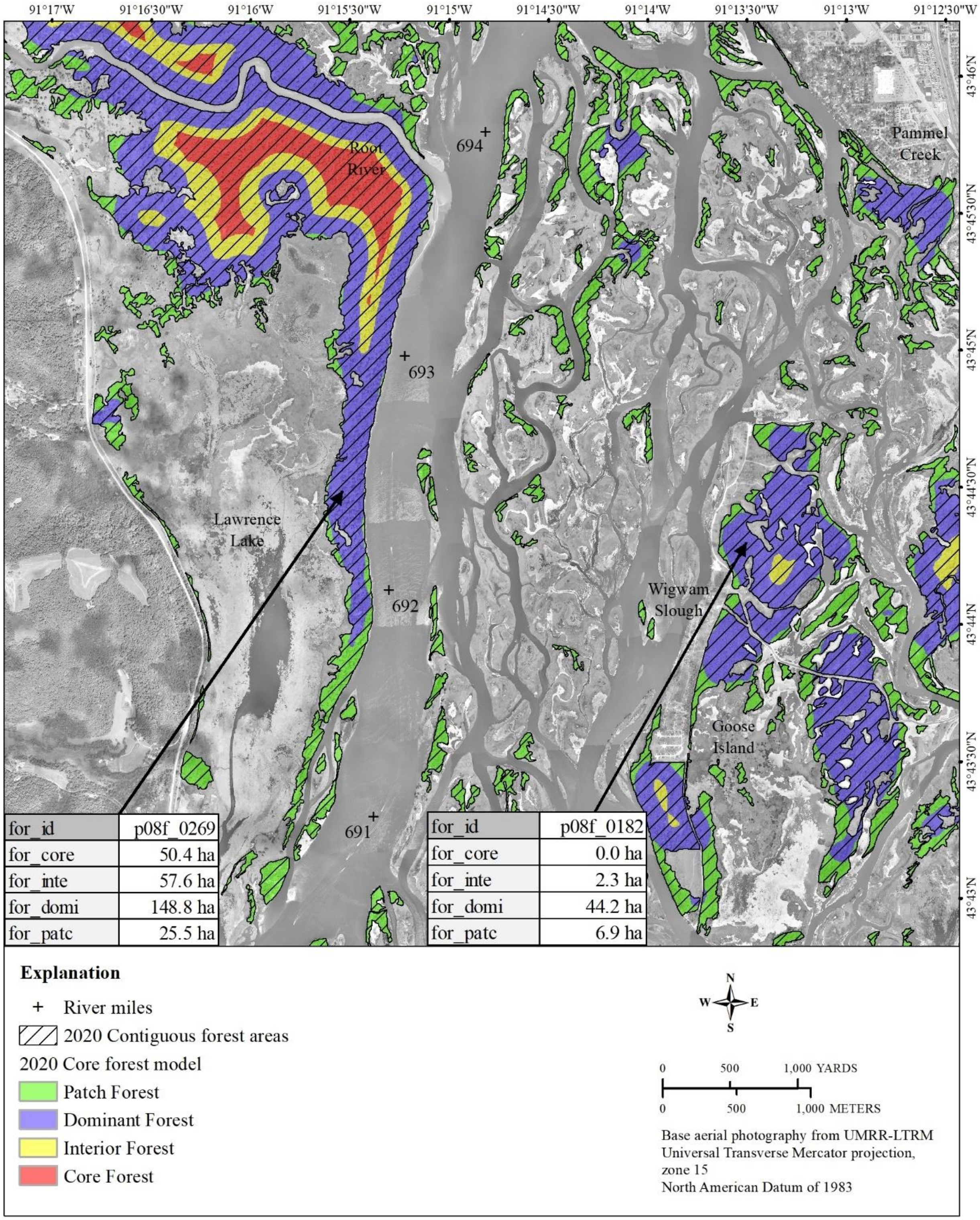


Figure 4. Map depicting the outputs of the core forest model developed using the 2020 UMRR-LTRM land cover data set. Several metric scores are listed related to the amount of each core forest model class for the contiguous forest area with the unique identifier "p08f_0269" and "p08f_0182".

Adjacent land cover metrics

Several metrics were developed for each contiguous forest area related to adjacent land cover types (Figure 5). The 2020 UMRR-LTRM land cover data set was used to define adjacent land cover types using the attribute "CLASS_7_N".

adj_ag_len	-	Length in meters of perimeter of contiguous forest area that has an adjacent land cover type classified as "Agriculture"
adj_dv_len	-	Length in meters of perimeter of contiguous forest area that has an adjacent land cover type classified as "Developed"
adj_fo_len	-	Length in meters of perimeter of contiguous forest area that has an adjacent land cover type classified as "Forest"
adj_gr_len	-	Length in meters of perimeter of contiguous forest area that has an adjacent land cover type classified as "Grass/forbs"
adj_ma_len	-	Length in meters of perimeter of contiguous forest area that has an adjacent land cover type classified as "Marsh"
adj_ow_len	-	Length in meters of perimeter of contiguous forest area that has an adjacent land cover type classified as "Open water"
adj_sm_len	-	Length in meters of perimeter of contiguous forest area that has an adjacent land cover type classified as "Sand/mud"
adj_un_len	-	Length in meters of perimeter of contiguous forest area that has an adjacent area that was unmapped (typically floodplain boundary)
hydcon_mc	-	Was the contiguous forest area hydrologically connected to the main channel when photography was collected? (1=Yes, 0=No)
island	-	Was the contiguous forest area located on an island within the river floodplain (surrounded by open water) when photography was collected? (1=Yes, 0=No)

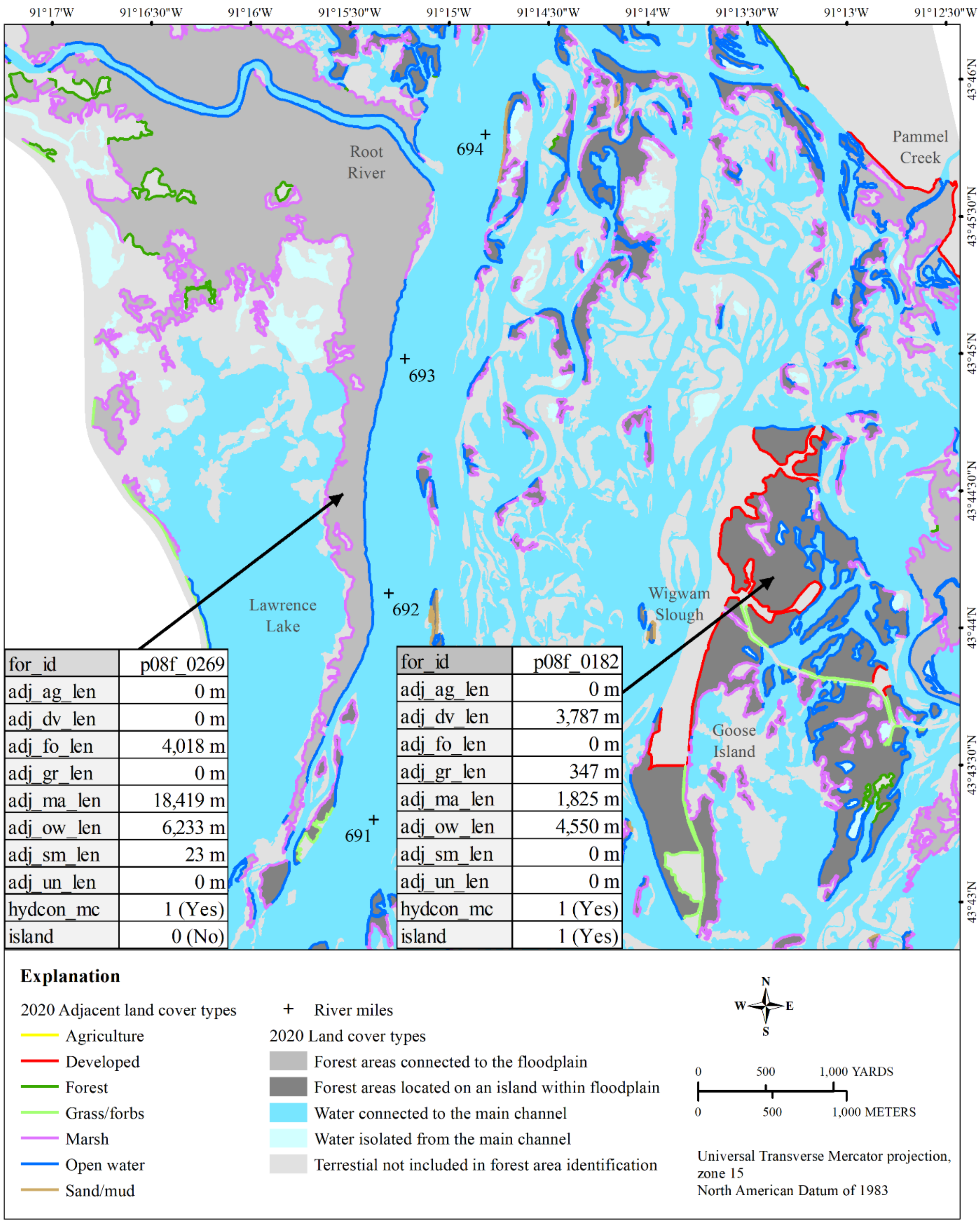
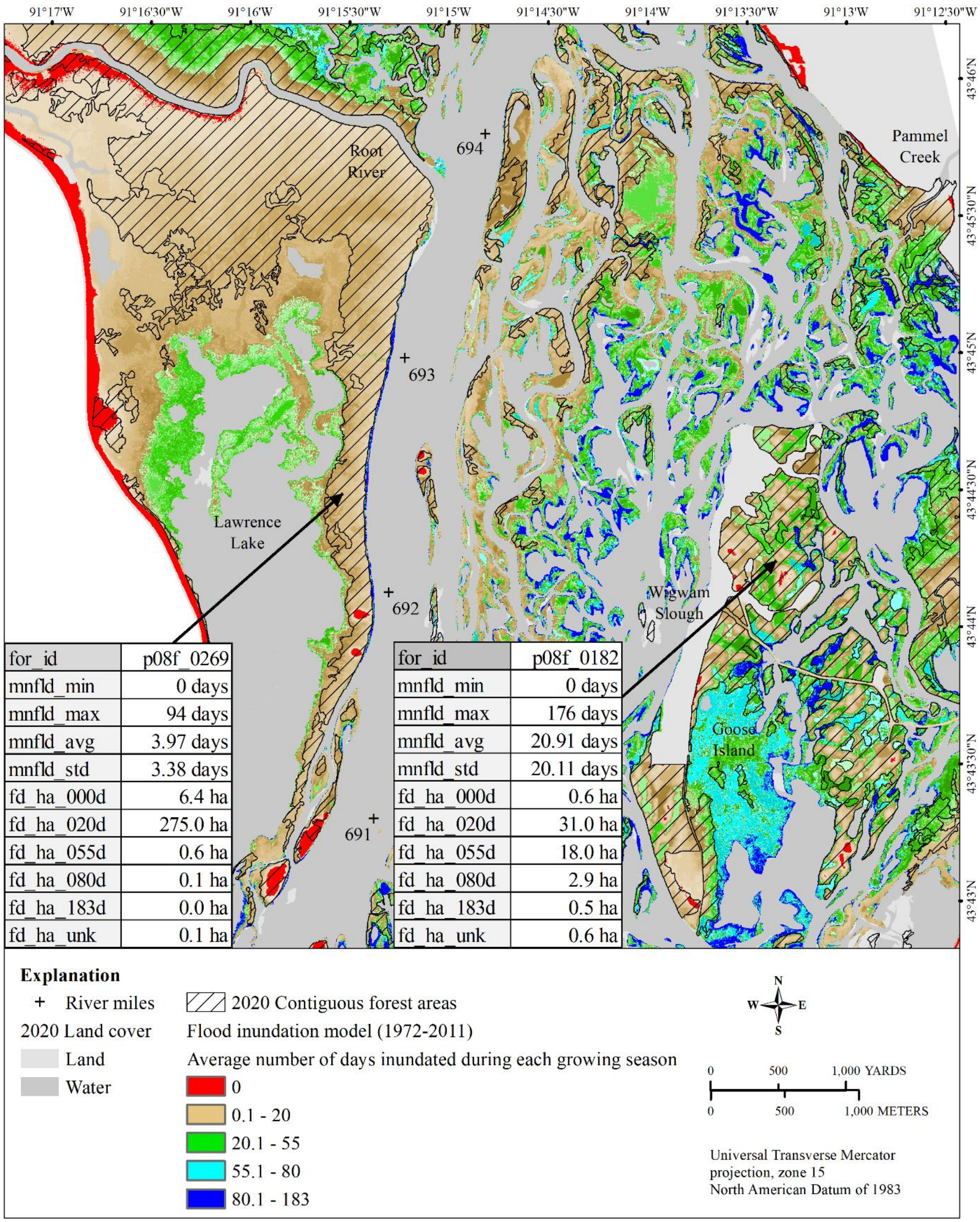


Figure 5. Map depicting the outputs of the adjacent land cover model developed using the 2020 UMRR-LTRM land cover data set. Several metric scores are listed related to the amount of shared boundary to different land cover classes and the contiguous forest area with the unique identifier "p08f_0269" and "p08f_0182".

Floodplain inundation model metrics

To assess the spatial variability of long-term average growing season flood characteristics, we overlaid each contiguous forest area over a flood inundation model (Van Appledorn and others 2020). The specific attribute used from this model was the 40-year mean growing season (1 April – 30 September) flood duration expressed as a mean value across the years of record (1972 – 2011) (Figure 6).

mnfld_min	-	Metric developed to identify the minimum value of all mean growing season flood duration cell values overlapping the contiguous forest area
mnfld_max	-	Metric developed to identify the maximum value of all mean growing season flood duration cell values overlapping the contiguous forest area
mnfld_avg	-	Metric developed to identify the average value of all mean growing season flood duration cell values overlapping the contiguous forest area
mnfld_std	-	Metric developed to identify the standard deviation value of all mean growing season flood duration cell values overlapping the contiguous forest area
fd_ha_000d	-	The area in hectares of the contiguous forest area with a mean total number of days inundated during the growing season equal to 0
fd_ha_020d	-	The area in hectares of the contiguous forest area with a mean total number of days inundated during the growing season greater than 0 and less than 20 days
fd_ha_055d	-	The area in hectares of the contiguous forest area with a mean total number of days inundated during the growing season greater than 20 and less than 55 days
fd_ha_080d	-	The area in hectares of the contiguous forest area with a mean total number of days inundated during the growing season greater than 55 and less than 80 days
fd_ha_183d	-	The area in hectares of the contiguous forest area with a mean total number of days inundated during the growing season greater than 80 days
fd_ha_unk	-	The area in hectares of the contiguous forest area that did not overlap the flood duration model (flood duration unknown)



for_id	p08f_0269
mnfld_min	0 days
mnfld_max	94 days
mnfld_avg	3.97 days
mnfld_std	3.38 days
fd_ha_000d	6.4 ha
fd_ha_020d	275.0 ha
fd_ha_055d	0.6 ha
fd_ha_080d	0.1 ha
fd_ha_183d	0.0 ha
fd_ha_unk	0.1 ha

for_id	p08f_0182
mnfld_min	0 days
mnfld_max	176 days
mnfld_avg	20.91 days
mnfld_std	20.11 days
fd_ha_000d	0.6 ha
fd_ha_020d	31.0 ha
fd_ha_055d	18.0 ha
fd_ha_080d	2.9 ha
fd_ha_183d	0.5 ha
fd_ha_unk	0.6 ha

Figure 6. Map depicting the outputs of the flood inundation model. Several metric scores are listed summarizing the average number of days that were inundated during each growing season from 1972-2011 that overlap the contiguous forest area with the unique identifier "p08f_0269" and "p08f_0182". Darker shading within each flood duration bin represents a larger average number of days inundated.

Forest type metrics

Several metrics were developed for each contiguous forest area related to forest type classification (Figure 7). The 2020 UMRR-LTRM land cover data set was used to define forest types using the attribute “CLASS_31_N”.

ftyp_ff_ha	-	Area in hectares of the contiguous forest area classified as "Floodplain forest" or “Lowland forest” using the 31-class classification
ftyp_pc_ha	-	Area in hectares of the contiguous forest area classified as "Populus community” using the 31-class classification
ftyp_sc_ha	-	Area in hectares of the contiguous forest area classified as "Salix community” using the 31-class classification
ftyp_uf_ha	-	Area in hectares of the contiguous forest area classified as "Upland forest” using the 31-class classification

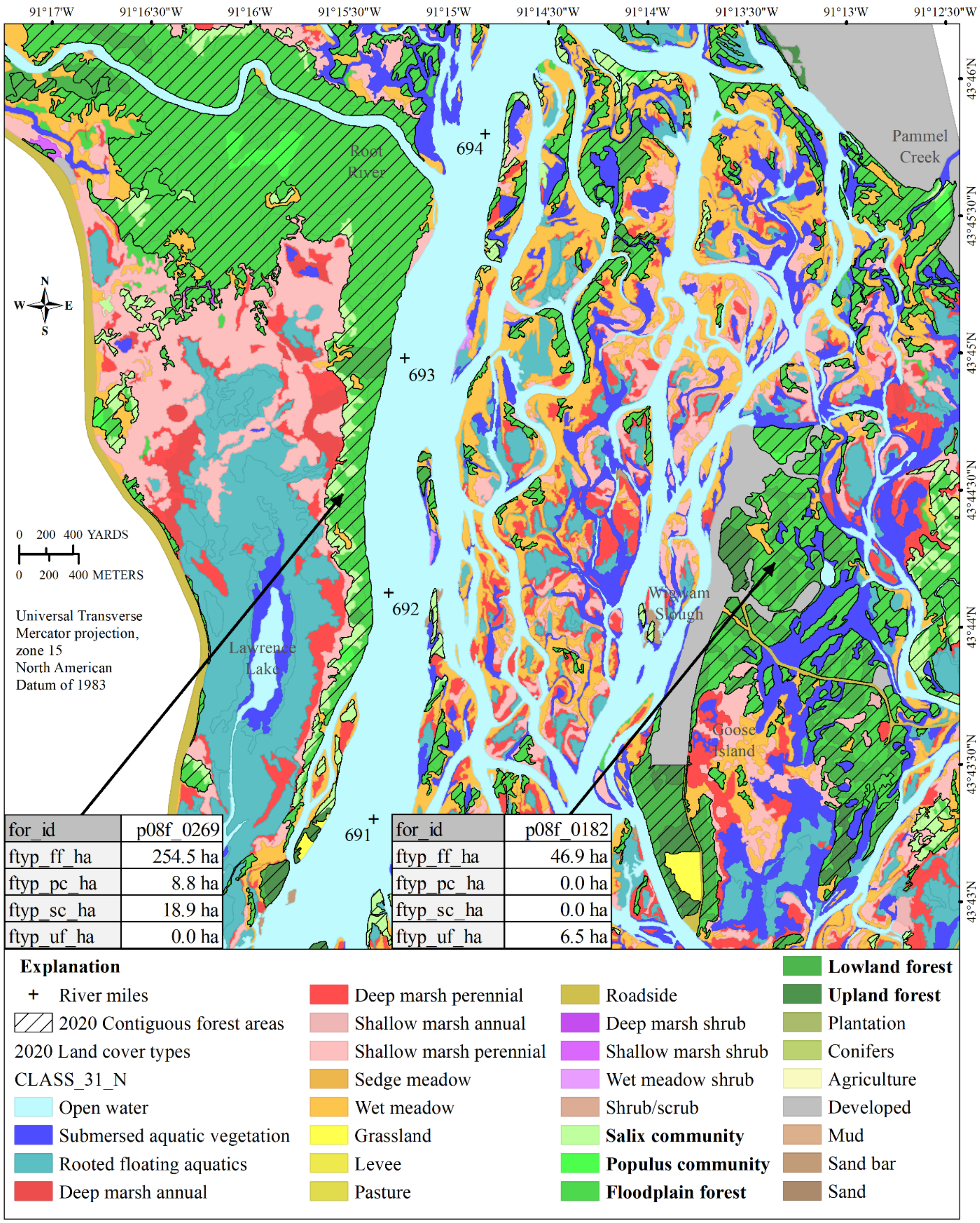


Figure 7. Map depicting the 31-class land use type using the 2020 UMRR-LTRM land cover data set. Metric scores are listed related to composition of each different forested land cover class within contiguous forest area "p08f_0269" and "p08f_0182".

Forest cover density metrics

Several metrics were developed for each contiguous forest area related to forest cover density classification (Figure 8).

fcov3366ha	-	Area in hectares of the contiguous forest area classified as having forest cover density of 33-66 percent cover as identified by the photo interpreter
fcov6690ha	-	Area in hectares of the contiguous forest area classified as having forest cover density of 66-90 percent cover as identified by the photo interpreter
fcovgt90ha	-	Area in hectares of the contiguous forest area classified as having forest cover density of greater than 90 percent cover as identified by the photo interpreter

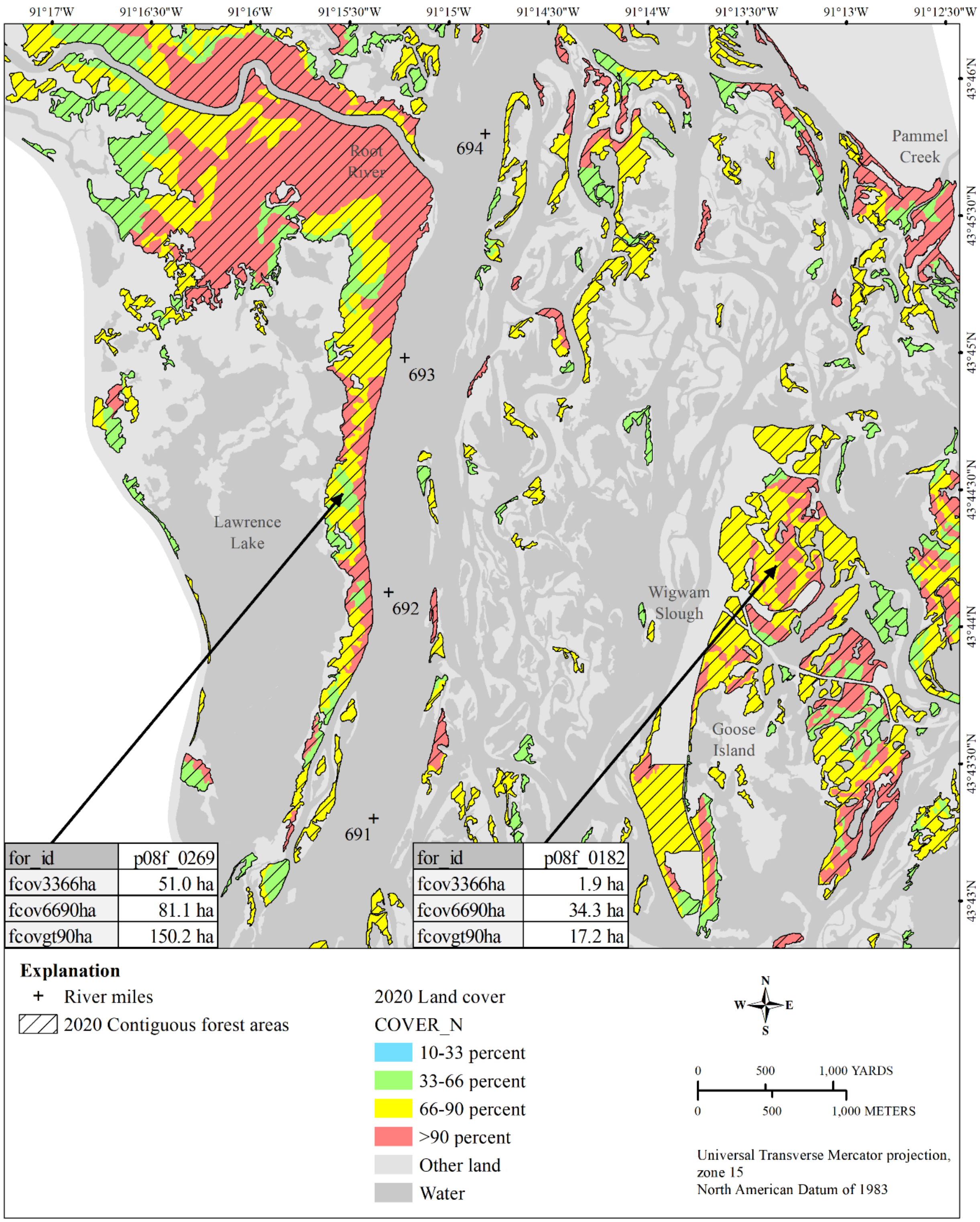
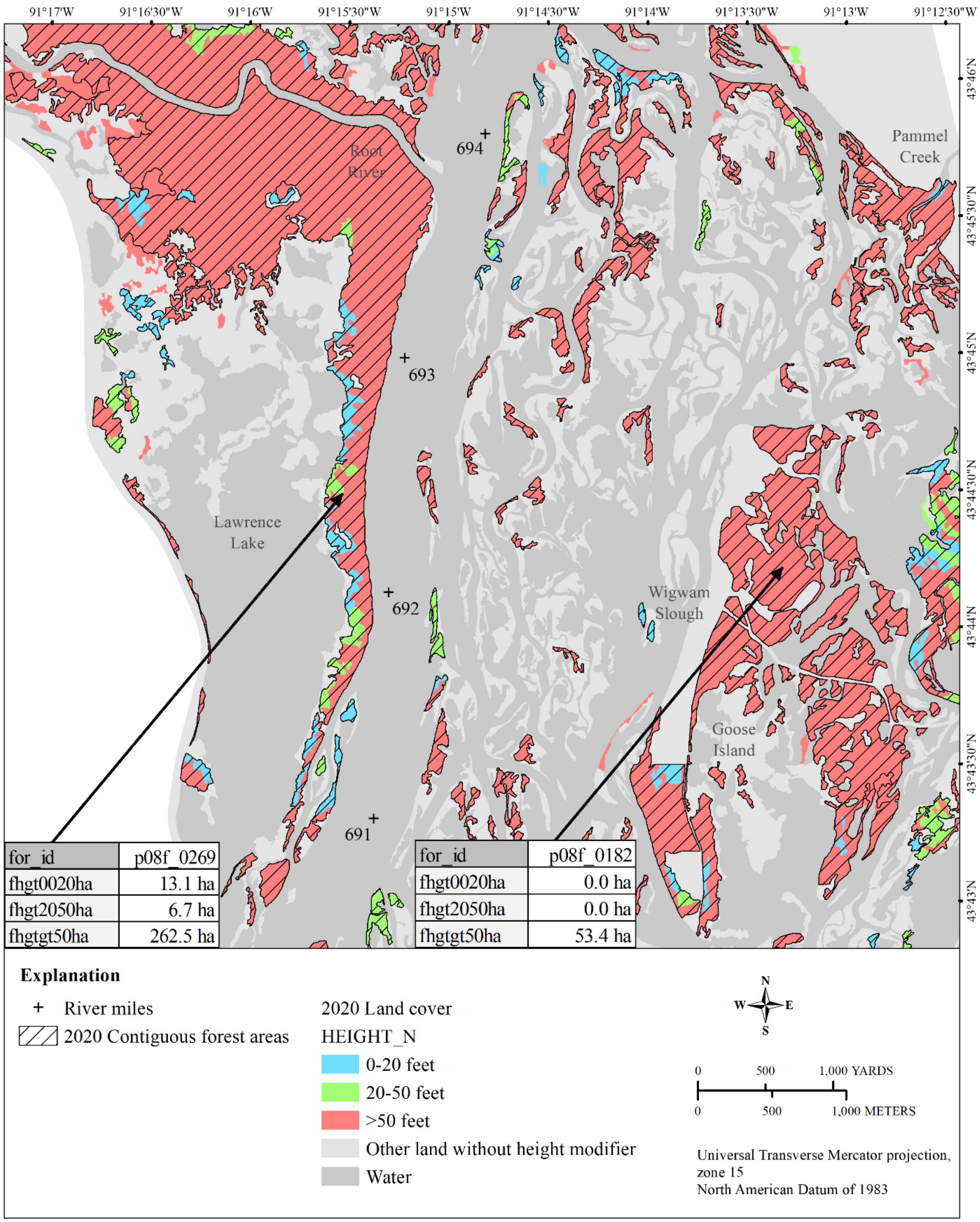


Figure 8. Map depicting the cover density values for contiguous forest areas using the 2020 UMRR-LTRM land cover data set. Metric scores are listed related to area of each cover density class within contiguous forest area “p08f_0269” and “p08f_0182”.

Tree height metrics

Several metrics were developed for each contiguous forest area related to tree height (Figure 9). The 2020 UMRR-LTRM land cover data set was used to define average tree height using the attribute "HEIGHT_N".

fhgt0020ha	-	Area in hectares of the contiguous forest area classified as having average tree heights of 0-20 feet as identified by the photo interpreter
fhgt2050ha	-	Area in hectares of the contiguous forest area classified as having average tree heights of 20-50 feet as identified by the photo interpreter
fhgtgt50ha	-	Area in hectares of the contiguous forest area classified as having average tree heights of greater than 50 feet as identified by the photo interpreter



for_id	p08f_0269
fhgt0020ha	13.1 ha
fhgt2050ha	6.7 ha
fhgtgt50ha	262.5 ha

for_id	p08f_0182
fhgt0020ha	0.0 ha
fhgt2050ha	0.0 ha
fhgtgt50ha	53.4 ha

Figure 9. Map depicting the tree height values using the 2020 UMRR-LTRM land cover data set. Metric scores are listed related to area of each tree height class within contiguous forest area "p08f_0269" and "p08f_0182".

Standing dead tree metric

An additional metric was developed for each contiguous forest area related to the presence of standing dead trees (Figure 10). The 2020 UMRR-LTRM land cover data set was used to define standing dead tree cover using the attribute “S_MOD”.

deadtr_ha	-	Area in hectares of the contiguous forest area classified as having the "S" modifier (at least 25% cover standing dead trees) by the photo interpreter

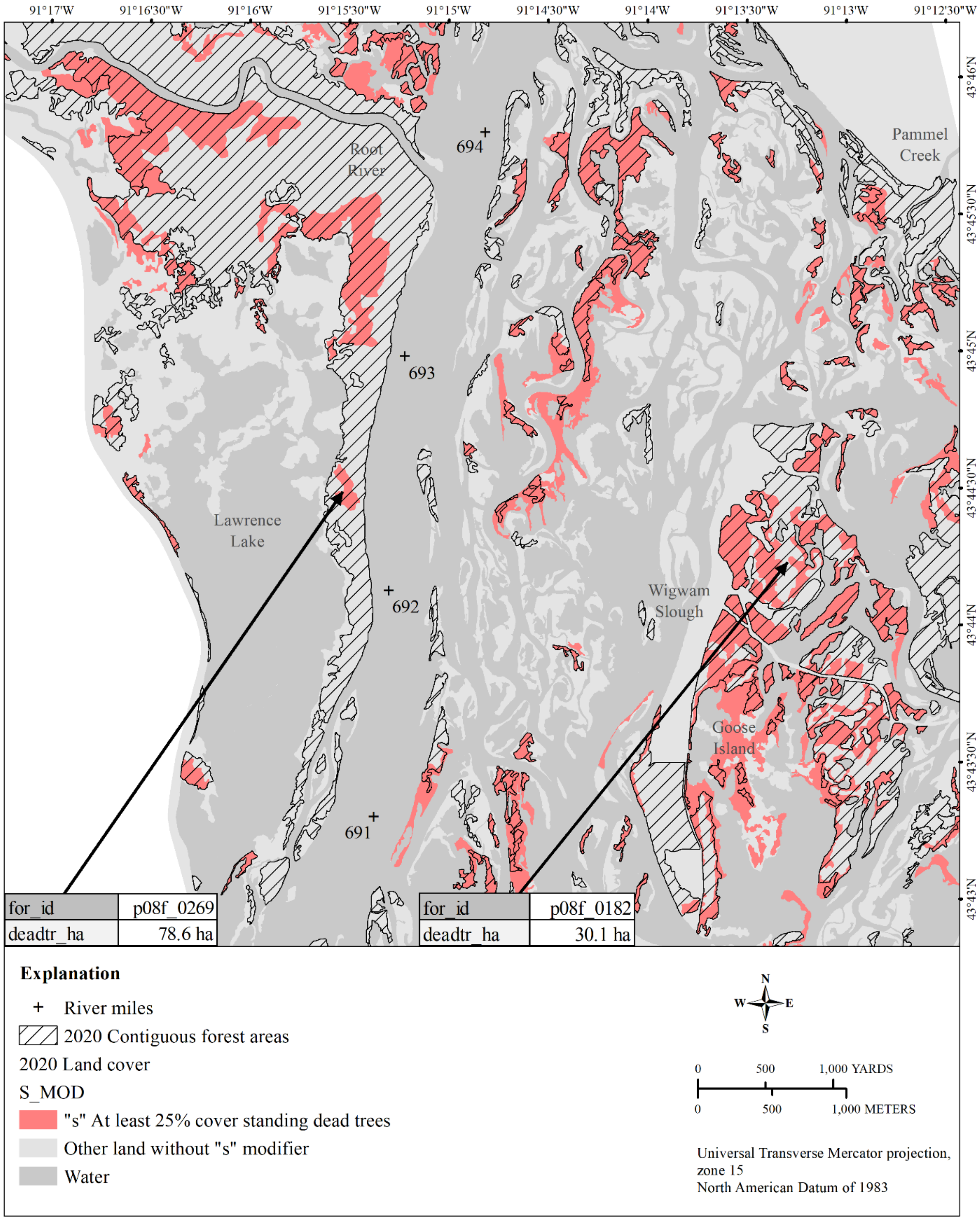
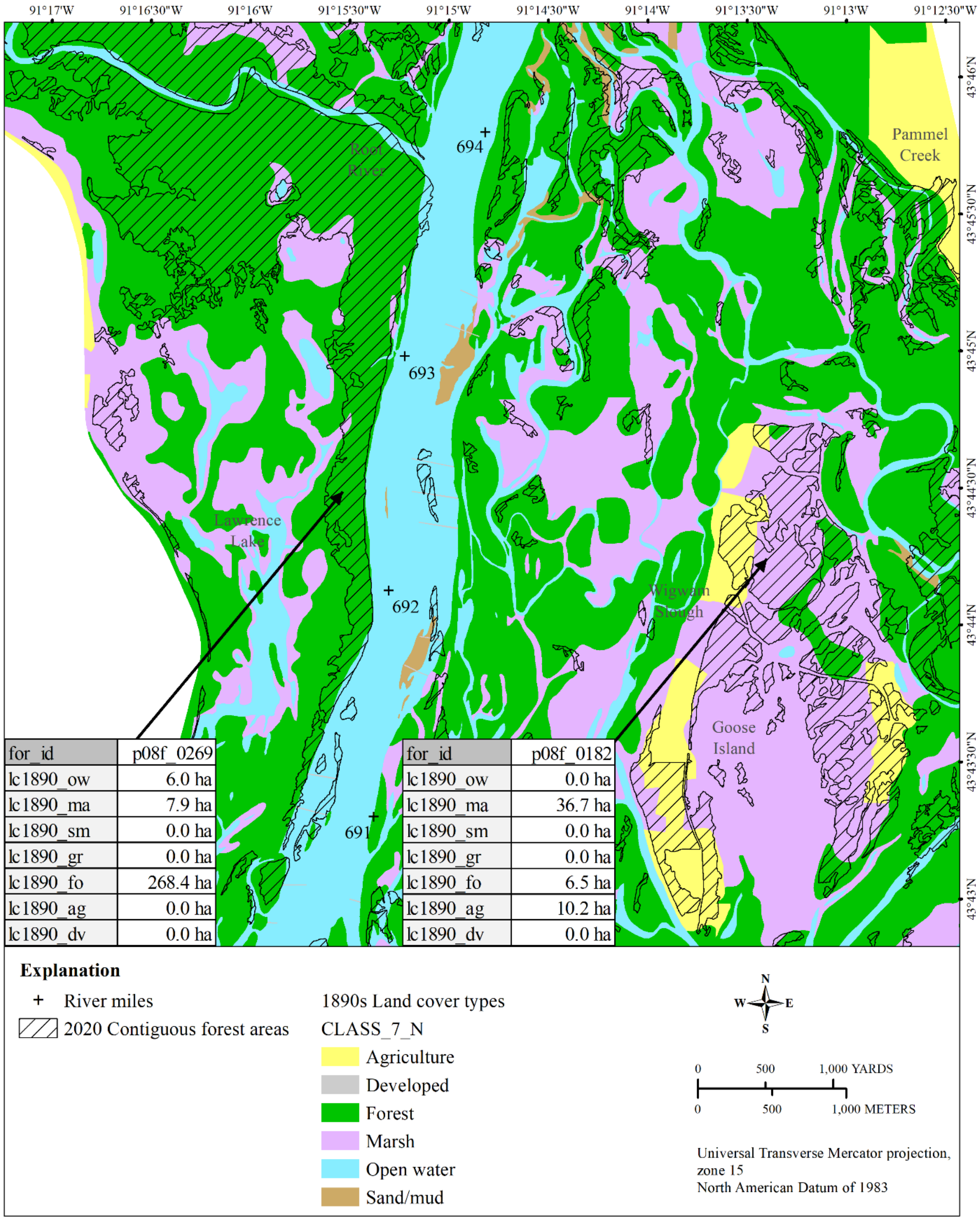


Figure 10. Map depicting the standing dead tree presence values using the 2020 UMRR-LTRM land cover data set. The metric score is listed related to area of the standing dead tree class within contiguous forest area "p08f_0269" and "p08f_0182".

Historic land cover metrics

Several metrics were developed for each contiguous forest area related to historic land cover types (Figure 11). The 1890s Mississippi River Commission UMRR-LTRM land cover data set was used to define adjacent land cover types using the attribute "CLASS_7_N".

lc1890_ow	-	Area in hectares of the contiguous forest area classified as "Open water" from the 1890s Mississippi River Commission land cover data set
lc1890_ma	-	Area in hectares of the contiguous forest area classified as "Marsh" from the 1890s Mississippi River Commission land cover data set
lc1890_sm	-	Area in hectares of the contiguous forest area classified as "Sand/mud" from the 1890s Mississippi River Commission land cover data set
lc1890_gr	-	Area in hectares of the contiguous forest area classified as "Grass/forbs" from the 1890s Mississippi River Commission land cover data set
lc1890_fo	-	Area in hectares of the contiguous forest area classified as "Forest" from the 1890s Mississippi River Commission land cover data set
lc1890_ag	-	Area in hectares of the contiguous forest area classified as "Agriculture" from the 1890s Mississippi River Commission land cover data set
lc1890_dv	-	Area in hectares of the contiguous forest area classified as "Developed" from the 1890s Mississippi River Commission land cover data set



for_id	p08f_0269
lc1890_ow	6.0 ha
lc1890_ma	7.9 ha
lc1890_sm	0.0 ha
lc1890_gr	0.0 ha
lc1890_fo	268.4 ha
lc1890_ag	0.0 ha
lc1890_dv	0.0 ha

for_id	p08f_0182
lc1890_ow	0.0 ha
lc1890_ma	36.7 ha
lc1890_sm	0.0 ha
lc1890_gr	0.0 ha
lc1890_fo	6.5 ha
lc1890_ag	10.2 ha
lc1890_dv	0.0 ha

Figure 11. Map depicting the overlap of the 1890s historic land cover class with each contiguous forest area. Metric scores are listed related to the area of each historic land cover class within contiguous forest area "p08f_0269" and "p08f_0182".

Results and Discussion

Size and Configuration Metrics

Metrics related to the size and configuration of contiguous forest areas varied from pool to pool. Pool 26 had the largest average size of contiguous forest areas (11.5 ha), the longest average distance between forest areas (83.7 m), and the largest average polygon development index (2.93). In comparison, pools 4, 8, and 13 had average sizes ranging from 4.0 - 7.0 ha, average distances between forest areas ranging from 46.2 - 61.6 m, and average polygon development indexes ranging from 2.29 - 2.61. All pools had relatively similar estimates of core forest area (0.5% - 2.6%) and interior forest area (5.0% - 7.6%). Pools 4 and 26 tended to have more forest area classified as dominant (55.4 - 58.8%) and less forest classified as patch (34.1 - 35.2) than pools 8 and 13, which had 41.4 - 47.0% forest classified as dominant and 47.2 - 50.9% classified as patch. All pools showed at least some increase in the amount of forest classified as patch between 2010 (results found in De Jager and Rohweder 2021) and 2020, suggesting that a recent large flood in 2019 may have contributed to the loss of forest cover and increase in the degree of fragmentation of the remaining forest area. Increases in patch forest ranged from just 3% of forest area in pool 4 to as much as 15% of forest area in pool 13.

Landscape Position Metrics

The position of forest areas within the broader landscape also varied by pool. Pool 26 was again different from the other pools in that just 8.5% of forest areas were located on islands and only 29.1% of forest areas were adjacent to open water connected to the main channel. In comparison, pools 4, 8, and 13 had 46.6% - 60.3% of forest areas on islands and 59.9% - 77.3% of areas adjacent to open water connected to the main channel. Pools 4 and 8 had contiguous forest areas with more area in the wettest inundation classes (>55 days inundated per growing season). These pools had 11.3% (pool 4) and 4.0% (pool 8) of total contiguous forest area in these classes while pools 13 and 26 had less than 2.5% of their area in these classes. The majority of the area of contiguous forests (59.9% - 90.8%)) were in locations with shorter inundation durations (<55 days per growing season). The perimeters of forest areas in pools 4, 8 and 13 were generally along open water or marsh cover types (69.6 - 82.7% total), whereas forest areas in pool 26 were adjacent to a wider-range of cover types, including open water (23.6%), marsh (18.8%), grass/forbs (19.7%), and agriculture (17.1%). Pools 13 and 26 had more perimeter along sand/mud than the other pools (9.2% and 4.1%) and pool 8 had more forest perimeter adjacent to developed areas than the other pools (7.1%).

Historically, just 50.3% - 62.0% of the forest area within the present-day contiguous forest areas that we mapped were forested in the 1890's. Historical non-forest cover in currently forested areas of pools 4 and 8 consisted of mostly open water and marsh (32.9% in pool 4 and 37.7% in pool 8) suggesting that some of today's forests may have recruited on newly developed land masses and in formerly herbaceous communities. Non-forest cover during the 1890's on areas presently forested in pools 13 and 26 were more likely to be agricultural landcover (13.0% in pool 13 and 11.4% in pool 26) or areas not mapped in the 1890's (8.0% in pool 13 and 25.5% in pool 26).

The general landscape position of forest areas in these pools is consistent with previous land cover analysis showing a general decline in island area and increase in agricultural land cover from the upper reaches of the UMRS to the lower ones (De Jager et al. 2013). Agricultural land cover was also more prevalent in the lower reaches of the UMRS in the 1890's (De Jager et al. 2013). In addition, there is a relatively high amount of developed area in pool 8 (La Crosse, WI) and pool 26 (St. Louis, MO) (De Jager et al. 2013).

Community Composition and Physical Structure Metrics

The community composition and physical structure of forests also varied by pool. Pools 13 and 26 had the largest amounts of floodplain and lowland forest communities (91.6 - 92.1%) within them, compared to pools 4 and 8 (76.8 - 86.8%), whereas pools 4 and 8 tended to support more *Salix* (8.7 - 16.2%) and upland forest (1.1 - 2.8%) compared with pools 13 and 26 (2.8 - 6.4% for *Salix* and 0 - 0.1% for upland forest). The higher abundance of *Salix* in these pools might be explained by the generally longer flood inundation found in forest areas and adjacency of forest communities to open water and marsh areas (see above) as willow communities tend to be associated with wetter conditions (De Jager et al. 2019). All pools had somewhat similar amounts of *Populus* communities (2.0 – 5.0%). Pool 26 had the smallest amount of standing dead trees (4.7% of forest cover), while pools 8 (23.6%) and 13 (19.2%) had the largest amounts. This may indicate larger impacts of flooding in 2019 in these pools.

All pools had relatively similar distributions of forest cover density with the 33-66% density class ranging from 11.3% to 15.8% of contiguous forest areas, the 66%-90% forest density class ranging from 42.4% to 44.7% of contiguous forest areas, and the 90%-100% forest density class ranging from 41.5% to 46.3% of contiguous forest areas. Pools 4 and 8 tended to support more forest in the shortest height class (0-20 feet) with 6.1% of contiguous forest area in this class in pool 4 and 7.1% in pool 8 compared to just 3.7% in pool 13 and 1.7% in pool 26. The percentage of contiguous forest area in the mid-level height class (20-50 feet) increased from 6.1% in pool 4 to 25.2% in pool 26, with pool 8 having 13.9% and pool 13 having 14.4% of contiguous forest area in this class. Meanwhile, the percentage of contiguous forest area in the tallest height class was smallest in pool 26 (73.2%) and increased to 79.0% in pool 8 and 81.9% in pool 13 to 87.8% in pool 4. While few previous studies have examined cover density or height attributes of UMRS forests, the higher abundance of *Salix* communities in pools 4 and 8 may explain the larger areas of forests there in the smallest height class.

Our results quantify some important features of forested areas in the UMRS. We used data for the most recent year (2020) and for pools that had available data, allowing us to illustrate the range of values expected for these metrics. As the 2020 land cover for additional pools becomes available, we will have the ability to compare the values of metrics across a broader area of the UMRS and better understand basic habitat and physical features of forests in this system. In addition, some metrics could be compared over time, both historically, and against future data collection efforts to examine change over time and space. Of the metrics we calculated, those related to the composition and physical structure of the vegetation within forest areas have the most potential for improvement by incorporating additional plot-level forest inventory data, lidar data, or other sources that more specific account for individual trees.

This data set will provide researchers, managers, and stakeholders the ability to query the current forested landscape within the UMRS to identify forested areas meeting sets of conditions relevant for their species or ecological condition of concern. Additionally, researchers will be able to use this data set to test for associations between species distributions or other ecological conditions and different forest area attributes.

Table 2. Summary of metric scores by pool.

Size and Configuration Metrics	Pool 4	Pool 8	Pool 13	Pool 26
Total area mapped (hectares)	25,662.8	18,427.2	34,071.9	55,627.8
Total forest unit block count	**595**	**572**	**738**	**673**
Average forest unit block Polygon Development Index (pdi)	2.51	2.29	2.61	2.93
Average distance between forest unit blocks (meters)	46.2	61.6	55.7	83.7
Average size of forest unit block (hectares)	7.0	4.0	5.5	11.5
Total area of forest unit blocks (hectares)	**4,180.5**	**2,311.3**	**4,050.4**	**7,768.1**
Percent of forest block area classified as "core forest"	0.6%	2.6%	0.5%	1.8%
Percent of forest block area classified as "interior forest"	6.5%	5.0%	5.2%	7.6%
Percent of forest block area classified as "dominant forest"	58.8%	41.4%	47.0%	55.4%
Percent of forest block area classified as "patch forest"	34.1%	50.9%	47.2%	35.2%
Landscape Position Metrics	**Pool 4**	**Pool 8**	**Pool 13**	**Pool 26**
Total perimeter length for all forest unit blocks (meters)	1,317,515	823,043	1,418,952	2,043,690
Percent of forest unit blocks located on islands within the river floodplain	46.6%	60.3%	48.4%	8.5%
Percent of forest unit blocks adjacent to open water connected to the main channel	73.1%	77.3%	59.9%	29.1%
Percent of forest block area with a mean total number of days inundated during the growing season equal to 0	2.5%	8.8%	1.8%	0.8%
Percent of forest block area with a mean total number of days inundated during the growing season greater than 0 and less than 20 days	35.5%	56.9%	57.9%	51.7%
Percent of forest block area with a mean total number of days inundated during the growing season greater than 20 and less than 55 days	24.4%	25.2%	16.6%	31.7%
Percent of forest block area with a mean total number of days inundated during the growing season greater than 55 and less than 80 days	9.5%	3.4%	0.8%	0.5%
Percent of forest block area with a mean total number of days inundated during the growing season greater than 80 days	1.8%	0.6%	0.3%	2.0%
Percent of forest block area that did not overlap the flood duration model (flood duration unknown)	26.3%	5.2%	22.6%	13.3%
Percent of perimeter length for all forest unit blocks that are adjacent to "Agriculture"	1.5%	0.1%	2.5%	17.1%
Percent of perimeter length for all forest unit blocks that are adjacent to "Developed"	2.2%	7.1%	1.5%	5.4%
Percent of perimeter length for all forest unit blocks that are adjacent to "Forest"	9.3%	3.5%	7.6%	10.9%
Percent of perimeter length for all forest unit blocks that are adjacent to "Grass/forbs"	7.2%	6.0%	9.5%	19.7%
Percent of perimeter length for all forest unit blocks that are adjacent to "Marsh"	40.1%	41.0%	34.0%	18.8%
Percent of perimeter length for all forest unit blocks that are adjacent to "Open water"	38.3%	41.7%	35.6%	23.6%
Percent of perimeter length for all forest unit blocks that are adjacent to "Sand/mud"	1.3%	0.7%	9.2%	4.1%
Percent of perimeter length for all forest unit blocks that are adjacent to unmapped areas	0.1%	0.0%	0.1%	0.4%
Percent of forest block area classified as "Open water" from the 1890s Mississippi River Commission land cover	14.2%	7.7%	9.1%	4.7%
Percent of forest block area classified as "Marsh" from the 1890s Mississippi River Commission land cover	18.7%	30.0%	5.6%	4.5%
Percent of forest block area classified as "Sand/mud" from the 1890s Mississippi River Commission land cover	1.5%	1.2%	2.0%	3.5%
Percent of forest block area classified as "Grass/forbs" from the 1890s Mississippi River Commission land cover	0.0%	0.0%	0.0%	0.0%
Percent of forest block area classified as "Forest" from the 1890s Mississippi River Commission land cover	60.2%	57.3%	62.0%	50.3%
Percent of forest block area classified as "Agriculture" from the 1890s Mississippi River Commission land cover	1.3%	3.6%	13.0%	11.4%
Percent of forest block area classified as "Developed" from the 1890s Mississippi River Commission land cover	0.1%	0.2%	0.3%	0.2%
Percent of forest block area that did not overlap the 1890s Mississippi River Commission land cover	4.0%	0.0%	8.0%	25.5%
Community Composition and Physical Structure Metrics	**Pool 4**	**Pool 8**	**Pool 13**	**Pool 26**
Percent of forest block area classified as "Floodplain forest" or "Lowland forest" using the 31-class classification	86.8%	76.8%	91.6%	92.1%
Percent of forest block area classified as "Populus community" using the 31-class classification	3.5%	4.2%	2.0%	5.0%
Percent of forest block area classified as "Salix community" using the 31-class classification	8.7%	16.2%	6.4%	2.8%
Percent of forest block area classified as "Upland forest" using the 31-class classification	1.1%	2.8%	0.0%	0.1%
Percent of forest block area classified as having the "S" modifier (at least 25% cover standing dead trees)	7.0%	23.6%	19.2%	4.7%
Percent of forest block area classified as having forest cover density of 33-66 percent cover as identified	12.0%	15.8%	11.3%	12.3%
Percent of forest block area classified as having forest cover density of 66-90 percent cover as identified	44.7%	42.7%	42.4%	44.2%
Percent of forest block area classified as having forest cover density of greater than 90 percent cover as identified	43.3%	41.5%	46.3%	43.5%
Percent of forest block area classified as having tree height of 0-20 feet as identified	6.1%	7.1%	3.7%	1.7%
Percent of forest block area classified as having tree height of 20-50 feet as identified	6.1%	13.9%	14.4%	25.2%
Percent of forest block area classified as having tree height of greater than 50 feet as identified	87.8%	79.0%	81.9%	73.2%

The spatial datasets developed for this study are available for download from (https://doi.org/10.5066/P9JM2AYX).

Acknowledgements

The authors would like to thank Dr. Molly Van Appledorn (Upper Midwest Environmental Sciences Center) and Andy Meier (US Army Corps of Engineers) for providing thoughtful comments and suggestions on several drafts of this report.

Literature cited

Dieck, J.J., Ruhser, Janis, Hoy, Erin, and Robinson, L.R., 2015, General classification handbook for floodplain vegetation in large river systems (ver. 2.0, November 2015): U.S. Geological Survey Techniques and Methods, book 2, chap. A1, 51 p., http://dx.doi.org/10.3133/tm2A1.

De Jager, N.R., and Rohweder, J.J., 2011, Spatial scaling of core and dominant forest cover in the Upper Mississippi and Illinois River floodplains, USA: Landscape Ecology, v. 26, no. 5, p. 697–708, accessed April 13, 2021, at https://doi.org/10.1007/s10980-011-9594-2.

De Jager, N.R., Thomsen, M.T., Yin, Y., 2012, Threshold effects of flood duration on the vegetation and soils of the Upper Mississippi River floodplain, USA. Forest Ecology and Management. 270. 135-146. 10.1016/j.foreco.2012.01.023.

De Jager, N. R., Rohweder, J. R., & Nelson, J. C. (2013). Past and predicted future changes in the land cover of the Upper Mississippi River floodplain, USA. River Research and Applications. doi:10.1002/rra.1615.

Harper K.A., MacDonald S.A., Burton P.J., Chen J., Brosofske K.D., Saunders S.C., Euskirchen E.S., Roberts D., Jaiteh M.S., Esseen P.-A., 2005, Edge influence on forest structure and composition in fragmented landscapes. Conserv Biol 19:768–782

Houser, J.N., ed., 2022, Ecological status and trends of the Upper Mississippi and Illinois Rivers (ver. 1.1, July 2022): U.S. Geological Survey Open-File Report 2022–1039, 199 p., https://doi.org/10.3133/ofr20221039.

Laurance W.F., Lovejoy T.E., Vasconcelos H.L., Burna E.M., Didham R.K., Stouffer P.C., Gascon C., Bierregaard R.O., Laurance S.G., Sampaio E., 2001, Ecosystem decay of Amazonian forest fragments: a 22-year investigation. Conserv Biol 16:605–618.

Lindenmayer D.B., Franklin J.F., 2002, Conserving forest biodiversity. Island Press, Washington, DC

Ramaharitra T., 2006, The effects of anthropogenic disturbances on the structure and composition of rain forest vegetation. Trop Resour Bull 25:32–37

Turner, M.G., Gergel, S.E., Dixon, M.D., Miller, J.R., 2004, Distribution and abundance of trees in floodplain forests of the Wisconsin River: Environmental influences at different scales. Journal of Vegetation Science 15: 729-738, 2004

Van Appledorn, M., De Jager, N.R., Rohweder, J.J., 2020, Quantifying and mapping inundation regimes within a large river-floodplain ecosystem for ecological and management applications. River Res Applic. 2020;1–15. https://doi.org/10.1002/rra.3628

Weathers K.C., Cadenasso M.L., Pickett S.T.A., 2001, Forest edges as nutrient and pollutant concentrators: potential synergisms between fragmentation, forest canopies, and the atmosphere. Conserv Biol 15:1506–1514

Zuidema P.A., Sayer J.A., Dijkman W., 1996, Forest fragmentation and biodiversity: the case for intermediate-sized conservation areas. Environ Conserv 23:290–297

Spatial data sets used in analysis

2020 Land Cover/Land Use Data for the Upper Mississippi River System

Citation

Hop, K.D., Hoy, E.E., Strassman, A.C., and Finley, B.C., 2021, 2020 Systemic Land Cover Data, Upper Mississippi River System (UMRS): U.S. Geological Survey data release, https://doi.org/10.5066/P9U46VQP

Summary

The U.S. Army Corps of Engineers' Upper Mississippi River Restoration (UMRR) program, through its Long Term Resource Monitoring (LTRM) element, collected aerial imagery of the systemic UMRS during the summer of 2020. A Land Cover/Land Use (LCU) spatial database was developed based on the 2020 aerial imagery, which adds a fourth systemic-wide database to the existing 1989, 2000, and 2010/11 LCU databases. The main purpose of the Land Cover/Land Use (LCU) spatial datasets is for resource managers and researchers to assess and evaluate current (2020) vegetation components and long-term vegetation trends of navigable pools (the stretch of river between locks and dams) and reaches of the UMRS. These pools and reaches include pools 1 through 26, the Open River Reach, the entire Illinois River, and the navigable portions of the Minnesota, St. Croix, and Kaskaskia Rivers.

1890s Mississippi River Commission Surveys Land Cover Data: Mississippi River

Citation

U.S. Army Corps of Engineers' Upper Mississippi River Restoration (UMRR) Program Long Term Resource Monitoring (LTRM) element. 2000, 1890 UMRS Land Cover Land Use: La Crosse, WI, https://www.sciencebase.gov/catalog/item/55929574e4b0b6d21dd67a20

Summary

In the late 1880's and early 1900's the Mississippi River Commission (MRC) conducted an extensive high-resolution survey of the Mississippi River from Cairo, Illinois to Minneapolis, Minnesota. These data were published as a series of 89 survey maps and index. In addition to image mosaics of the maps, in the 1990's, the Upper Midwest Environmental Sciences Center (UMESC) in conjunction with the Upper Mississippi River Restoration (UMRR) Program Long Term Resource Monitoring (LTRM) element automated the maps' land cover/land use symbology to create a turn of the century/pre-impoundment land cover/use data set. These data were referenced using the map's existing lines of latitude and longitude.

Floodplain Inundation Attribute Rasters: Mississippi & Illinois Rivers

Citation

Van Appledorn, M., De Jager, N., and Rohweder, J., 2018, UMRS Floodplain Inundation Attribute Rasters: U.S. Geological Survey data release, https://doi.org/10.5066/F7VD6XRT

Summary

Floodplain inundation is believed to be the dominant physical driver of an array of ecosystem patterns and processes in the UMRS. Here, we present the results of a geospatial surface-water connectivity model in support of ecological investigations fully described in the USGS Open File Report entitled “Indicators of Ecosystem Structure and Function for the Upper Mississippi River System” (De Jager and others 2018). Briefly, we identified likely instances of floodplain submergence by comparing a daily time series of gage-derived water surface elevations to topo-bathymetric data modified to account for slopes and hydrologic routing. The resulting raster attribute table contains columns for unique characterizations of surface water inundation dynamics (including measures of event frequency, duration, depth, and timing), yearly sums of the number of days a surface was inundated, and a classification of floodplain areas based on average annual duration values. All calculations summarize patterns occurring during 1 April – 30 September from 1972 to 2011. We excluded areas permanently wetted (aquatic areas), surfaces in agricultural production, roads, and developed areas. The data are intended for use in geospatial analyses of UMRS floodplain ecosystem patterns and processes.