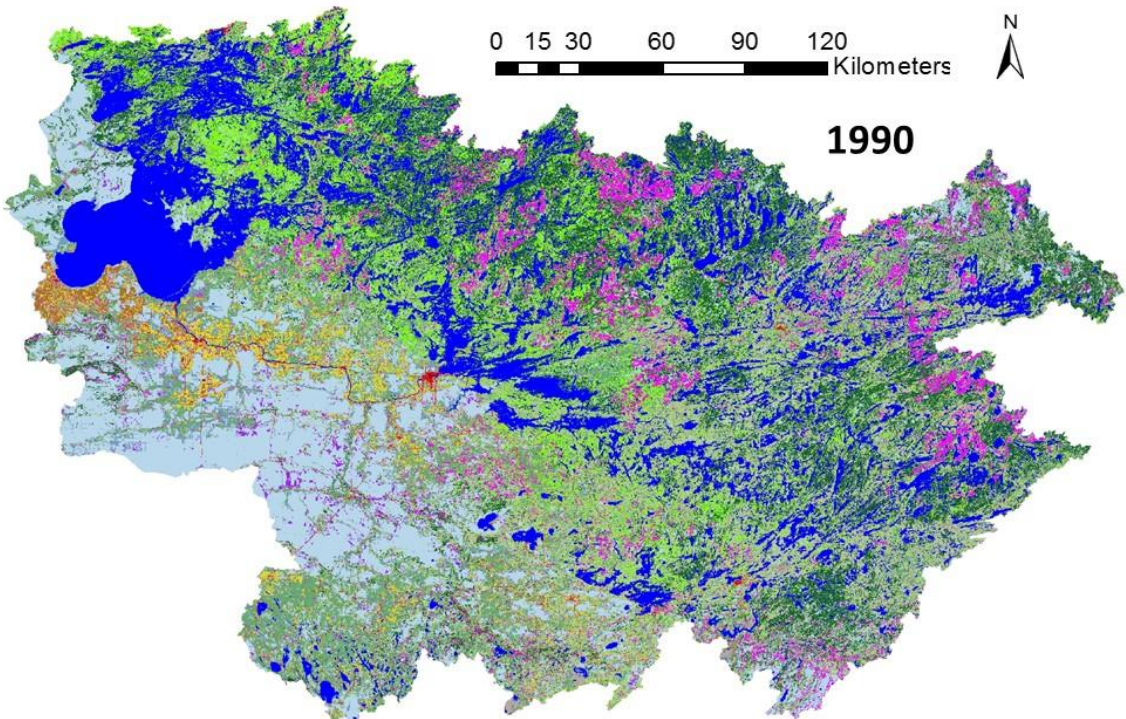
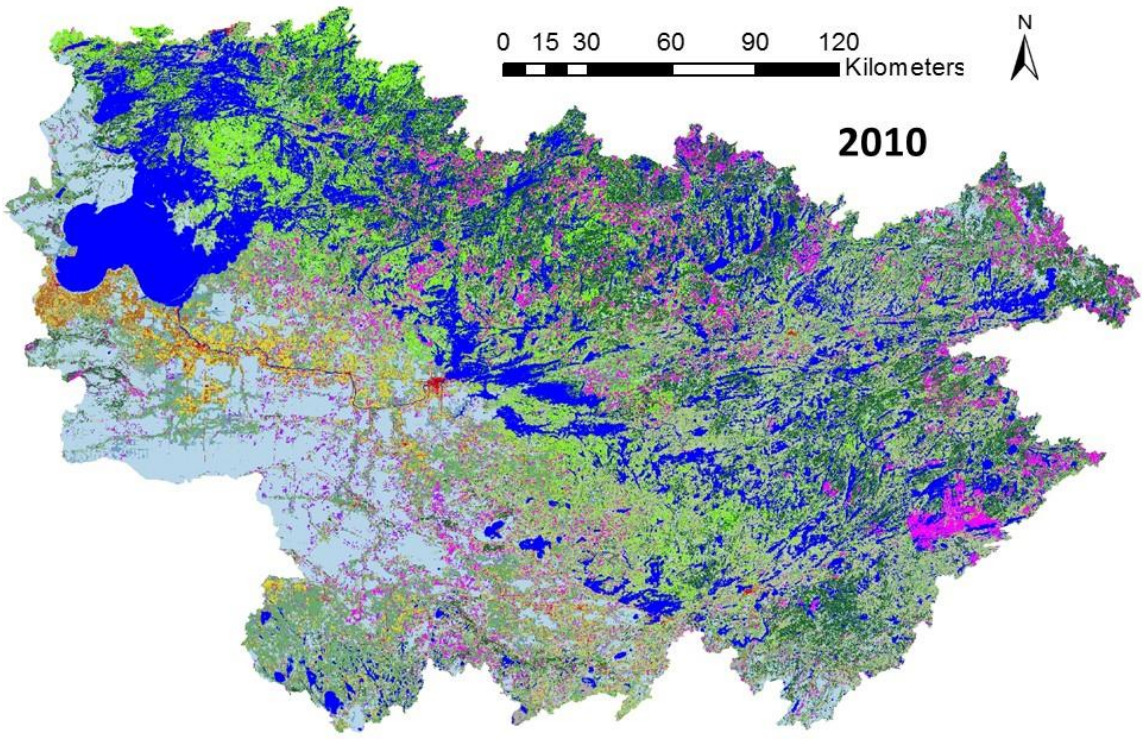


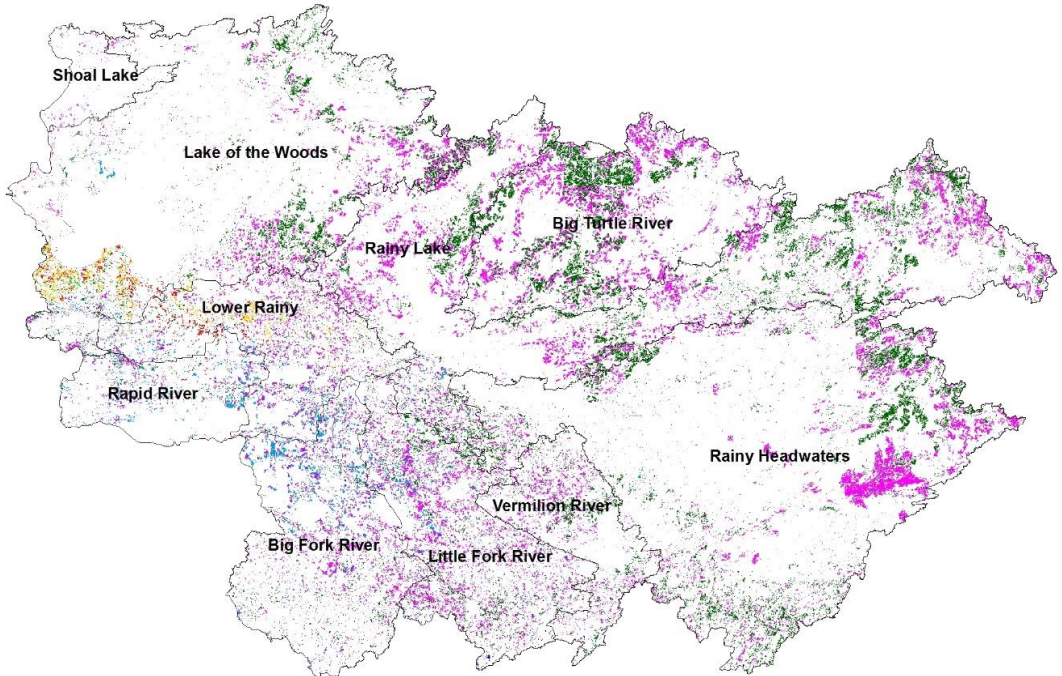
















































Lake of the Woods/Rainy River Basin Land Cover and Change 1990 and 2010

This page last updated: 8/31/2015

Metadata created using Minnesota Geographic Metadata Guidelines

Originator	Department of Forest Resources, Remote Sensing and Geospatial Analysis Laboratory, University of Minnesota		
Abstract	This is a 10-meter raster dataset of ~1990 and ~2010 land cover for the Lake of the Woods/Rainy River Basin. The classification was created using a combination of multitemporal Landsat data and lidar data (Minnesota portion) with object-based image analysis. The classification files have been provided to the Minnesota Pollution Control Agency. Maps and statistics in a web mapping application will also be available at http://land.umn.edu/ .		
Browse Graphic	 <p style="text-align: center;">1990</p> <p style="text-align: center;">Legend</p> <table border="0" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; vertical-align: top;"> <ul style="list-style-type: none"> Developed High density Developed Medium density Developed Low density Developed Managed Grass Developed Roads Extraction Row Crops and Small Grains Hay, Grassland and Pasture Coniferous Forest </td> <td style="width: 50%; vertical-align: top;"> <ul style="list-style-type: none"> Deciduous Forest Mixed Forest Sparse Forest Regenerating Forest Lakes and Ponds Herbaceous Wetlands Woody Wetlands Regenerating Forested wetland Wetland/Sandbar </td> </tr> </table>	<ul style="list-style-type: none"> Developed High density Developed Medium density Developed Low density Developed Managed Grass Developed Roads Extraction Row Crops and Small Grains Hay, Grassland and Pasture Coniferous Forest 	<ul style="list-style-type: none"> Deciduous Forest Mixed Forest Sparse Forest Regenerating Forest Lakes and Ponds Herbaceous Wetlands Woody Wetlands Regenerating Forested wetland Wetland/Sandbar
<ul style="list-style-type: none"> Developed High density Developed Medium density Developed Low density Developed Managed Grass Developed Roads Extraction Row Crops and Small Grains Hay, Grassland and Pasture Coniferous Forest 	<ul style="list-style-type: none"> Deciduous Forest Mixed Forest Sparse Forest Regenerating Forest Lakes and Ponds Herbaceous Wetlands Woody Wetlands Regenerating Forested wetland Wetland/Sandbar 		

<p><i>Time Period of Content Date</i></p>	<p>~1990 Level 2 land cover classification</p>
<p><i>Browse Graphic</i></p>	 <p>0 15 30 60 90 120 Kilometers</p> <p>N</p> <p>2010</p>
<p><i>Time Period of Content Date</i></p>	<p>~2010 Level 2 land cover classification</p>

<p>Browse Graphic</p>	 <p>Legend</p> <table border="0"> <tr> <td></td> <td>Forest to developed</td> <td></td> <td>Hay to Forest</td> </tr> <tr> <td></td> <td>Grass to developed</td> <td></td> <td>Regrown forest</td> </tr> <tr> <td></td> <td>Hay to developed</td> <td></td> <td>Forest harvested</td> </tr> <tr> <td></td> <td>Forest to grass</td> <td></td> <td>Wetland/sand to open water</td> </tr> <tr> <td></td> <td>Hay to grass</td> <td></td> <td>Forested wetland harvested</td> </tr> <tr> <td></td> <td>Forest to extraction</td> <td></td> <td>Forested wetland regrown</td> </tr> <tr> <td></td> <td>Row crop to hay</td> <td></td> <td>Forest to wetland/sand</td> </tr> <tr> <td></td> <td>Hay to row crop</td> <td></td> <td>Open water to wetland/Sand</td> </tr> </table>		Forest to developed		Hay to Forest		Grass to developed		Regrown forest		Hay to developed		Forest harvested		Forest to grass		Wetland/sand to open water		Hay to grass		Forested wetland harvested		Forest to extraction		Forested wetland regrown		Row crop to hay		Forest to wetland/sand		Hay to row crop		Open water to wetland/Sand
	Forest to developed		Hay to Forest																														
	Grass to developed		Regrown forest																														
	Hay to developed		Forest harvested																														
	Forest to grass		Wetland/sand to open water																														
	Hay to grass		Forested wetland harvested																														
	Forest to extraction		Forested wetland regrown																														
	Row crop to hay		Forest to wetland/sand																														
	Hay to row crop		Open water to wetland/Sand																														
<p>Time Period of Content Date</p>	<p>Land cover change from 1990 to 2010</p>																																
<p>Currentness Reference</p>	<p>A multitemporal composite of Landsat imagery from the spring and summer of ~1990 and ~2010 and lidar data (Minnesota portion) acquired in 2009-2012 were used for classification.</p>																																
<p>Access Constraints</p>																																	
<p>Use Constraints</p>																																	
<p>Distributor Organization</p>	<p>Remote Sensing and Geospatial Analysis Laboratory, University of Minnesota</p>																																
<p>Ordering Instructions</p>	<p>Contact Leif Olmanson at the University of Minnesota</p>																																
<p>Online Linkage</p>																																	

Metadata Summary

Go to Section:

1. Identification Information
2. Data Quality Information
3. Identification Information
4. Spatial Reference Information
5. Entity and Attribute Information
6. Distribution Information
7. Metadata Reference Information

Section 1	Identification Information
<i>Originator</i>	Remote Sensing and Geospatial Analysis Laboratory, University of Minnesota
<i>Title</i>	Lake of the Woods/Rainy River Basin Land Cover and Change 1990 and 2010
<i>Abstract</i>	A combination of multitemporal Landsat data and lidar data with object-based image analysis was used to generate level 1 and 2 land cover classifications for ~1990 and ~2010. The classification files have been provided to the Minnesota Pollution Control Agency. Maps and statistics in a web mapping application will also be available at www.land.umn.edu .
<i>Purpose</i>	Hydrological modeling of Lake of the Woods/Rainy River Basin.
<i>Time Period of Content Date</i>	~1990 and ~2010
<i>Currentness Reference</i>	A multitemporal composite of Landsat imagery from the spring and summer of ~1990 and ~2010 and lidar data (Minnesota) collected in 2009-2012 were used for classification
<i>Progress</i>	Complete
<i>Maintenance and Update Frequency</i>	
<i>Spatial Extent of Data</i>	Lake of the Woods/Rainy River Basin
<i>Bounding Coordinates</i>	
<i>Place Keywords</i>	Lake of the Woods/Rainy River Basin
<i>Theme Keywords</i>	Landsat, lidar, image classification, land cover
<i>Theme Keyword Thesaurus</i>	Landsat – an earth-orbiting satellite that acquires digital multispectral imagery at 30-meter spatial resolution. Lidar – Light detection and ranging. Lidar data provide information on height and elevation.
<i>Access Constraints</i>	None
<i>Use Constraints</i>	None
<i>Contact Person Information</i>	Leif Olmanson University of Minnesota, 1530 Cleveland Avenue North, St. Paul, MN 55108 Phone: 651-206-9102 E-mail: olman002@umn.edu

<i>Associated Data Sets</i>	
Section 2	Data Quality Information
<i>Attribute Accuracy</i>	The data set has an overall average classification accuracy of 96.4% for level 1 and 92.2% for level 2 land cover classifications.
<i>Logical Consistency</i>	GeoTiff (.tif) file
<i>Completeness</i>	Data provides complete coverage over the stated extent of the data.
<i>Horizontal Positional Accuracy</i>	RMS error of the Landsat data is less than 7.5 meters (0.25 Landsat pixel). The horizontal accuracy of the lidar data meets or exceeds 0.6 m RMSE.
<i>Vertical Positional Accuracy</i>	The vertical accuracy of the lidar data meets or exceeds 12.5 cm RMSE.
<i>Lineage</i>	<p><u>Landsat Images</u>: The Landsat imagery consisted of four Landsat paths (26, 27, 28 and 29) of Landsat Thematic Mapper and OLI imagery from rows 25, 26 and 27. Imagery dates include: Path 26 (April 19, 1990, August 28, 1991, March 25, 2010, May 15, 2011, June 26, 2009 and September 30, 2009); Path 27 (May 12, 1990, July 31, 1990, April 17, 2010 and September 16, 2013) Path 28 (April 20, 1991, September 5, 1989, August 24, 2008, April 8, 2010 and August 17, 2011) Path 29 (April 24, 1990, August 30, 1990, May 27, 2008, September 19, 2009, July 31, 2014 and October 19, 2014). Further information about Landsat is available at http://landsat.usgs.gov/.</p> <p><u>Lidar Data</u>: Lidar LAS files were acquired from the Minnesota DNR for the tiles within the areas covering the Minnesota portion of the Lake of the Woods/Rainy River Basin. The LAS tiles were used to generate mean and maximum vegetation height rasters at 20-meter spatial resolution. The DNR-provided 1-meter bare earth DEM was also used to create additional lidar-derivative layers at 10-meter spatial resolution, such as Compound Topographic Index (CTI), slope, and dissection. For more information, the 2011 lidar metadata are available at: http://www.mngeo.state.mn.us/chouse/metadata/lidar_metro2011.html.</p> <p><u>Reference Data</u>: Reference data used for classifier training and accuracy assessment were created by identifying objects of representative land cover types using the Landsat imagery and derivatives, lidar derivatives and high-resolution aerial photos available through Google Earth, Bing Maps and for the Minnesota portion the MnGeo Geospatial Image Service (http://www.mngeo.state.mn.us/chouse/wms/geo_image_server.html). For classes, such as agriculture, ancillary datasets were used to identify characteristic areas for training.</p> <p><u>Image Classification</u>: Object-based image analysis (OBIA) was used for classification of the Landsat and lidar data. Objects include more information than individual pixels, enabling the ability to take advantage of all the elements of image interpretation, particularly spatial information, including shape, size, pattern, texture, and context. The OBIA approach using eCognition, software system, included three main steps: (1) segmentation of the image into objects, (2) extraction of the object features, and (3) classification of the objects. Once image objects were created, a large number of features could be derived and potentially used for classification. The primary features included: spectral data, including means, modes, standard</p>

deviations and quantiles of individual bands and several transformations; geometry, including asymmetry, compactness, density, rectangular fit, roundness and shape index.

Random forest, a state-of-the-art approach which could handle and take advantage of the large number of features, was used for the classification of objects. It is an ensemble learning method for classification that operates by constructing multiple decision trees. Each tree is grown from different random subsamples of the training data and during the split selection process uses a subsample of the available features. It allows for the use of a large number of features or variables and identifies the important predictors.

Accuracy Assessment: Classification accuracy was evaluated by comparing the classification results to an independent stratified (by class) random reference sample of 6,610 objects (20 percent of the reference data that were withheld from classifier training) and reporting the error matrix and statistics derived from it including overall accuracy and user and producer accuracies (Conglaton, 1991; Foody, 2002).

Generation of Output Products: The primary output of the project is the maps and statistics of land cover in an ArcGIS database. Maps and statistics summarizing the classifications by Lake of the Woods/Rainy River Basin and sub-basins will be added to our online database available at land.umn.edu. Maps and statistics can also be generated for user defined areas. All classification data have been provided to the Minnesota Pollution Control Agency.

Source Scale Denominator

Section 3 Spatial Data Organization Information

Native Data Set Environment

Geographic Reference for Tabular Data

Spatial Object Type

Spatial Object Type

Tiling Scheme

Section 4 Spatial Reference Information

Horizontal Coordinate Scheme

UTM

Ellipsoid

WGS 1984

Horizontal Datum

WGS 1984

Horizontal Units

Meters

Distance Resolution	Cell size: 10 x 10 meters
Altitude Datum	Not applicable
Depth Datum	Not applicable
UTM Zone Number	15

Section 5	Entity and Attribute Information																																													
Entity and Attribute Overview	<p>The land cover data are level 1 and (level 2) land cover classes as follows:</p> <table border="1"> <thead> <tr> <th>Level 1</th> <th>Level 2</th> <th>Code</th> </tr> </thead> <tbody> <tr> <td rowspan="5">Urban / Developed</td> <td>High density</td> <td>11</td> </tr> <tr> <td>Medium density</td> <td>12</td> </tr> <tr> <td>Low density</td> <td>13</td> </tr> <tr> <td>Managed Grass</td> <td>14</td> </tr> <tr> <td>Roads</td> <td>15</td> </tr> <tr> <td>Extraction</td> <td>Extraction</td> <td>21</td> </tr> <tr> <td rowspan="2">Agriculture</td> <td>Row Crops & Small Grains</td> <td>31</td> </tr> <tr> <td>Hay & Pasture</td> <td>32</td> </tr> <tr> <td rowspan="5">Forest</td> <td>Coniferous Forest</td> <td>41</td> </tr> <tr> <td>Deciduous Forest</td> <td>42</td> </tr> <tr> <td>Mixed Forest</td> <td>43</td> </tr> <tr> <td>Sparse Forest</td> <td>44</td> </tr> <tr> <td>Regenerating Forest</td> <td>45</td> </tr> <tr> <td>Open water</td> <td>Lakes & Ponds</td> <td>51</td> </tr> <tr> <td rowspan="4">Wetlands</td> <td>Herbaceous Wetlands</td> <td>61</td> </tr> <tr> <td>Woody Wetlands</td> <td>62</td> </tr> <tr> <td>Regenerating Forested wetland</td> <td>63</td> </tr> <tr> <td>Wetland/Sandbar</td> <td>64</td> </tr> </tbody> </table>	Level 1	Level 2	Code	Urban / Developed	High density	11	Medium density	12	Low density	13	Managed Grass	14	Roads	15	Extraction	Extraction	21	Agriculture	Row Crops & Small Grains	31	Hay & Pasture	32	Forest	Coniferous Forest	41	Deciduous Forest	42	Mixed Forest	43	Sparse Forest	44	Regenerating Forest	45	Open water	Lakes & Ponds	51	Wetlands	Herbaceous Wetlands	61	Woody Wetlands	62	Regenerating Forested wetland	63	Wetland/Sandbar	64
Level 1	Level 2	Code																																												
Urban / Developed	High density	11																																												
	Medium density	12																																												
	Low density	13																																												
	Managed Grass	14																																												
	Roads	15																																												
Extraction	Extraction	21																																												
Agriculture	Row Crops & Small Grains	31																																												
	Hay & Pasture	32																																												
Forest	Coniferous Forest	41																																												
	Deciduous Forest	42																																												
	Mixed Forest	43																																												
	Sparse Forest	44																																												
	Regenerating Forest	45																																												
Open water	Lakes & Ponds	51																																												
Wetlands	Herbaceous Wetlands	61																																												
	Woody Wetlands	62																																												
	Regenerating Forested wetland	63																																												
	Wetland/Sandbar	64																																												

The from 1990 to 2010 land cover change data classes are as follows:

Change	Code
No change	0
Forest to developed	16
Grass to developed	17
Hay to developed	18
Forest to grass	19
Hay to grass	20
Forest to extraction	29
Row crop to hay	38
Hay to row crop	39
Hay to Forest	47
Regrown forest	48
Forest harvested	49
Wetland/sand to open water	59
Forested wetland harvested	66
Forested wetland regrown	67
Forest to wetland/sand	68
Open water to wetland/Sand	69

Entity and Attribute Detailed Citation

Metadata: Leif Olmanson and Marvin Bauer. 2015. Lake of the Woods/Rainy River Basin Land Cover and Change 1990 and 2010

Full report: Leif Olmanson and Marvin Bauer. 2015. Lake of the Woods/Rainy River Basin Land Cover 1990 and 2010. Final Report to the Minnesota Pollution Control Agency.

Section 6 Distribution Information

Publisher Remote Sensing and Geospatial Analysis Lab, University of Minnesota

Publication Date August 2015

Contact Person Information Leif Olmanson
Remote Sensing and Geospatial Analysis Lab, University of Minnesota
1530 Cleveland Avenue North
St. Paul, MN 55108
Phone: 651-206-9102
Email: olman002@umn.edu

Distribution Liability The data are provided as is and without any warranty to their performance, merchantability, or fitness for any particular purpose. The University of Minnesota does not represent or warrant that the data or documentation are error-free, complete, or current. The user should consult the data documentation to determine its limitations and accuracy. The user is responsible for any consequences resulting from use of the data or reliance on it. The entire risk of the results of the use of the data are assumed by the user.

<i>Transfer Format Name</i>	GeoTiff (tif)
<i>Transfer Format Version Number</i>	
<i>Transfer Size</i>	166 megabytes
<i>Ordering Instructions</i>	Contact Leif Olmanson at the University of Minnesota, or Cary Hernandez at the Minnesota Pollution Control Agency.
<i>Online Linkage</i>	
Section 7	Metadata Reference Information
<i>Metadata Date</i>	8/31/2015
<i>Contact Person Information</i>	Leif Olmanson Department of Forest Resources Remote Sensing and Geospatial Analysis Laboratory University of Minnesota 1530 Cleveland Avenue North St. Paul, MN 55108 Phone: 651-206-9102 E-mail: olman002@umn.edu
<i>Metadata Standard Name</i>	Minnesota Geographic Metadata Guidelines
<i>Metadata Standard Version</i>	1.2
<i>Metadata Standard Online Linkage</i>	