Identifying and Mapping Wildlife Corridors, Isolated Habitats, and Important Resources within the Obed Wild and Scenic River National Park

Anna M. Davis
Department of Resource Analysis, Saint Mary's University of Minnesota, Winona, MN 55987

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Abstract

Changes in landcover (i.e. land development for human uses) often results in habitat fragmentation. Impacts of habitat fragmentation cascade beyond the immediate area of landcover change resulting in a loss of biodiversity within adjacent areas. External landscape patterns and connectivity are important metrics used to assess biodiversity in ecosystems. These metrics are important for assessing the condition of the immediate and surrounding landscapes (Fahrig, 2003). Habitat fragmentation degrades watershed water quality and quantity in rivers and streams (Emmott, Murdock, Ranney, and Flaherty, 2005). This study includes an analysis of the structural landscape pattern and morphology of natural habitats within the Obed and Emory Rivers, Daddy's Creek, and Clear Creek that make up the external landscape of the Obed Wild and Scenic River (OBRI) area (Figure 1) in north-central Tennessee. The analysis was focused specifically on the landscape within this greater Obed River watershed. Using this greater watershed context, the analysis was used to determine what percent of these rivers' watersheds are still in their most natural condition and how much of the landscape has been disturbed, developed, or lost to urban sprawl and agriculture (Gross, Svancara, and Philippi, 2009). An NPScape toolset was used to produce outputs that can be used to make informed decisions in conservation efforts and define focal areas where Obed River impairment may be higher due to changes in the greater watershed landscape.

Introduction

In 1976, the National Park Service (NPS) established the Obed Wild and Scenic River to preserve the un-impounded nature of the Obed and Emory Rivers, Daddy's and Clear Creeks. These rivers are located in north-central Tennessee, adjacent to the Catoosa Wildlife Management area, and were carved into the Cumberland Plateau over many millennia. The OBRI protects a riverine system with exceptional water quality, rare and sensitive plants, and freshwater mussel species (Emmott, Murdock, Ranney, and Flaherty, 2005). Rare species include Cumberland rosemary, Purple spiraea, and the Purple Bean [a federally endangered species of freshwater mussel] which are vulnerable to upstream landscape disturbances that have, over time, degraded the park's water quality, particularly in the Obed River (Ahlstedt, Connell, Bakaletz, and Fagg, 2001). The OBRI was selected for an

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analysis as a landscape dynamics monitoring project using the NPscape toolsets. As part of the Appalachian Highlands Network (ACHN), OBRI was one of three park units selected for monitoring landscape level changes occurring beyond the park boundaries (Emmott and Murdock, 2008). The OBRI has a unique situation where there are private inholdings within the park boundary and numerous oil and gas well developments within the greater watershed of the park's high-quality, free-flowing streams and rivers. Streams and rivers in the OBRI have remained un-impounded through NPS management and legislation since it was designated (National Park Service, 2015a). Since the watershed landscape context of this park can directly affect the habitat conditions of rare and endangered aquatic natural resources within the park, NPScape metrics were used to gain an understanding of landscape-level activities within the greater Obed watershed (Gross *et al.*, 2009). What are defined as the greater Obed watershed for this analysis are two tributary creeks and the Obed river and Emory river watersheds combined (Figure 1).

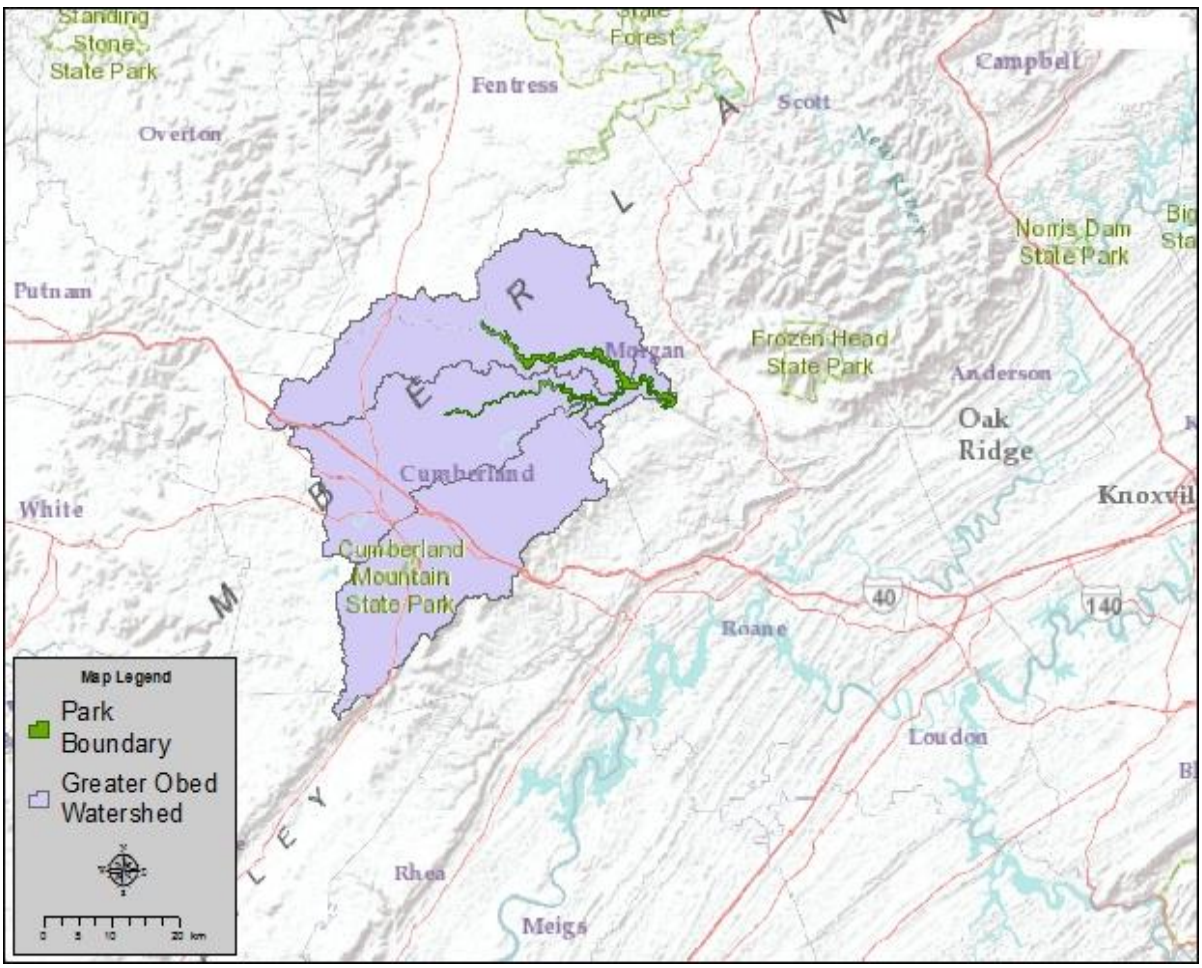

Figure 1. The greater Obed watershed, and the Obed Wild and Scenic River park area located west of Knoxville, Tennessee.

Watersheds of rivers are defined in Hydrologic Unit Codes (HUC) ranging from large rivers such as the Mississippi and Tennessee Rivers (2-6 digits) and smaller tributary rivers, creeks, and streams (6-10 digits). In the OBRI, the rivers included in the analysis are tributaries to the Tennessee River. The greater Obed watershed is a HUC 8 level watershed that encompasses the Obed and Emory River, Clear, and Daddy's Creek watersheds.

The landscape within this catchment area has both protected and developed lands which impact the park in various ways through landscape dynamics. Land protection efforts are established to preserve the high level of biodiversity and the rugged and remote wilderness character within what is described as the "world's longest stretch of hardwood forest." according to The Nature Conservancy. Protection is organized with the Tennessee State Wildlife Action Plan and carried out by agency collaboration and ecoregional planning. OBRI is part of this collaborative conservation effort and is also directly adjacent to the Catoosa Wildlife Management Area (WMA). The Nature Conservancy has collaborated with the state of Tennessee to place nearly 130,000 acres of land along an area of the Cumberland Plateau under protection from further development. OBRI surrounds a portion of the Obed River and Daddy's Creek channels and flanks the southern bank of Clear Creek and part of the Emory River. Mature forest has historically covered the majority of the Cumberland Plateau and provides important ecological services to the free-flowing and wild river, rugged and primitive terrain, and rare and threatened ecosystems preserved in the park (National Park Service, 2015b). The creeks and rivers have a history of excellent water quality, any decline in water quality is considered a deviation from historic conditions, as are reductions in forest cover. There are large population centers within the greater Obed watershed, Crossville, TN has the largest population (11,246 people [2013]) within the upstream watershed area. The NPScape evaluates potential impacts these areas may have, or have had, on park resources based on changes to the landscape occurring within the greater Obed watershed.

Data and Methods

To measure landscape changes to the greater Obed watershed two NPScape toolboxes were selected, each containing script tools selected for measuring changes in total area of selected landscape attributes. Changes in total area of "natural vs. converted" landcover and in natural landcover morphology were measured using the scripts and data provided by NPScape. The greater Obed watershed area, which is referred to as the Area of Analysis (AOA), was created with a polygon of the selected watershed boundaries of the Obed River and pertinent tributaries (Appendix A). Simple polygons of these watershed units were used to create the boundaries of the greater Obed watershed. These boundaries were obtained from data available from the National Hydrology Dataset (NHD) which delineates patterns in surface waters and their respective catchment basins.

The greater Obed watershed scale analysis captures relevant information on things occurring beyond the park boundary that can directly impact hydrology, water chemistry, both aquatic and terrestrial biota (Gross *et al*., 2009). The National Landcover Dataset (NLCD) is raster data produced by the Multi-Resolution Land Characteristics Consortium (MRLC). Each raster file is classified into 16 distinct landcover types in 30-meter resolution (Table 1).

Table 1. NPScape Natural vs. Converted area per Category metric creates an aggregated landcover scheme.

Anderson Level II	Natural/Converted
mixed forest	Natural
evergreen forest	
Herbaceous	
shrub/scrub	
deciduous forest	
barren land	
open water	
emergent herbaceous wetlands	
woody wetlands	
developed, open space	Converted
developed, low intensity	
developed, medium intensity	
developed, high intensity	
cultivated crops	
hay/pasture	

NLCD for the greater Obed watershed was available for years 2001, 2006, and 2011 (National Park Service [NPS], 2013a). In order to run the script tools provided in the selected NPScape toolboxes, all input data is spatially referenced to Contiguous Albers Equal Area Conic USGS projection to minimize distortion between standard parallels of the AOA. The NPScape landcover script tool was used to re-classify pre-processed (correctly projected and clipped to my AOA) NLCD raster data to identify the extent of areas within the landscape cover types that have been converted from a natural state (NPS, 2013a) (Monahan, Gross, Svancara, and Philippi, 2012). The 16 classifications within the NLCD are aggregated into two, “natural vs converted” classifications for the AOA (Table 1; NPS, 2013a). Natural landcover is landcover classifications which have not been converted from their baseline condition and largely undisturbed. Converted landcover includes cultivated and pastured areas and areas that are characterized as having at least 30% coverage of the land by constructed materials such as buildings, roads, or parking lots.

The NPScape patch morphology script was also selected to measure eight categories of landcover patch morphology of forest and grassland using reclassified NLCD (Table 2) (NPS, 2013a; NPS, 2013b).

Table 2. Patch structural morphologies and their meaning.

Patch morphology	Definition
Background	No grassland/forest
Branch	Connected at one end to edge, perforation, bridge, or loop
Edge	Outside perimeter
Islet	Disconnected and too small to contain core
Core	Interior area of patch excluding perimeter
Bridge	Connected at both ends to different core patches
Perforated	Inside perimeter
Loop	Connected at both ends to the same core patch

Changes in the size of each patch type that has occurred between 2006 and 2011 were calculated to identify trends in habitat conversions that are occurring around the park (NPS, 2013b). Change in edge size, quantified based on the pattern morphology metric results, was measured in two effective edge sizes, one-pixel edge and five-pixel edge widths of each structural category of patch morphology, which results in two different perspectives (Ostapowicz, Vogt, Riitters, Kozak, and Estreguil, 2008). The change in edge size was measured both forest and grassland that lie within the AOA around the park in order to determine whether the patches of core habitat are becoming smaller with an increase to edge area.

Results

Fifteen of the 16 distinct Anderson Level II classifications of landcover are found within the AOA (Table 3, Appendix B). Each landcover classification that was found within the AOA in 2001, 2006, and 2011 are listed in Table 3 (NPS, 2013a). Areas of natural landcover have slightly decreased while converted areas have somewhat increased between 2001, 2006, and 2011 (Tables 3 and 4, Appendix B).

Natural landcover within the AOA is predominantly mixed forest 31,890 ha and hay/pasture 23,590 ha. Mixed forest in 2001 covered 32,990 ha and by 2011 decreased by 1,100 ha. Hay and pasture landcover covered 24,190 ha as of 2001 and as of 2011 had decreased to 23,580 ha. Deciduous forest decreased from 11,660 ha in 2001, to 11,290 ha, a change in coverage of 370 ha.

Table 3. The Anderson Level II classifications in the NLCD and amount of coverage of each cover class within the AOA. One km^2 is equal to 100 hectares.

	Area (km^2)		
NLCD Anderson Level II classifications	2001	2006	2011
Mixed forest	329.9	322.5	318.9
Hay/pasture	241.9	237.8	235.8
Herbaceous	207.4	227.2	212.6
Developed, open space	138.9	141.4	143
Deciduous forest	116.6	114.2	112.9
Developed, low intensity	51.5	53.4	65.4
Evergreen forest	49.2	51	53.6
Open water	20.8	20.7	28.9
Barren land	16	16.7	20.4
Developed, medium intensity	15.5	12.3	17.6
Woody wetlands	4.9	12	11.8
Developed, high intensity	4.2	4.8	5.2
Cultivated crops	3	4.8	4.8
Shrub/scrub	1	3.3	3.3
Emergent herbaceous wetlands	0	0.1	0.4

Developed areas increased between 2001 and 2011. Low intensity developed areas increased from 5,150 ha to 6,540 ha, an increase of 1,390 ha. Medium and high intensity development increased between 2001 and 2011, increasing by 210 ha and 60 ha, respectively.

Table 4. Summary of the amount of natural and converted land coverage within the AOA for 2001, 2006, and 2011.

Year	2001 km^2	2006 km^2	2011 km^2
Natural	1,795.40	1,792.90	1,791.80
Converted	454.9	457.5	458.6

Changes to habitat through landcover conversions for housing and agricultural development upon the landscape have resulted in a reduction of core areas forest and alteration of the patch morphology, while areas of grassland have increased between 2006 and 2011. Patch morphology classifications include eight types of forest or grassland patch types, listed in Table 2 and displayed in Appendices C and D. The area of forest patch was 152,260.7 ha in 2001 and 151,769.7 ha in 2011, a reduction in total area of 491 ha (Table 5). Grassland has increased much more dramatically. In 2001, grassland landcover consisted of 23,253.5 ha and by 2011 reached a total of 44,839.4 ha, an increase of 21,139.8 ha. In an analysis with a single pixel edge width, the core areas are inevitably larger since what is deemed an area of edge is narrower. In the five-pixel edge width analysis there are larger areas of forest or grassland that are constituted as islet, bridge, branch, and loop as a consequence of a larger effective edge width being applied. Although the overall area of forested habitat patches has been reduced between 2006 and 2011, there have not been drastic changes in edge size of forested habitat patches. Grassland edges have increased much more so than forest. However, these areas have become larger and more connected in general, while forest area has been shrinking. An increase in edge for grassland area is simply a result of there being more and more patches of grassland around the park.

Discussion

Forest and grassland within the greater Obed watershed are present as structural elements, or habitat patches. Changes in structural patch morphology of forest and grassland have experienced varying degrees of fragmentation. Patches of forest and grassland both have increased perforations and segmentation. Areas where grasslands have increased overall are primarily around the city of Crossville which is about 35 miles southwest of the OBRI and is within the AOA. This increase may be explained with housing development that is primarily urban and exurban sprawl in the area. For example, among forest patches, there has been a reduction in core areas within the AOA via perforation and segmentation of core areas. This is also occurring in the vicinity of Crossville, an area having the largest concentration in human population within the AOA. Loss of connectivity with public/protected lands is a concern since patch size and isolation affect the amount of core area available to various species of plants and animals (Fahrig, 2003; Worsham, Sundin, Nibbelink, Mengak, and Grossman, 2013). Core habitat patches are what supports the highest level of biodiversity. Loss of connectivity between core habitats is described as fragmentation and is associated with losses in biodiversity and environmental quality (Fahrig, 2003).

Table 5. Area size comparison between 2006 and 2011 of structural patch morphology for forest and grassland landcover within the AOA (one km^2=100 ha).

Forest (Km^2)				
Edge width	One pixel		Five pixels	
Class	2006	2011	2006	2011
Background	727.7	732.7	727.7	732.7
Branch	54.2	54.9	112.2	111.5
Edge	*222.2*	*225.5*	*483.4*	*489.9*
Islet	15.9	15.6	88.6	88.7
Core	1187.5	1174.7	620.2	596.6
Bridge	9.8	10.6	143.9	158.8
Perforated	25.0	27.6	19.5	16.3
Loop	8.1	8.8	54.9	55.8

Grassland (Km^2)				
Edge width	One pixel		Two pixels	
Class	2006	2011	2006	2011
Background	2015.1	1802.0	2015.1	1802.0
Branch	42.3	56.6	6.9	36.7
Edge	*61.2*	*148.6*	*14.1*	*60.9*
Islet	65.3	39.8	195.4	264.8
Core	52.2	181.9	2.6	10.3
Bridge	8.7	14.3	8.9	49.1
Perforated	0.3	1.5	n/a	n/a
Loop	5.3	5.8	7.2	26.595

Loss of connectivity with public/protected lands is a concern since patch size and isolation affect the amount of core area available to various species of plants and animals (Fahrig, 2003; Worsham *et al*., 2013). Core habitat patches are what supports the highest level of biodiversity. Loss of connectivity between core habitats is described as fragmentation and is associated with losses in biodiversity and environmental quality (Fahrig, 2003). The forested Cumberland Plateau is likely an attractive setting in the minds of those intending to build homes used for vacation getaways. A major threat to the area surrounding, and within, OBRI is exurban development. Population growth invariably increases exurban development of the landscape; increasing edge effects and habitat fragmentation, and results in the loss of habitat connectivity (Gross *et al*., 2009).

Conversion of natural habitat within the Cumberland Plateau, is known to cause shifts in existing native biotic communities (Maestas, Knight, and Gilgert, 2003). This poses a threat to the OBRI's ecologically significant floral communities which support federally listed plant species such as Virginia spiraea (*Spiraea virginiana*) and Cumberland rosemary (*Conradina verticillata*) (Emmott *et al*., 2005; Wolfe, Fitch, and Ladd, 2007).

Development adjacent to the park includes a menagerie of possible impacts to the landscape. Certainly, an increase in impervious surface with the construction of roads, parking lots, and structures would alter the infiltration rates of the surrounding watersheds (Gross *et al*., 2009). Development also contributes to unintentional introductions of invasive species, alters migration patterns of wildlife, and expands the wildland-urban interface (i.e. edge effects) (Emmott and

Murdock, 2008). These developments alter the energy and nutrient dynamics of the surrounding landscape. Introduction of contaminants, and shifts in the hydrological regime also often follow development (Gross *et al*., 2009).

Resource extraction (e.g. coal, gas, and oil) and withdrawals of water upstream of OBRI may impact the Obed River water quality and base flow (Emmott and Murdock, 2008). Although it appears that an oil spill within the park did not result in any long term damage to the stream, but destroyed vegetation after it caught fire, leaving a lasting mark (National Park Service [NPS], 2004). Coal mining is highly associated with environmental degradation that often extends far beyond the site of mining operations and is practiced in the Cumberland area, though it is unknown if coal extraction is practiced within the AOA. The predominant method of coal extraction in the area surrounding OBRI is strip mining, which involves striping away the land surface followed by detonation of explosives to breach the surface and reach the coal deposit beneath (Emmott *et al*., 2005; Perks, 2009).

The explosives are ammonium nitrate/fuel oil based and once detonated, the materials are bulldozed to the side and extraction then commences (Emmott *et al*., 2005; Perks, 2009). Current and past mining for coal pose a threat to the park biodiversity because of degradation to water quality from acid mine drainage, other pollutants, and industrial and domestic effluents from both coal mining activities and the surrounding developments of the landscape (Emmott *et al*., 2005; NPS, 2004).

Conclusions

The landscape surrounding the OBRI was analyzed to measure potential impacts to the rare and sensitive aquatic and terrestrial resources within the park. Change in external landcover, change in patch size, and change in edge are occurring in the greater Obed watershed, however, NPScape outputs show a relatively mild decrease in natural cover. In short, there does not appear to be intensive changes to the external landscape within the AOA surrounding the OBRI.

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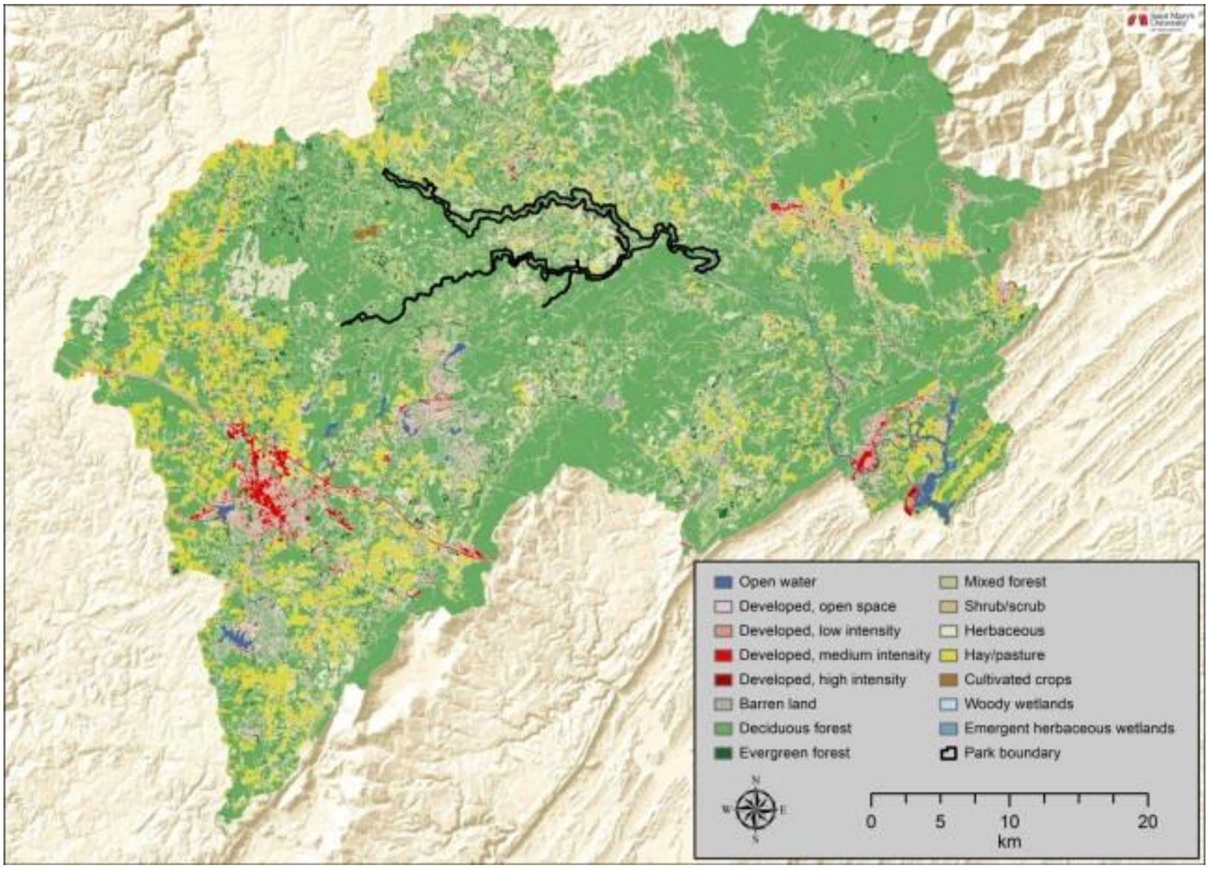
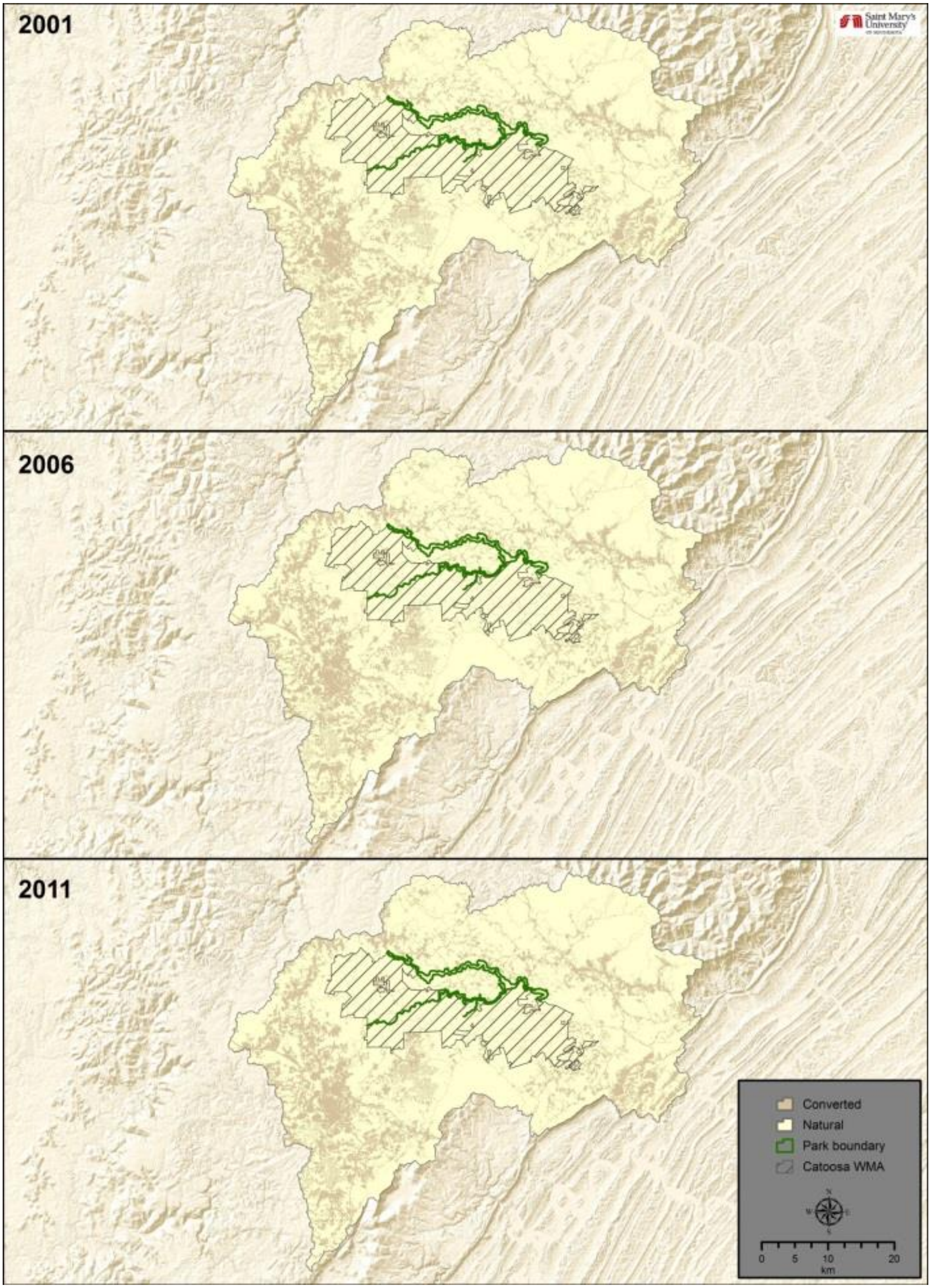
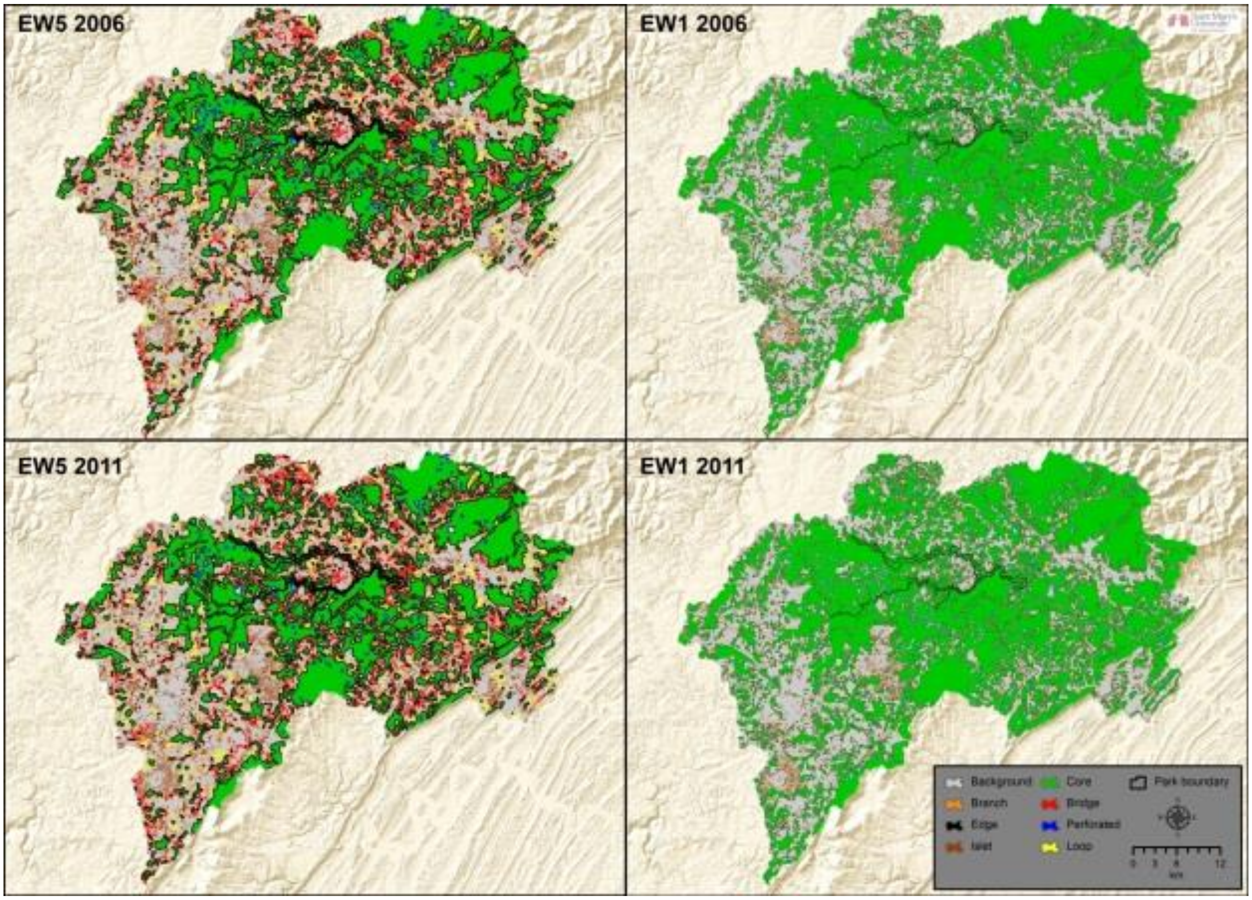
Appendix A. This NLCD external landcover raster was created in 2001 and displays color-coded areas of each landcover classification within the AOA and the location of the OBRI.



Appendix B. Natural and converted landcover (NLCD reclassified) within the AOA in 2001, 2006, and 2011.



Appendix C. Forest morphology within the AOA around the park, both the one meter edge width (EW), and 5 meter EW are shown for two periods (2006 and 2011).



Appendix D. Grassland morphology within the AOA around the park, both the one meter edge width (EW), and 5 meter EW are shown for two periods (2006 and 2011).