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Mapping Wilderness Character in Adams County, Pennsylvania

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Abstract: The spatial trends in wilderness character in Adams County, Pennsylvania were examined to evaluate how influenced specific areas are impacted by human activity and development. Indicators of wilderness character were selected as natural, untrammeled, undeveloped, along with solitude and unconfined recreation by the Death Valley National Park staff in which a 0-4 ranking system was based upon to portray a range of most degraded to optimal land. This was executed through examination of factors such as abundance of biodiversity and human development within the given area before a Monte Carlo simulation was run to show sensitivity of change. It was found that overall wilderness quality is most optimal along the Michaux Forest boundary and small sections of land on the southwestern and eastern edge of Adams County. Areas that are most sensitive to a change in the weights of wilderness character factors are small sections of land throughout the middle areas of Adams County along the roads while areas of land that are least sensitive to change are mainly the areas associated with the Michaux Forest boundary along the northwestern parts of Adam's County. It was concluded that an increase in human interaction tends to lead to land that is more degraded and misused for infrastructure purposes.

Introduction

        Wilderness character refers to how natural and untouched a given area is by human activity with the ideology that areas with the least anthropological contact are best. It is important to map wilderness character in order to see which areas need to be given special attention in regard to preservation and conservation due to unusually high human degradation as well as to track the severity and frequency of anthropological effects of climate change. A former study inspected and identified the state of wilderness character in natural areas in the United States as a case study.

        Indicators of wilderness character were selected as natural, untrammeled, undeveloped, along with solitude and unconfined recreation by the Death Valley National Park staff (Figure 1). Natural quality was defined in terms of plant and animal species, physical resources, and biophysical processes while untrammeled quality was defined by federal authorization and biophysical state of the land. Undeveloped quality was based on indicators such as the loss of cultural sites, developments, inholdings, and use of mechanical transport. Solitude quality was based on the remoteness of an area from sounds and modified areas outside of the natural land. Other indicators of solitude include facilities that decrease self-reliance and management restrictions on visitor behavior (Carver, Tricker, and Landres 2012). The four indicators were based on a ranking system from 0-155 with 0 representing optimal

wilderness character and 155 representing most degraded wilderness character (Carver et al. 2012).
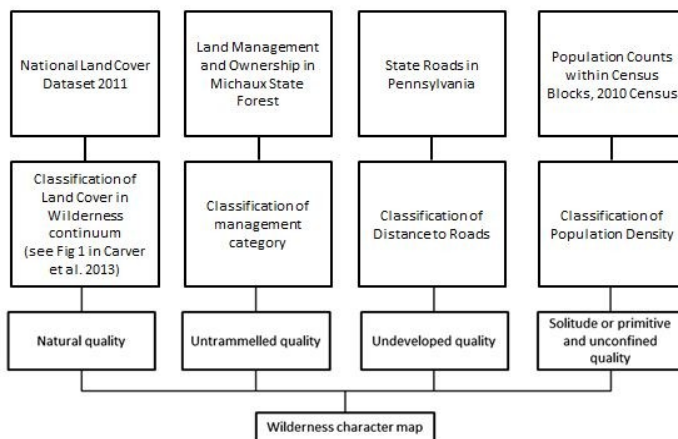
Figure 1. Wilderness qualities derived from single data input that were ranked 0-4 with 0 as optimal wilderness quality and 4 as most degraded wilderness character.

In this case study, the objective was to map the wilderness character of Adams County, Pennsylvania using a scale of 0-4 with 0 representing most optimal wilderness quality and 4 representing most degraded wilderness quality. The research question was to explore what the spatial trends in wilderness character are in Adams County. It was hypothesized that the area of the county near Gettysburg College would have a less optimal wilderness quality in comparison to areas such as the Michaux State Forest boundary which experiences significantly less human interaction. The study area was 1,352 km^2 in size and located along the southern, center

edge of the Pennsylvania state border (United States Census Bureau 2017).

Methods

The Adams_Countyborder.shp shapefile was used as the extent for all four rasters (natural, untrammeled, solitude, and undeveloped quality) and a cell size of 328 feet. In order to create the natural quality raster (Table 1), the land cover raster was reclassified in accordance to wilderness quality with 0 representing optimal wilderness character and 4 as most degraded wilderness character in accordance with the National Land Cover 2011 Database Product Legend (United States Geological Survey 2011). The old values were ranked in accordance to biodiversity, abundance of vegetation, and amount of human population. Natural quality was based on the idea that optimal quality consists of high biodiversity and abundant, green terrain like forests and woods (Table 2; Figure 2).

The undeveloped quality raster was created by using the Euclidean distance tool on the PaStateRoad2018_07.shp shapefile. A manual classification method was used along with the reclassify tool to give the following wilderness quality ranks to the given break values: 0-2,000 = 4, 2,001- 3,800 = 3, 3,801-5,700=2, 5,701-7,600=1, and 7,601-9,500 = 0. Higher numbers were given a lower rank closer to 0 since they represent areas with better wilderness quality meaning that they are farther away from the developed roads (Figure 2).

The solitude raster (Table 1) was created by calculating the population density of Adams County residents to each census block in square kilometers. A manual classification system was used, and the break values were changed to $5, 50, 100, 500$, and $20,712$ before the reclassify tool was used to assign the break values with the ranks $0, 1, 2, 3, 4$ respectfully. The ranks were given in regard to the fact that lower population densities correlate to less human interaction and thus better wilderness quality closer to 0 (Figure 2; Sherbinin et al. 2007).

The untrammeled quality raster (Table 1) was created by assigning the land_conservancy, SH_boundary, PGCStateGameland2018, Michaux_Boundary, and GNMP_boundary a wilderness rank from 0-4 in accordance to the amount of undisturbed land from human interaction and infrastructure before merging the shapefiles (Table 3; Figure 2).

The final wilderness raster (Table 1) was created by using the raster calculator on the FinalWilderness raster. An analytic hierarchy process (AHP) was then executed: the average class weights as percent for the natural, land management, distance from state roads, and population qualities were used in the raster calculator equation ("untrammeled" $* 0.172$) + ("undeveloped" $* .243$) + ("solitude" $* .19$) + ("natural" $* .395$) (Figure 3). The new raster was then used in a Monte Carlo simulation using the solitude, untrammeled, natural, and undeveloped raster inputs for 100 iterations for the creation of the Monte Carlo simulation raster

(Figure 4). This was done to see how sensitive different areas of land in Adams County are to the change of the weights of the four wilderness character qualities.

Results

Natural quality is most optimal along the western parts of the Adams County border where the Michaux Forest boundary is located with minimal "bad" degradation that lies near middle sections of the county. Untrammeled quality is most optimal along the Michaux Forest boundary and most degraded in most other parts of Adams County due to frequent human interactions with the natural landscape. Undeveloped quality is most optimal along the Michaux Forest boundary on the western part of Adams county and most degraded throughout the county in linear, outward formations. Solitude quality is most optimal in fragmented sections throughout the middle of Adams County and most degraded in the privately-owned areas of Michaux Forest as well as dispersed areas throughout Adams County (Figure 2). Overall wilderness quality is most optimal along the Michaux Forest boundary and small sections of land on the south western and eastern edge of Adams County. The majority of the middle section of Adams County has a neutral, good natural quality while areas with roads like highways that lead to major cities consist of the most degraded areas in respect to wilderness quality (Figure 3). The Monte Carlo Simulation reveals that the areas that are most sensitive to a change in the weights of wilderness character factors are small slivers of land throughout the middle sections of

Adams County along the roads. Areas of land that are least sensitive to change are mainly the areas associated with the Michaux Forest boundary along the north western parts of Adams County (Figure 4).

Discussion

The three indicators of wilderness (natural, untrammeled, and undeveloped) showed that the Michaux Forest boundary has optimal wilderness quality other than the areas that are privately-owned because it has the least amount of human interaction as well as the most biodiversity as shown with its abundant land cover of vegetation (United States Geological Survey 2011). The area of Michaux Forest with most degraded wilderness quality from the untrammeled classification (Figure 2) is due to logging that occurs in the privately-owned areas (Pennsylvania Department of Conservation and Natural Resources 2018). Michaux Forest is ranked as being not very sensitive to being moderately sensitive to change because the only areas that could possibly be noticeably affected by any change are the logged, privately-owned areas. Otherwise, Michaux Forest is fairly uninhabited and affected by anthropogenic factors. An increase in human interaction tends to lead to land that is more degraded and misused for infrastructure purposes — resources like wood tend to also be logged excessively if the population grows to a be a plentiful, surplus amount (Sherbinin, Carr, and Cassels 2007). The landscape of Michaux Forest is also mainly composed of

trees and plantation that make up most of the land cover which was the primary logic I used when ranking various values from 0-4 (Figure 2). More trees can oftentimes mean that the area has better biodiversity which leads to a healthier forest with a more positively ranked natural and overall wilderness quality and wilderness ranking. This characteristic makes the area more durable from change occurring (Sherbinin et al. 2007). This is also a reason why the overall wilderness character map displayed the Michaux Forest boundary as having mainly optimal wilderness character (Figure 3).

  The weights assigned to each wilderness quality had a great effect on the sensitivity of each wilderness quality to any possible change and random occurrences as determined by the Monte Carlo simulator. Areas like Michaux Forest where there were land cover types like deciduous, evergreen, and mixed forests that were all assigned optimal wilderness ranks of 0 were shown as having a low standard deviation and variability. These areas are not as susceptible to change as other areas where there were mixed value rankings that differed and ranged from 0-4 evenly and dispersedly. Areas with plentiful rank variability also had high standard deviation because these areas are most susceptible to change from the slightest of factors (Figure 4).

  The solitude quality shows that there are more degraded and bad areas as opposed to neutral, good, and optimal areas for solitude because Adams County, although not heavily populated, still has a growing population from its previous years

(Gettysburg History 2018) which thus promotes more frequent occurrences of environmental degradation. Every year the population of the town increases, especially the population at Gettysburg College. Populations in major areas like those near Gettysburg College where there is a significant amount of student population contribute to the most degraded solitude. Since there is a larger amount of people living in the condensed area, there is more possibility of change affecting and changing the area (Sherbinin et al. 2007) (Figure 2).

Other than the college, Adams County is mainly agricultural land with a small to moderate population (Gettysburg History 2018). The overall wilderness character map shows most areas in Adams County as having normal, good wilderness quality. The majority of the area consists of open fields from the Battlefields that have a history tied to environmental degradation from the Civil War. During this period, weapons like rifles and bombs were used and polluted the air with chemicals and damaged wildlife. However, the land is now preserved as a national landmark which is a factor of its wilderness quality (Gettysburg History 2018).

The most degraded areas overall are those associated with major highways and roads (Figure 3). Because the Michaux Forest boundary has high biodiversity and is more secluded from human populations than other areas in Adams County, it is less sensitive to change than areas that are neutral to change, including agricultural land with regular human interaction that can affect the

overall wilderness quality on a regular basis (Sherbinin et al. 2007). Limitations to the study include the lack of data input of other possible natural factors such as flooding and wildfires that may affect the wilderness quality indicators. Limitations can be solved by creating and assigning values from 0-4 for the land cover raster specifically for natural disasters and their assigned rankings. This way natural disasters can be accounted for in the natural quality raster and thus the Monte Carlo Simulation as well.

Appendix

Table 1. Data sources

Name	Who Created	Time Valid For	Description
Adams_Countyborder.shp	U.S Census Bureau	2010	Geography for Census Blocks with housing unit count and population of Adams County, PA; each Census Block in layer is a statistical area surrounded on every side by visible features like streets, railroad tracks, and roads
Michaux_Boundary.shp	Pennsylvania Department of Conservation and Natural Resources	2012	Outline and boundary of Michaux State Woods in Fayetteville, PA
GNMP_boundary.shp	National Park Service	-	Outline and boundary of the Gettysburg National Military Park
land_conservancy.shp	Land Conservancy of Adams County	-	Land preserved by the Land Conservancy of Adams County, PA

PGC_StateGameland2018.shp	Pennsylvania Game Commission	-	Defined individual boundaries of the Pennsylvania State Game Lands for the Management of public resources
SH_boundary.shp	Strawberry Hill Nature Preserve	-	Boundary of Strawberry Hill Nature Preserve in Adams County, PA
PaStateRoad2018_07.shp	Pennsylvania Spatial Data Access	2018	Geography, directionality, and length of roads in Pennsylvania
tabblock2010_42_pophu.shp	U.S Census Bureau	2010	Population and housing unit counts in blocks in Pennsylvania accounted for during 2010 U.S Census
NLCD2011_LC.tif	United States Geological Survey	2011	National land cover dataset in 2011

Table 2. Reasoning for Natural Quality Rankings

Value (Land Cover)	Rank	Reasoning
Open Water	2	Less than 25% of vegetation and soil (United States Geological Survey 2011) but high biodiversity if ocean/lake with diverse marine life; amount land cover may not be directly correlated to natural quality of biodiversity.
Developed, Open Space	3	High possibility of fertilizer overuse and other harmful chemicals like sulfur dioxide and nitrogen oxides that pollute soil/air; leads to acid rain and plant death (United States Environmental Protection Agency 2018).
Developed, Low Intensity	3	Combined range of 20-79% impervious surfaces and single-family housing units (United States Geological Survey 2011) direct correlation between increase in population and env. degradation (Sherbinin et al. 2007).
Developed, Medium Intensity	3	High populations which lead to environmental degradation through pollution and increased land use (United States Geological Survey 2011)(Sherbinin et al. 2007).
Developed, High Intensity	4	Highest populations (United States Geological Survey 2011) and env. degradation (Sherbinin et al. 2007); least amount natural areas like woods/forests

Barren Land	1	Less than 15% of vegetation cover (United States Geological Survey 2011) correlates to low biodiversity but is still natural with minimal manipulation by development/infrastructure.
Deciduous Forest	0	Rich biodiversity and a high percentage of plantation land cover (United States Geological Survey 2011)
Evergreen Forest	0	High diversity of plant and animal species; abundant land cover (United States Geological Survey 2011)
Mixed Forest	0	Plentiful biodiversity and a high percentage plantation land cover (United States Geological Survey 2011)
Shrub/Scrub	2	Slightly more than 20% vegetation cover (United States Geological Survey 2011)
Herbaceous	1	80% of total vegetation (United States Geological Survey 2011)
Hay/Pasture	3	Clearing of natural forest and woods for agricultural practices and overuse of chemicals like pesticides (United States Environmental Protection Agency 2018)
Cultivated Crops	3	Clearing of natural forest and woods for agricultural practices and overuse of chemicals like pesticides (United States Environmental Protection Agency 2018)
Woody Wetlands	2	Slightly more than 20% of vegetative cover (United States Geological Survey 2011)

Emergent Herbaceous Wetlands	1	More than 80% of vegetative cover (United States Geological Survey 2011); saturation may not allow for tall plantations to thrive

Table 3. Reasoning for Untrammeled Quality Rankings

Value (Land owner)	Rank	Reasoning
Gettysburg National Military Park	3	Formerly part of Civil War where many rifles and bombs used but now is preserved land for education of history (Gettysburg History 2018)
Land Conservancy	2	Land conserved and not preserved; human interaction and use still allowed which can lead to misuse and overuse of resources if not monitored (Gettysburg History 2018)
Michaux "Natural Area"	0	High biodiversity and forest land cover; limited human interaction (Pennsylvania Department of Conservation and Natural Resources 2018)
Michaux "State Forest"	0	Diverse plant and animal species with limited human engagement (Pennsylvania Department of Conservation and Natural Resources 2018)
Michaux "In Holding"	2	Privately owned land that is sometimes used for logging (Pennsylvania Department of Conservation and Natural Resources 2018)

Pennsylvania State Game Lands	3	Hunting grounds and rifle use; possible misuse of land (Pennsylvania Department of Conservation and Natural Resources 2018)
Strawberry Hill	1	European settlers in 1700s use to use forest for logging, hunting, mining and farming; currently used as preserved land for environmental education (Strawberry Hill Preserve 2018)
Private/Unspecified	4	Gettysburg County boundary with no efforts to maintain wilderness since more concerned with human population (Gettysburg History 2018)

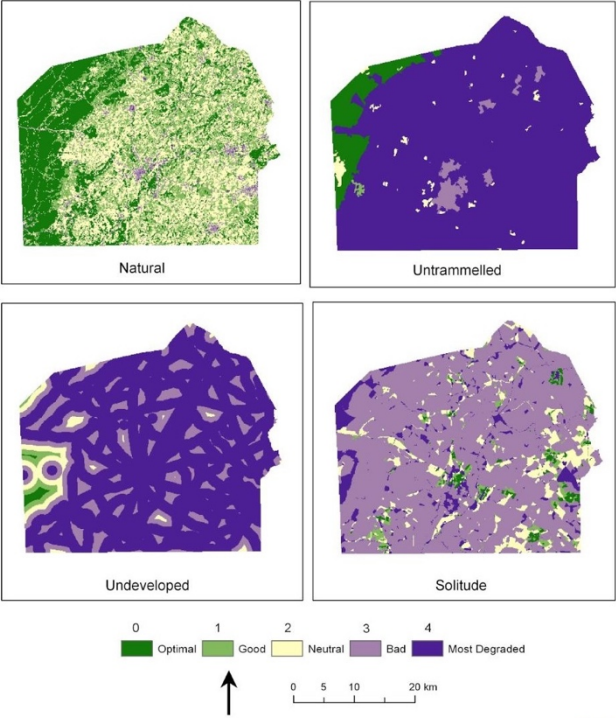Figure 2. Indicators of Wilderness Character Index, Adams County
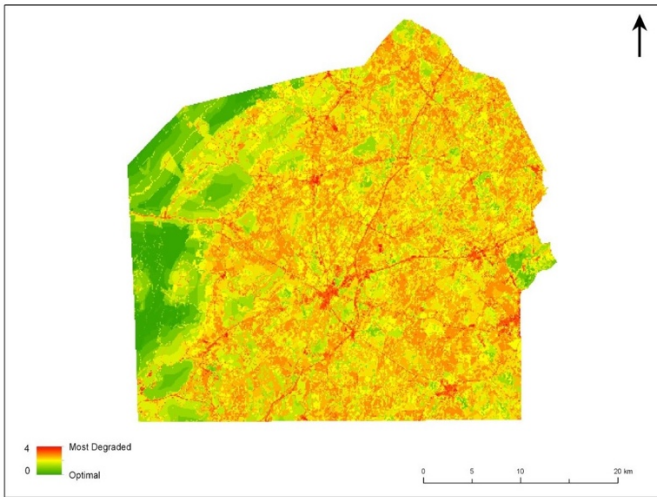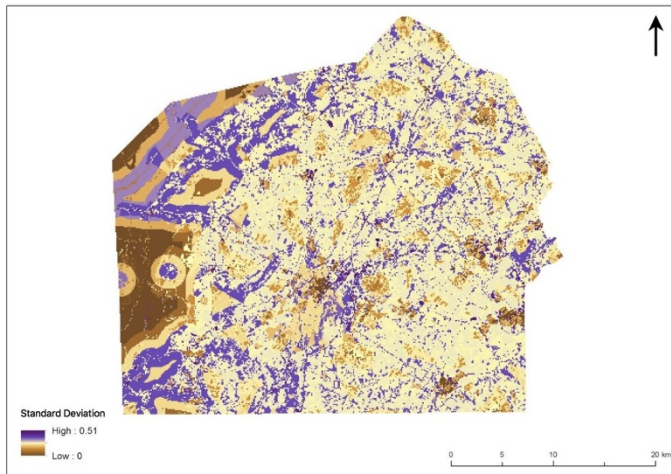
Figure 3. Wildnerness Character Map, Adams County

Figure 4. Monte Carlo Simulation for Sensitivity Analysis, Adams County

Standard Deviation
High : 0.51
Low : 0

0   5   10   20 km

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