Utilizing Viewshed Analysis to Identify Viewable Landcover Classes and Prominent Features within Big Bend National Park

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Abstract

This study examined viewshed and landcover class preservation in nine Integral Vista locations or scenic overlooks within Big Bend National Park (BIBE). This study defined the most viewed areas of the park, essentially detailing which areas are of the utmost importance to protect and to maintain the unobstructed and scenic viewshed of BIBE. A viewshed is an area visible from a particular location or set of locations. Viewshed analysis determines visibility to and from a particular cell or set of cells in a digital elevation model (DEM) resulting in a viewshed layer. The analysis determined a total of 385,822 ha (953,386 acres) were viewable from the nine BIBE Integral Vista locations. The most prevalent viewable landcover class was identified as shrub/scrub, totaling 235,826 viewable ha (582,740 ac). These outputs can be used by park managers and visitors to determine management plans, observe change in landcover, or by park visitors for planning a visit to desired park areas.

Introduction

Preserving and protecting natural environments unique to geographic areas is a goal federal and state parks have been trying to maintain since each park's inception. Not only is preservation a goal, but so is education. Preserving natural areas and resources aid in educating the public, as these areas are recognized and prized for their sustainability and value within our ecosystem. In order to preserve these areas, parks are usually managed through federal or state resources. Managing these areas requires effective use of time and resources to equitability balance preservation efforts through legislation governing their existence.

Resources and preservation priorities vary from park to park. However, lists of priority resources within each park are lengthy and often have intangible value since they are not replaceable. Federal and state parks have governing acts to help support and preserve many park features for priority management. For example, the National Park Service (NPS) Organic Act (16 U.S.C. l) implies the need to protect the viewscapes of National Parks, Monuments, and Reservations. In addition, the Clean Air Act acknowledges the need to protect national parks that have exceptional visibility. Given the role viewsheds or viewscapes and visibility have within National Park systems, park managers have interest in managing these resources for assessment, education, and determining impacts to surrounding areas inside and out of target management areas.

As such, this research focused on examining the role nine Integral Vistas –

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or scenic overlooks – have on Big Bend National Park.

Study Area and Significance

Big Bend National Park (BIBE) is located in a remote area of west Texas distant from incorporated cities and towns. The park is located southeast of Albuquerque, New Mexico (Figure 1).

Figure 1. Location of Big Bend National Park in Western Texas (Google Maps, 2015.)

The landscape within the park borders is nearly unaltered and naturally occurring. According to NPS (2004) only 526 ha (1,300 ac; less than 1% of the total park area) are categorized as being affected by man-made developments. These developments include power lines and structures, which although minimal, are already obstructing scenic views along roads, trails, and key resource areas (NPS, 2004).

A viewshed is the area visible from a particular location or set of locations. An airshed is the geographic area associated with the air supply of a region. As such, parks are defined as having exceptional visibility if they are located within a Class I airshed. BIBE is located in a Class I airshed. Class I status identifies the BIBE air supply and region as having the highest level of protection under the Clean Air Act of 1963. Recognizing the necessity to protect viewsheds within Class I airsheds, NPS created the Integral Vistas program, which focuses on identifying these crucial viewing areas. The NPS identified Integral Vistas by accounting for a variety of factors in a given landscape including legislation, cultural importance, scientific importance, and the propensity of visitation of non-local park patrons. Through this process, NPS defined nine Integral Vista locations within the boundaries of BIBE (Figure 2).

This study is being conducted to ensure the scenic views from BIBE Integral Vista locations will not be affected by future developments as well as to obtain landcover information for future planning. In doing so, a viewshed from each Integral Vista location was created and evaluated for landcover analysis to aid NPS management. This study selected the nine Integral Vistas in Big Bend National Park to generate a composite viewshed detailing the most viewable landscapes and their corresponding landcover classes.

In addition, multiple studies indicate people prefer natural landscapes compared to developed landscapes (Sheppard, 2001; Kearney, Bradley, Petrich, Kaplan, Kaplan, and Simpson-Colebank, 2008; Han, 2010). Kim, Rana, and Wise (2004) consider the capability of viewshed analysis to site features of interest from pre-determined overlooks as one of the best practices and capabilities of viewshed analysis.

A viewshed is often determined using Geographic Information System (GIS) tools. Two datasets are required to calculate a viewshed using GIS: a digital elevation model (DEM), and a point or set of points defining the locations at which a person would be viewing a landscape.

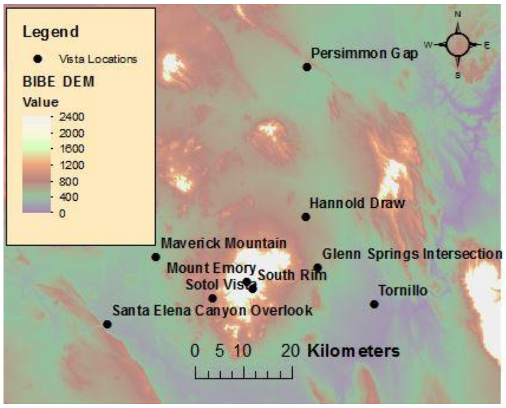

Figure 2. Integral Vista locations and elevation map (elevation in meters) of the study area.

Viewshed analysis is a commonly used spatial analysis tool which determines regions within a terrain of interest that are visible from certain pre-determined points. However, several challenges reside around viewshed analysis. When executed correctly, the product of a viewshed has several applications across a wide range of disciplines including defining scenic overlooks in national parks, management planning, and telecommunication tower placement (Yanli, Padmanabban, and Shaowen, 2013).

Combining viewshed GIS layers with other layers that identify areas of undesirable impacts on the landscape or vegetation classes provides a visual means to assess impacts, stresses, park feature locations, and/or total landcover area of vegetation classes found within a viewshed. Viewshed analysis has evolved to be increasingly useful for National Park Service areas, environmental agencies, and land use planning contractors (Yanli *et al*., 2013).

Formal identification of Integral Vistas and their viewsheds will enable park managers to better prepare and protect the nine BIBE Integral Vista locations and viewshed areas from visual degradation and air pollution (NPS, 1980).

Methods

General methods for this study included obtaining data, generating a design for data analysis, and exploratory and descriptive analysis of viewshed and related landcover analysis. Data required for this study primarily included GIS digital data for computer mapping and analysis.

Data for Viewshed Analysis

Several vector data sets were obtained from the BIBE park staff. In order to prepare the data for consistent mapping and analysis, each layer was projected into Universal Transverse Mercator North American Datum 1983 Zone 13N. Additional GIS layers critical to viewshed analysis were also downloaded and created during this study.

- NPS Provided GIS Layers/Data
  - Nine Integral Vista Points
  - Integral Vista Viewshed Angles
  - Digital Photos from each Integral Vista Point
  - Prominent Park Features Layer
  - BIBE Park Boundary
- Downloaded GIS Data (Layers)
  - Digital Elevation Model (DEM)
  - National Landcover Dataset (NLDS)
- GIS Layers Created During the Study
  - Viewshed Points
  - Vista Viewsheds Analysis

National Park Service Data

The GIS Integral Vista point layer provided the location coordinates and name of each Integral Vista. Locations of each Integral Vista are all accessible by hiking trail and are prominent scenic overlooks within the park. The prominent park features layer (point layer) identifies the name and coordinates of prominent landscapes. Viewshed angles (polyline layer) identify the field of view from each Integral Vista. The BIBE park boundary (polyline layer) and digital photos taken from each Integral Vista were also provided. The data included in the previously outlined downloaded GIS layers and created GIS layers is described later in this section.

Park-provided GIS layers and data were edited and queried to expel data outside the study region. Only relevant information that would be displayed for each Integral Vista viewshed was kept. For example, prominent park features and digital photos of park landscapes were retained for this study only when identified within one of the nine Integral Vistas.

The data separation for the park-provided GIS layers and data yielded a specific folder for each of the nine Integral Vistas identifying the location of the Integral Vista, Prominent Features, Digital Photograph from the Integral Vista Location, and Viewshed Angle. Beyond the park-provided GIS layers and data, each of the nine Integral Vista location folders also included the output viewshed determining the viewable and not viewable areas from each Integral Vista.

All of the GIS layers and data united together express a visual story. As an example, the Santa Elena Canyon viewshed can be seen in Figures 3 and 4. The aforementioned process and subsequent figures were duplicated for each of the nine Integral Vistas selected for viewshed analysis.

Downloaded GIS Data

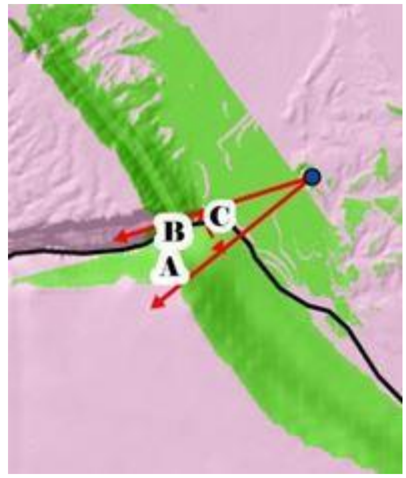

Figure 3. Santa Elena Canyon output viewshed created during this study (Green = visible), Location of Santa Elena Canyon Integral Vista (Blue Dot) Digital Elevation Model (Transparent Fuchsia) Prominent Features (Letters), Viewshed Angle (Red Arrows) and BIBE Park Boundary (Black Line).

Figure 4. Santa Elena Canyon digital photo presenting prominent features (A) Santa Elena Canyon, (B) Rio Grande, and (C) Terlingua Creek identified as viewable in Figure 3 from viewshed analysis.

Selection and attainment of the proper DEM to provide the platform for viewshed analysis of the nine Integral Vistas during this study was the last step during data acquisition. Based on Riggs and Dean's (2007) investigation into spatial accuracy of input data, the smallest resolution available is necessary to avoid inaccuracies in output data displaying visible and non-visible areas. Resolution is critical to preserve accurate areas for quantitative measurement. The finest resolution obtainable for the remote region of west Texas was 10 meters. A DEM of 10 meter resolution with an extent approximately 40 kilometers beyond the BIBE park boundary was defined, selected, and downloaded from the National Map Viewer website. The DEM had an extent of 968,347 ha (2,392,834 ac).

To define the viewable area of each landcover class within BIBE, a National Landcover Dataset (NLDS) was needed. A NLDS from 2006 with a resolution of 10 meters originally produced by USGS was provided by Saint Mary's University of Minnesota. Utilizing the Raster Clip tool, the NLDS was re-sized to fit the extent of the DEM previously acquired. The clipped NLDS was used to define the total area of viewable landcover classes from the nine BIBE Integral Vista points.

GIS Layers Created: Viewshed Points

Viewshed points were created around each of the nine Integral Vista locations to simulate viewable landscapes a park visitor would observe from each Vista point (Figure 5). Viewshed points provide one of the two inputs needed to complete viewshed analysis. Creating viewshed points resulted in a cluster of points around each Integral Vista location (Figure 5). A cluster of points were created to identify the most accurate position of elevation and "view" possible from each Integral Vista. In this process, each vista point, viewshed photo angles, and vista digital photographs obtained from NPS as well as the 10 m DEM, trails layer, roads layer, and Google Earth images were used together before each final viewshed elevation point was selected. This process helped to ensure each viewshed point was at the highest and most viewable area at each vista.

Typically, a number of elevation viewshed points were tested in this manner. As such, each vista resulted in approximately 2-9 test points – all with the goal of identifying the highest location at each vista. Generally, locations with a narrow Integral Vista viewshed angle (60° and under) and few landscape obstructions near the Integral Vista point, required fewer viewshed points (2-4) to accurately portray the viewable area one would observe if at the vista location.

Santa Elena Canyon (Figure 5) provides an example of a well-defined, unobstructed Integral Vista point. Integral Vista locations on mountain peaks with a

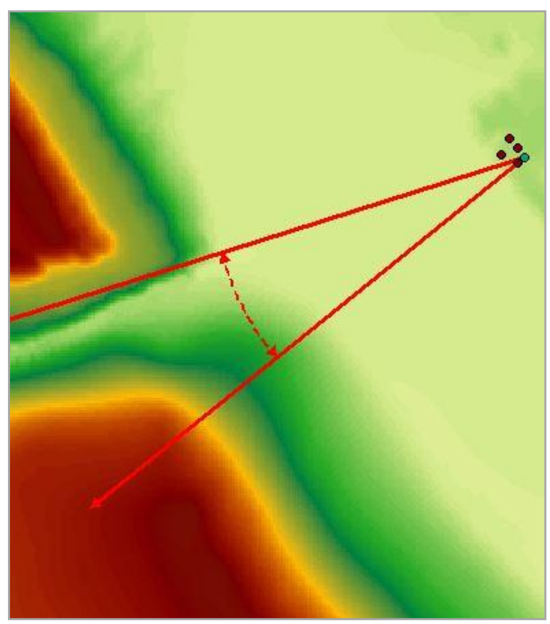

Figure 5. The Santa Elena Canyon Overlook with viewshed point cluster (Burgundy Dots) defined Integral Vista location (Teal Dot), Viewshed Angles (Solid and Dashed Red Lines), and DEM.

nearly 360° view angle or varied elevations near the Integral Vista location overlook required more viewshed points (5-9) to accurately portray the viewable area a park visitor or manager would observe.

Viewshed Analysis

All nine Integral Vista locations defined by the NPS within BIBE were chosen for viewshed analysis. The complete list includes: Glenn Springs Intersection, Hannold Draw, Maverick Mountain, Mount Emory, Persimmon Gap, Santa Elena Canyon, Sotol Vista, South Rim, and Tornillo (Figure 2).

Viewshed analysis was achieved utilizing the viewshed tool in ArcGIS. Viewshed analysis requires two inputs: viewshed points and a DEM. Viewshed points for the Integral Vista being analyzed were selected from the viewshed points attribute table (Figure 6).

OBJECTID	Vista_Poin	Viewshed_P	OFFSETA
24	Mount Emory	5	1.8
25	Mount Emory	6	1.8
26	Mount Emory	7	1.8
27	Hannold Draw	3	1.8
28	Hannold Draw	4	1.8
29	Glenn Springs Intersection	2	1.8
30	Glenn Springs Intersection	3	1.8
31	Maverick Mountain	3	1.8
32	Santa Elena Canyon Overlook	1	1.8
33	Santa Elena Canyon Overlook	2	1.8
34	Santa Elena Canyon Overlook	3	1.8
35	Santa Elena Canyon Overlook	4	1.8
36	Sotol Vista	2	1.8

Figure 6. Selected Santa Elena Canyon Overlook viewshed points (highlighted) used in analysis.

The viewshed points attribute table was selected for the “input point or polyline observer features” window. The DEM of BIBE was selected for the input raster window (Figure 7). All other categories were default, however, it is important to note the z factor can be used as a correction between the x and y values, and z values, if units are not consistent (Figure 7). A z factor calculation was not needed in this study. To simulate the visible area from the elevation of the human eye, an “OFFSET A” column was added to the viewshed points attribute table (Figure 6). The input value in the “OFFSET A” elevates the z value by 1.8 meters above the ground (average height of the human eye) for each of the input viewshed points.

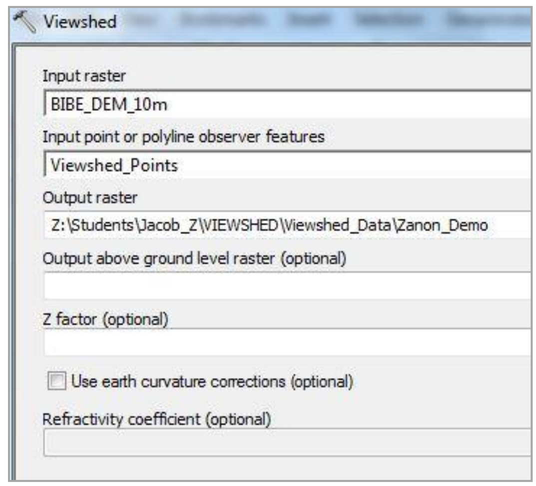

Figure 7. Example of the viewshed tool window and inputs.

The output from the viewshed tool is a Boolean raster defining the visible and non-visible cells across the extent of the input DEM (Figure 8). Typical return values display visible areas of land in green; other areas not visible from the elevation are represented in a red color.

Composite Viewshed/Viewable Landcover

A composite viewshed of BIBE determines the most viewable areas from the nine Integral Vista locations. A composite viewshed of the study region was created using the raster calculator tool to unify the nine Integral Vista Boolean raster viewsheds.

The most viewable landcover classes within the study area were determined with the composite viewshed and NLDS raster. The composite viewshed served as the mask while preforming the Raster Clip tool on the NLDS raster. Through this process, the NLDS was re-sized to fit the extent of the composite viewshed. The output extent of the NLDS identified only the viewable landcover classes and allowed for a quantified value (in hectares) to be computed for each viewable landcover class. Multiplying the number of viewable cells in the landcover class by 100 and dividing by 10,000 defines the area in hectares.

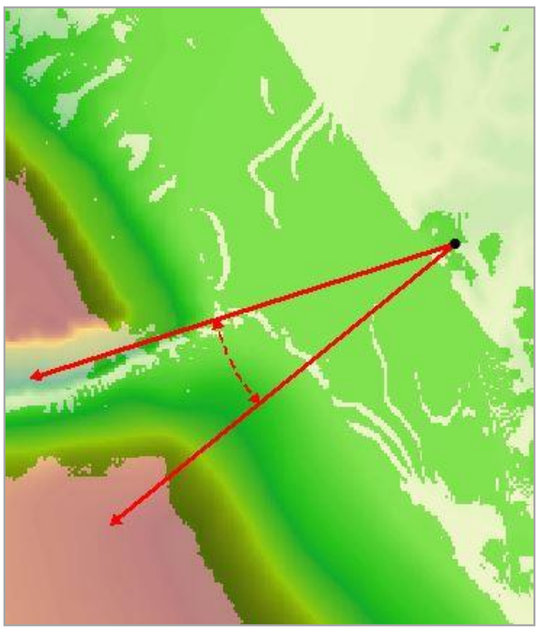

Figure 8. A portion of the viewshed Boolean raster output for Santa Elena Canyon Integral Vista (Black Dot) and visible area (Green).

Results

Specific results for this study include a viewshed analysis from each of the nine Integral Vista locations. A composite viewshed of the study area, individual viewable landcover classes, and the total area in hectares of each landcover class. Results of these findings are presented below.

Integral Vista Viewsheds

Viewshed analysis of the nine Integral Vista locations in BIBE was successful in yielding a Boolean raster defining the viewable and non-viewable area from each overlook (Figure 8). Viewshed analysis of the Integral Vista locations confirmed the viewshed angles to be correct. Confirming viewshed angles and defining each Integral Vista viewshed aids park staff in land management decisions and land cover assessments. For example, a layer pin-pointing a proposed area for development can be input into each of the nine Integral Vista viewsheds. The number of viewsheds impacted by the development can then be quantified. The nine viewshed Boolean rasters from each of the nine Integral Vistas also provided data support for analysis including the composite viewshed and the total viewable landcover classes within the study region.

Composite Viewshed

A composite viewshed was created by combining the nine Integral Vista viewsheds. The intent was to define the most viewable areas of the study. A total of 385,822 ha (953,386 acres) can be viewed from the nine BIBE Integral Vista locations. However, the viewable area is limited, as some of the viewsheds have viewable areas beyond the extent of the DEM. This is a limitation of the DEM analysis.

A total of 840,081 ha (2,075,884 ac) were defined as being either not visible (704,755 ha [1,741,486 ac]) or visible within Mexico (135,326 viewable ha [334,398 ac] within Mexico) (Table 1). Defining the most viewable landscapes of the study region isolates areas of most concern to protect from development.

Viewable Landcover Classes

A total of 16 viewable landcover classes were identified within the viewable area of the nine Integral Vista locations. Among the landcover classes identified, shrub/scrub was the most commonly viewed landcover class, totaling 235,826 viewable hectares (582,740 ac) (Table 1).

Table 1. 2006 Viewable landcover classes as determined by viewshed analysis from the nine Integral Vista point locations.

Landcover Type	**Hectares (ha)**
Not Visible	704,756
Shrub/Scrub	235,827
Visible Within Mexico	135,326
Barren Land	10,282
Evergreen Forest	2,074
Developed, Open Space	656
Woody Wetlands	586
Grassland/Herbaceous	330
Cultivated Crops	205
Developed, Low Intensity	205
Deciduous Forest	135
Emergent Herbaceous Wetlands	68
Open Water	45
Developed, Medium Intensity	4

For display purposes, landcover classes with similar characteristics were combined (Appendix A). For example, the Developed landcover class displayed in Appendix A is a combination of the Developed Open Space, Developed, Medium Intensity, and Developed, Low Intensity fields (Table 1). Defining the viewable landcover from the park's scenic overlooks provides baseline data available for future land cover change investigations.

Discussion

A unique dilemma exists regarding the geographic location of BIBE. The park's entire southern border is shared with Mexico. Viewshed analysis from the nine Integral Vista locations determined over 135,000 hectares to be visible within Mexico. However, because neither a DEM nor the NLDS provides data for lands within Mexico, no further analysis could be completed. Therefore, the respective viewable area was not able to be represented in the study.

The most current regional data available for the viewable landcover analysis (Table 1) was the 2006 NLDS. Therefore, the most accurate representation of the current landcover conditions of the study region are not represented. However, landcover within the region does not change very rapidly. Results are a close, but not perfect representation of the current landcover extents of the study area. Results could serve as a benchmark for future studies to determine landcover changes from human developments or climate change.

Viewshed analysis during this study attempted to represent the viewable area a human being would observe from nine Integral Vista points. To perform viewshed analysis from the average human eye height (1.8 m), the "OFFSET A" field must be present in the viewshed points table (Figure 6). The selection process of the viewshed points described earlier attempted to replicate how an observer might view these nine Integral Vista points from each vista overlook.

However, a representation of how a human will observe an Integral Vista outlook can never be completely accurate. Therefore, the viewsheds presented are likely accurate, but not precise, representations of the viewable area from each Integral Vista.

Conclusions

Viewshed analysis yielded a defined viewshed for all nine Integral Vista locations within BIBE. Defining the visible and non-visible areas from the nine Integral Vistas ensures that park managers are better equipped to protect the scenic overlooks from future developments and the unavoidable visual degradation that would ensue. These viewsheds also provide baseline data for the composite viewshed from all nine Integral Vista locations.

The composite viewshed identified 385,822 ha (953,386 acres) to be visible from the nine BIBE Integral Vista locations. An additional 840,081 ha (2,075,884 ac) were defined as being either not visible (704,755 ha [1,741,486 ac]) or not within the extent of the DEM (135,326 viewable ha [334,398 ac] within Mexico) (Table 1). The composite viewshed determines the most viewable areas within BIBE. Park managers now possess well-defined boundaries regarding the landscapes most important to protect from development and visual degradation.

Of the 16 landcover classes identified to be viewable from integral vistas within BIBE, shrub/scrub was the most commonly viewed landcover class. A total of 235,826 viewable ha (582,740 ac) (Table 1) were defined as shrub/scrub. Defining the viewable landcover from the parks scenic overlooks will allow for any changes to the park's landcover classes from either human or natural causes to be determined. Additionally, it will be possible to determine if these changes will affect the viewable pristine natural and scenic landscapes of BIBE.

Acknowledgements

I would like to thank the BIBE park staff for providing some of the data used in this analysis. A special thanks to Mr. Michael Komp for guidance and interpretation of the finer points of viewshed analysis. I would also like to show my appreciation to Greta Bernatz and John Ebert, professors of the Geographic Information Science Department of Saint Mary's University of Minnesota, for their dedication to my learning and experience while seeking degree completion.

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Appendix A. Viewable landcover classes from Integral Vista locations.