Landscape Visual Quality Assessment Using GIS in Washtenaw County, MI

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Abstract: Past research has shown that the perception of the environment is caused by certain landscape features within that environment. This paper presents one methodology for assessing visual quality by analyzing these landscape features. We tried to quantify the landscape visual quality values of Washtenaw County through an objective analysis from fixed points at ground level. Key landscape features were first selected and overlaid to create a landscape quality map. Random viewpoints were then selected. Based on the landscape quality map, viewshed quality analysis was performed for each viewpoint. Similar methodologies can be applied in other regions.

Introduction

Visual quality assessment, landscape visual quality (LVQ) assessment, or view quality assessment is an important component of spatial analysis and landscape modeling. Applications include (i) gaining a better understanding of landscape; (ii) assisting with landscape planning and location analysis; (iii) providing objective scenic beauty assessment.

A Geographical Information System (GIS) can be used to explore the spatial properties of the visual structure inherent in space (Llobera, 2003). The ability to deal with spatial data makes GIS especially suitable to address landscape visual quality problems. It is also a cost-effective method. In addition, GIS-based methods can make the assessment output easily used in combination with other spatial data as a component of a Spatial Decision Support System (SDSS) leading to a full landscape assessment (Wu *et al.* 2006). However, research in combining GIS and landscape assessment is not sufficient and is still undergoing parameter optimization and technical development.

The visual quality of a landscape comes from two sources that is equally important: from the observed object itself and from the observer (Laurie 1975). Therefore, in this study, visual quality assessment is defined as: analysis of human landscape preferences as viewed from fixed points at ground level (Wu *et al.* 2006).

As can be seen from its definition, the assessment or quantification of visual quality has several inherent difficulties need to be resolved, such as the selection of landscape components and the associated attributes (Shang and Bishop, 2000), and the assessment criteria from the observer. Landscape components and the associated attributes can be more easily measured as they are physical properties; the human aspect is however more complicated, because it depends on human's subjective landscape perception, considering the landscape not as a neutral space (Boira, 1992), but as a part of their own perception space, where individuals have their own perception and relationship with certain landscape (Rodrigues et al). Considering its complexity, to be specified, in this study, visual quality are mainly defined from the ecological aspect. Landscapes that have more natural features were considered to be of higher visual quality.

Several methodologies have been developed for the visual impact assessment using GIS. Early work includes that of Steinitz (Steinitz 1990), Bishop and Hulse (Bishop and Hulse 1994), they mapped visual quality based on the occurrence of key features within the viewshed of each selected point, and used regression analysis to identify eight key variables of landscape public preference; Wu et al. (Wu *et al.* 2006) addressed this problem by using statistical methods to determine the formula of LVQ and applying the formula to generate LVQ for selected viewpoints, then they used spatial interpolation to map LVQ across the study area (Wu *et al.* 2006); More interdisciplinary methods have also been developed recently. Manyoky, Madeleine *et al.* suggested using game engine to build GIS-based virtual 3D landscape model, and they assessed not only visual impact of landscape, but also acoustic impact (Manyoky, Madeleine *et al.* 2014). Artificial intelligence has also been used in this problem, as the work done by González used fuzzy logic and GIS method (González *et al*., 2014). In this paper, a simple GIS-based method was presented to approach this problem.

Study Area

The study area for this project is Washtenaw County, Michigan. The county seat of Washtenaw County is Ann Arbor. As of the 2010 census, the population was 344,791. According to the U.S. Census Bureau, the county has a total area of 722 square miles (1,870 km^2).

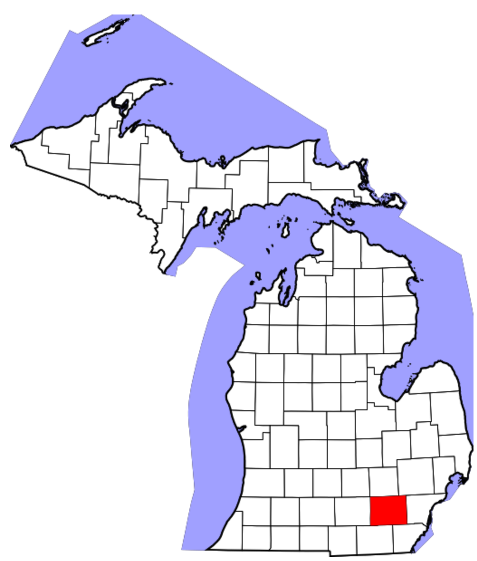

Figure 1. Study area

Methodology & Results

There are four stages in the procedure (fig. 2): stage 1, data preparation; stage 2: landscape quality map generation; stage 3: viewshed quality analysis; stage 4: visual quality score calculation. (Fig. 2) All stages are completed in ArcGIS 10.2.2.

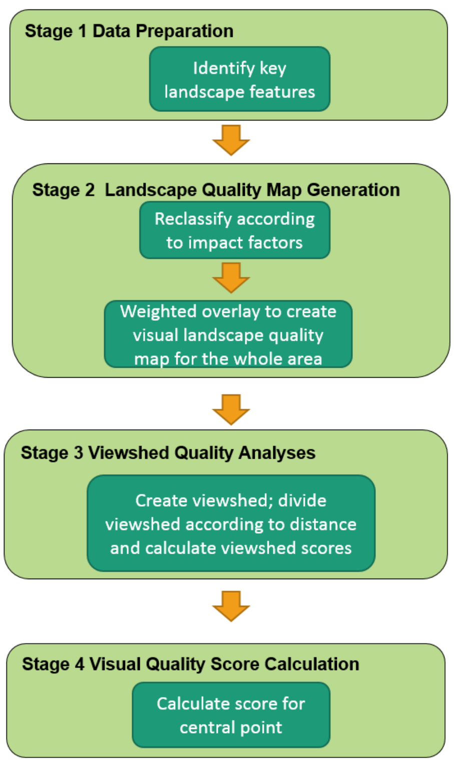

Figure 2. Main stages involved in landscape visual quality assessment

Stage 1 Data Preparation

Data Collection:

Theoretically, every feature in the landscape can be considered as a LVQ factor. However, there were at least three important considerations when choosing landscape features: first, some of the features were considered to have similar effects on LVQ through cognitive experiments, and therefore were categorized as one key visual feature. Second: some landscape features have neutral effects on LVQ. These landscape features were not taken into consideration. Third, the effect of other factors are considered to offset each other, these factors were not being considered too.

Therefore, after selection, five representative features from the study area were identified: forest, industrial area, park, road and open water. Each landscape feature is represented in a corresponding spatial layer for later processing. These layers are mostly derived data sets from land use or land cover maps, others are from specific maps.

Forest

Since the study area has large areas of forest, and forest is an important factor in LVQ, forest comes as a potential factor of LVQ. The data was derived from land cover data from 2011 National Land Cover Database (NLCD). Among the fields of the forest data layer, the area of forest can most reflect the impact of forest to LVQ. Therefore, NLCD data was first converted to Shapefile format, and then land cover types that are “deciduous forest” , “evergreen forest” or “mixed forest” (grid code 7, 8 or 9) were selected using select by attribute command in ArcGIS.

Water

The water information was derived from land cover data from 2011 National Land Cover Database (NLCD). Similarly, the water data was first converted to Shapefile before selection.

Industrial area

The industrial area data was derived from 2008 Generalized Land Use for Southeast Michigan, which belongs to Southeast Michigan Council of Governments. Land use types that is “industrial” were selected.

Road

This layer contains all classes of roadways in the study area. The data was derived from USGS National Transportation Dataset (NTD) for Michigan, of year 2009.

Park

The data was also derived from 2008 Generalized Land Use for Southeast Michigan.

DEM

The DEM data used in this project was downloaded from Michigan Geographic Data Library. The spatial resolution of the raw data is 30 meters.

After selection, the above data layers were then converted to raster format to facilitate the following overlay analysis. The output cell sizes is 30 meters in order to be consistent with DEM data. For forest, industrial area, park and water layer, the field used to convert is “Shape_Area”. For road layer, because road rank is the main factor that influences, road rank is used as the field to convert.

Stage 2 Landscape Quality Map Generation

Reclassification

In order to convert all rasters into a common evaluation scale to generate visual quality map, all five layers were reclassified to five classes according to different criteria. Higher classes mean higher visual quality score. Nodata value is reclassified to 0 to facilitate the following raster overlay step.

For park layer, forest layer and water layer, the larger the area, the more positive impacts they will have on visual quality. Therefore, reclassification was performed based on areas of park layer, forest layer and water layer.

For road layer, the higher the road class, the more negative impacts it has on visual quality. Reclassification was performed based on road class.

For industrial layer, the larger the industrial area is, the more negative impacts it has on visual quality. Therefore the new values were first reversed to perform reclassification.

Weighted overlay

According to the impact of different landscape features on LVQ, the five layers were overlaid (Fig. 3) using weighted overlay tool in ArcGIS to generate Washtenaw County landscape quality map (Fig. 4). On the map, higher quality scores indicate higher visual qualities. The highest score is 5.

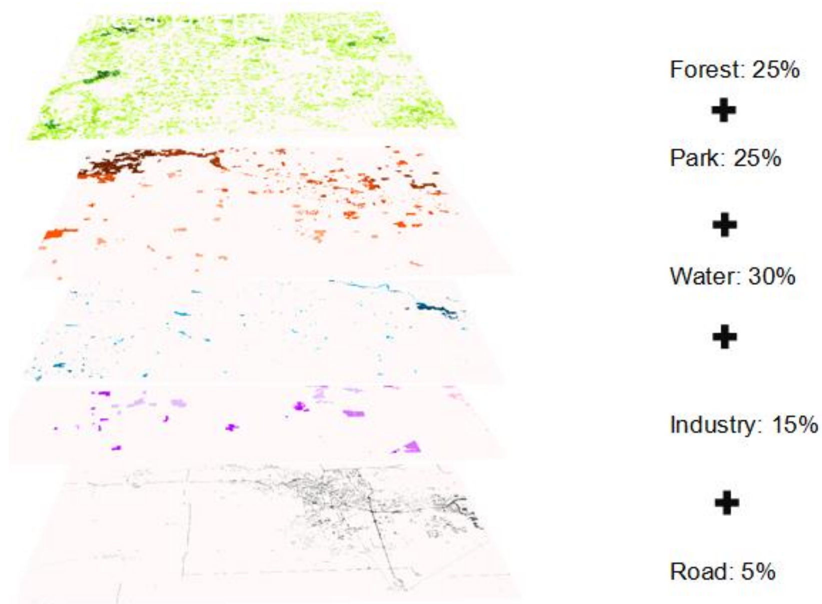

Figure 3. Overlay five key feature layers

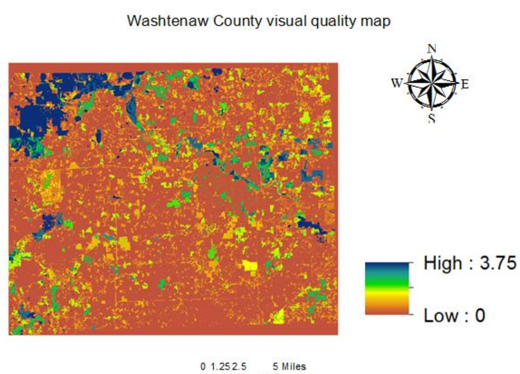

Figure 4. Washtenaw County landscape quality map

Stage 3 Viewshed Quality Analysis

Viewshed generation

A viewshed identifies the cells in an input raster that are visible from one or more observation locations according to topography and surface features. Landscape visual quality assessment is based on viewsheds.

Viewshed analysis can follow several approaches, each suitable for different purposes (Arthur *et al.*, 1977). Most quantitative approaches are based on either line-of-sight visibility analysis or on perspective computer simulations. Line-of-sight analysis determines whether two points in space are intervisible by connecting viewpoint and the feature, and is the basis for creating planimetric 'maps' of all areas visible from an observation point" (Germino, Matthew J., *et al.*).

To conduct viewshed quality analysis, 20 random viewpoints were generated in the map using "Create Random Points" tools, then viewshed generation was performed. In the output of viewshed in ArcGIS, each cell that can see that observer point is given a value of 1. All cells that cannot see the observer point are assigned a value of 0. The observer points feature class can contain points or lines. The nodes and vertices of lines will be used as observation points. (Esri, 2012)

Viewshed dividing

Distance of landscape features is important. The background features and the foreground features are perceived significantly differently by humans. In modeling terms, visual quality depends on the particular features and patterns present in the view, and whether these features and patterns are close or distant. A closer object clearly has more impact than a distant one and should be weighted accordingly. (Wu *et al.* 2006)

Humans can typically see buildings from 8 kilometers away. Therefore 8 kilometers (approximately 24,000 feet) was used as the largest visual distance in this study. For each viewpoint, the corresponding viewshed was divided into three rings according to distance, with the distance of 8,000 feet, 16,000 feet and 24,000 feet from the viewpoint.

This operation had four parts: (Fig. 5 and Fig. 6)

A. Use “Multiple Ring Buffer” tool to generate three buffers of different radiuses.

B. Use the buffers to clip the viewshed map

C. Convert the result map to polygon

D. Intersect the polygon viewshed data with the multiple ring buffer.

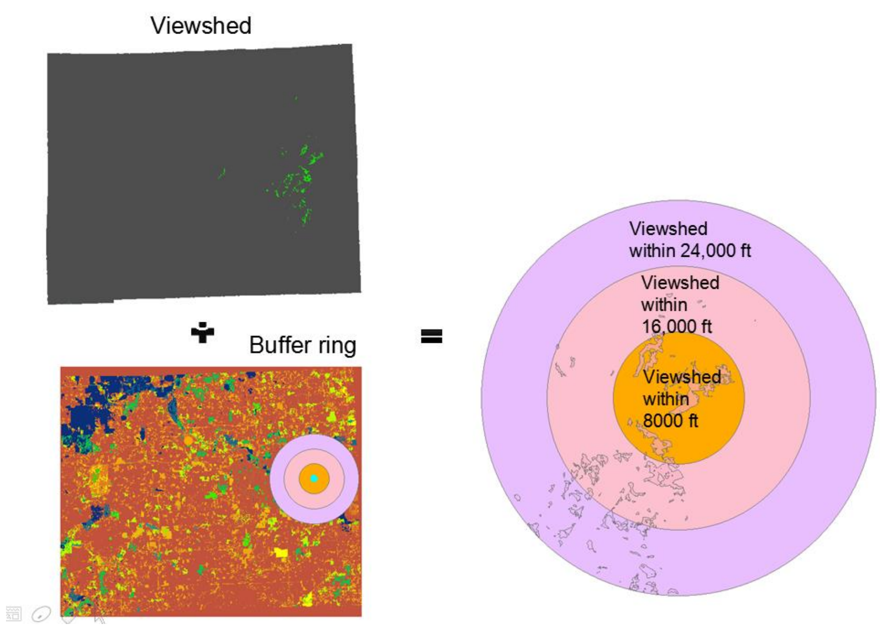

Figure 5. Divide the viewshed according to distance

Ring score calculation

Zonal statistics was then used to calculate visual quality score within each ring. Zonal statistics is a useful function to determine location-specific statistical values. It determines statistical parameters within cartographic zones such as location alternatives (Marinoni *et al.,* ESRI 2014).

Because in the same ring, all key landscape features are considered to have similar effect on the scenic beauty, therefore, the statistic being used is sum. In this way, the landscape feature score of each cell (from stage 2) in that ring was added up together. The total landscape feature score in each ring was assigned to all cells in that ring.

Stage 4: Visual Quality Score Calculation

The geometry of vision suggests that as the distance between object and observer d increases, the size of the object diminishes as $1/d^2$. However, perception studies suggest that the true rate of decline of influence is considerably slower. Indeed some works (e.g. Benson *et al.*, 1998, as reviewed by Bishop *et al.*, 2004) suggest a linear relationship between distance and influence.

In some studies, the relationship between the feature and its impact to local LVQ was considered as some relationship between the $1/d^2$ relationship, suggested by geometry, and a linear relationship. Therefore, a 1/d relationship was assumed (Wu *et al.* 2006) in this study. Using this relationship, the weight of each ring was determined accordingly. (Fig. 7). Then the weighted score of three rings were added together to get the central point score.

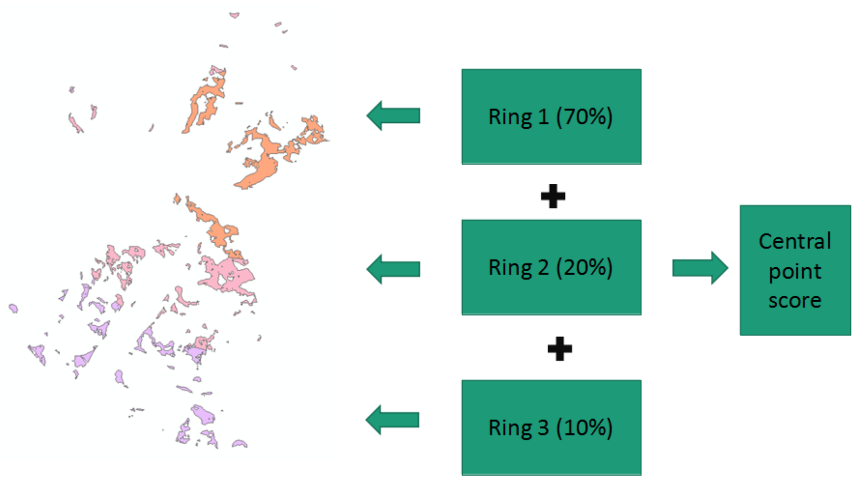

Figure 6. Assign weights to rings according to distance

Since the viewshed analysis has to be done multiple times. A model was created to complete the process. By modifying input parameters, this analysis can be done for each viewpoint.

Analysis of Result

Each viewpoint was calculated a visual quality score. Photos from Google Earth were used to assess the reliability of the results. The scores from stage 4 were used to compare with Google Earth photos. (Fig. 7, Fig 8)

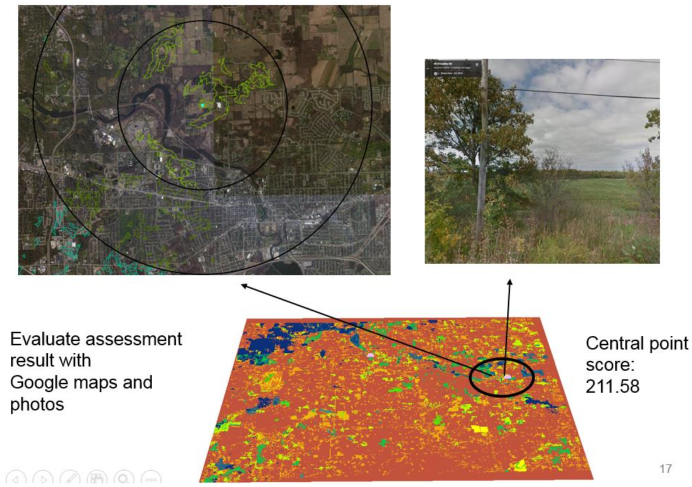

Figure 7. Evaluation of result

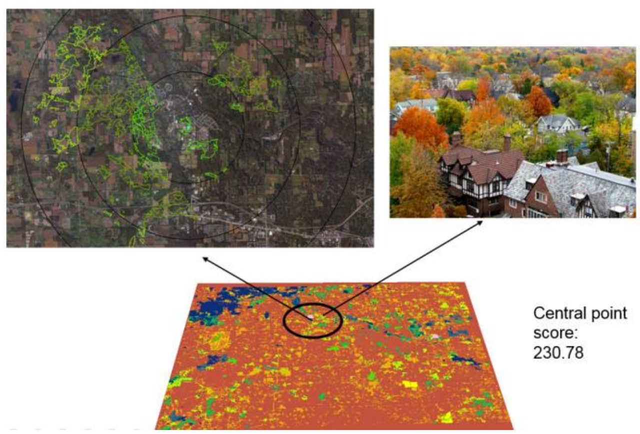

Figure 8. Evaluation of result

Discussion and Future Work

In this paper, a new simple method for assessing the visual quality of landscapes has been described and applied in the region of Washtenaw County, Michigan. Similar methodologies can be applied in other regions to explain and rank the scenic beauty of landscapes.

As I continue working on this study, the methodology used in this study will be further improved. In the near future, I plan to conduct an online visual preference survey to get the formula between LVQ score and landscape features. The formula will then be used in stage 2. This survey will not be designed specifically for this site but aims to find the general relationship between LVQ and landscape features. The survey will contain two parts:

A. 50 Landscape photos will be taken. These picture are of similar quality to exclude unrelated factors. Each of the photo will include the key landscape features in different ratio.

B. The survey will be conducted online mainly through emails. In each survey, the photos will be shown to the participants. Participants will then be asked to rank the landscape preference of each pictures from least to most preferred (scaled 1 to 5) based on their intuition. Participants will include people from different culture, race, country and age group.

Then multiple linear regression will be used to analyze the result. Multiple linear regression-based modeling of factors weights is widely accepted in the visual preference survey (Palmer 1983 and 2004; Daniel and Vining 1983; Wherrett 2000; Real *et al.* 2000; Daniel 2001; Arriaza *et al.* 2004; Wu *et al.* 2006). Another more complex method would be to use neural network based mapping (Bishop. 1996).

I was also considering using building height and vegetation height data to modify the DEM to generate precise viewshed. This kind of data for the study area is unavailable now and hope to be open to public in the future.

It should also be noted that one drawback of this study is that it only calculates scores for certain points. Researchers used spatial interpolation to solve this problem. However, interpolation might lead to inaccuracy because viewsheds of different points vary significantly in undulate terrain. This is a problem worth of further research.

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References

Altman, I., Wohwill, J.F. (Eds.), Behaviour and the Natural Environment. Plenum Press, New York, pp. 39–83.

Arriaza, M., et al. "Assessing the visual quality of rural landscapes."*Landscape and urban planning* 69.1 (2004): 115-125.

L.M. Arthur, T.C. Daniel, R.S. Boster. Scenic assessment: an overview. Landscape Plann., 4 (1977), pp. 109–129

Benson, E.D; Hansen, J.L; Schwartz, A.L; Smersh, G.T. 1998. 'Pricing residential amenities: The value of a view'. Journal of Real Estate Finance and Economics 16: 55–73.

Bishop, Ian; Hulse, David W. 1994. 'Predicting scenic beauty using mapping data and geographic information systems'. Landscape and Urban Planning 56: 59–70.

Bishop, Ian D. 1996. 'Comparing regression and neural net based approaches to modelling of scenic beauty. Landscape and Urban Planning 34: 125–134.

Bishop, I.D; Lange, E; Mahbubul, A.M. 2004. 'Estimation of the influence of view components on high-rise apartment pricing using a public survey and GIS modeling'. Environment and Planning B: Planning and Design 31: 439–452.

Boira, 1992. J.V. Boira. The study of the subjective space (in Spanish). Estud Geogr, 53 (1992), pp. 573–592

Daniel, Terry C. 2001. 'Whither scenic beauty? Visual landscape quality assessment in the 21st Century'.

Esri Inc. 2012 ArcGIS 10.2. ESRI Inc., Redlands, California

Esri Inc. 2014 ArcGIS 10.2. ESRI Inc., Redlands, California

Germino, Matthew J., et al. "Estimating visual properties of Rocky Mountain landscapes using GIS." Landscape and urban planning 53.1 (2001): 71-83.

González, Victor Estévez, Luis Garmendia Salvador, and Victoria López López. "Measuring Landscapes Quality Using Fuzzy Logic and GIS."*Foundations and Applications of Intelligent Systems*. Springer Berlin Heidelberg, 2014. 433-441.

Laurie, I. 1975. Aesthetic factors in visual evaluation, In: Zube, E.; Brush, R.; Fabos, J. (eds) Landscape Assessment: Values, Perceptions and Resources. Stroudsburg: Dowden Hutchinnson and Ross. 102–107.

Llobera, Marcos. "Extending GIS-based visual analysis: the concept of visualscapes." International journal of geographical information science 17.1 (2003): 25-48.

Manyoky, Madeleine, et al. "Developing a GIS-Based Visual-Acoustic 3D Simulation for Wind Farm Assessment." ISPRS International Journal of Geo-Information 3.1 (2014): 29-48.

Marinoni, Oswald. "A stochastic spatial decision support system based on PROMETHEE." International Journal of Geographical Information Science 19.1 (2005): 51-68.

Palmer, J. 2004. 'Using spatial metrics to predict scenic perception in a changing landscape: Dennis, Massachusetts'. Landscape and Urban

Planning 69: 201–218.

Palmer, J., 1983. Visual quality and visual impact assessment. In Finsterbusch, K.; LLewellyn, L.; Wolf, C.(eds). Social Impact Assessment Methods. London: Sage Publications. 268–283.

Rodrigues, Marcos, Carlos Montañés, and Norberto Fueyo. "A method for the assessment of the visual impact caused by the large-scale deployment of renewable-energy facilities." Environmental Impact Assessment Review 30.4 (2010): 240-246.

Shang, H., I.D. Bishop. Visual thresholds for detection, recognition and visual impact on landscape settings. J Environ Psychol, 20 (2000), pp. 125–140

State & County QuickFacts". United States Census Bureau. Retrieved August 29, 2013.

Wherrett, J. 2000. 'Creating landscapepreference models using the Internet as medium for surveys', Landscape Resources. 25: 79–96

Wu, Yingxin, et al. "Using GIS in landscape visual quality assessment."Applied GIS 2.3 (2006): 18-1.