Title: The use of crowdsourced and georeferenced photography to aid in visual resource planning and conservation

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Abstract

The advent of Web 2.0 and the growth of social media platforms have fostered an environment for the documentation and sharing of landscape imagery. In addition to looking at the site scale, using these big data allows for visual landscape assessment at the regional scale. At larger scales, photographs may reveal broad patterns in the landscape including preference for certain land cover types and ease (or lack of) access to visual and cultural resources. Studies have shown that clustering of georeferenced photos indicates interest in a point of view within the landscape or a particular visual or cultural resource. This clustering can also aid in prioritizing visual resource conservation efforts by indicating preference for certain locations over others. Frequency of use, "liking", of photos recorded as metadata provides a metric of citizen evaluation, both local and visitor, to the greater process of visual resource planning and conservation. Alternatively, crowdsourced photography can document visual impacts of landscape change as experienced by the people of the place. Sites like Google Earth, Panoramio and Flickr permit users worldwide to upload and share georeferenced photographs, while others like FrackTracker.org archive landscape impacts, in this case, those associated with development from the natural gas industry all over the U.S. This paper uses the state of Pennsylvania as a case study example to discuss the opportunities for crowdsourced and georeferenced photography to aid in visual resource conservation and planning.

Introduction

The onset of Marcellus shale gas development in the state of Pennsylvania concurrent with the rapidly widening availability of crowd-sourced citizen photography has provided a valuable opportunity to study crowdsourced and georeferenced photography as an aid in visual resource conservation design and planning. As Trombulak and Baldwin (2010) outline, the goals for this work include identifying spatially explicit measures of change in the landscape, being able to predict spatially explicit threats to the landscape, recognizing sites within the region that are important or irreplaceable, and prioritizing areas for conservation action to address pressures and preserve/conserve exceptional sites in the future.

From site scale to regional scale

In their introduction to landscape-scale conservation planning, Trombulak and Baldwin (2010) emphasize that "…conservation planning is a multilayered, systematic process that progresses in an orderly fashion from conservation vision to science, to communication of results and engagement of stakeholders, to design, and finally to implementation (8)," and "…[the] importance of selecting the proper temporal and spatial scale for the conservation goals chosen, considering both cultural and natural history, responding to present and emerging economic trends, engaging both stakeholders and experts, developing multivariate measures of threats and opportunity, and practicing patience, creativity, and collaboration (13)." Visual and cultural conservation may need to be done at scales larger than those typically addressed by past cultural landscape studies, scales at which specialist consultants and designers are only part of larger teams working on a problem. At regional scales these may include elected policy-makers, designers, NGO stakeholders, and scientists, to name a few, to collaborate in order to establish a satisfactory conservation plan (Steinitz 2012, Trombulak and Baldwin, Introduction: Creating a Context for Landscape-Scale Conservation Planning 2010). This work proposes ways of addressing visual and cultural conservation at larger scales.

Beyond the kinds of records traditionally collected at the site scale, using these big data allow for more efficient visual landscape assessment at the regional scale along with the integration of broader representation of stakeholder viewpoints throughout the impacted region. At larger scales, photographs may reveal broad patterns in the landscape including preference for certain land cover types and ease (or lack of) access to visual and cultural resources.

Background

History of photographs and landscape preference

Traditional methods of visual resource assessment in landscape architecture and allied disciplines have long included the use of photographs and video, both analog and more recently digital. One process of assessment has the investigator provide images for test respondents to analyze and rank, sometimes allowing for projection of preference across the landscape. This top down approach is usually implemented with respondents removed from the actual landscape experience. Another predominant method is for trained landscape architects (typically) to apply principles of formal aesthetics to judge the value of landscape settings. Daniel (2000) and Zube (1984) warn against this "expert" approach indicating that it may not take into consideration all of the public's values and perceptions. Finally, as Riley (1997) suggests, all of these forms of visual analysis tend to be atemporal. Addressing these shortcomings, another approach has users take a camera into the field and take photographs either at their whim or to a prompt such as "scenic" or "beautiful". These photos are then returned to the investigator for later analysis. The investigator may have even asked the subjects to record their reasons for photographing. These approaches, termed "visitor employed photography" or "photo-voice" while addressing weaknesses in other methods, require that the subjects are aware that they are part of a study, which may sway their intentions or subject matter of the photos they take. We postulate that crowdsourced data from volunteered photographs taken in situ remedy both the atemporal and "top-down" problems in visual analysis.

Big data, crowdsourced photography, and social media

The advent of Web 2.0 and the growth of social media platforms have fostered a new environment for the taking and sharing of photos. These new resources allow investigators to access large data reserves of photographic imagery taken in situ, many with substantial metadata and geographic coordinates. These images are taken without prompt and voluntarily contributed to various image hosting websites. These photos represent what the individual was observing in their landscape, in a particular moment, and their willingness to share the image suggests a positive valuation of that photo. A New York Times (2011) study on online sharing via social media (n=2,500) reveals that 68% *share to give people a better sense of who they are and what they care about*, 73% of those surveyed *share information because it helps them connect with others who share their interests*, 84% *share because it is a way to support causes or issues they care about*, and 94% *carefully consider how the information they share will be useful to the* recipient, suggesting that most social media posting is meaningful to the user and not haphazardly done.

Social media websites like Panoramio (previously the image hosting site for Google Earth, closed as of November, 2016) and Flickr permit users worldwide to upload and share georeferenced photographs, while others like FrackTracker.org catalog landscape impacts, in this case, those associated with development from the natural gas industry all over the U.S. identified by state. More recently, studies have been looking at publicly available online crowdsourced data for perceptions of the environment or landscape (Dunkel 2015, Newsam 2010) and some look particularly at scenicness as their metric (Alivand and Hochmair 2013, Hochmair 2010, Xie and Newsam 2011). We incorporate crowdsourced georeferenced photos in a similar manner as Alivand and Hochmair (2013) and Hochmair (Hochmair 2010) who state that a location or artifact is scenic if more than one photo, posted by unique users, is located in a particular place. In this way, we are using photos as an archaeological artifact or currency of visual perception and preference. As an artifact, the photos are a spatial event. Relying on analogies from ecology, we recognize that these events occur in a spatial context. In order to capture or model that context we buffered each location. With scenic vistas, there are often several vantage points from which a view can be seen, so a distance buffer is required for those images. Similarly, though their studies do not state this, an artifact such as a building can be photographed from multiple sides and locations, again requiring a buffer to associate those images with one another, or the filtering of metadata tags (Dunkel 2015) to find relationships.

Summary of work

This work looks to investigate the usefulness of using crowdsourced photos for integrating cultural resources and information into landscape scale conservation design and planning. Photo location offers a unique opportunity to assess how other physical environmental variables potentially influence the photo cluster locations. These results can then be used to inform design and planning decisions at the regional scale. The work began by examining where in Pennsylvania people were taking photos. Google Earth imagery sourced from now non-operational (as of November 2016) Panoramio allowed us to see where people are taking photos geographically. To provide some context for conservation, these photo locations will be shown in relation to Marcellus shale development in Pennsylvania, however, this method is also meant to be applied with other forms of impacts, such as climate change or population growth and urban/suburban sprawl.

Methods

The data collection process gathered photos manually from Google Earth's Panoramio Layer. Since photos cluster differently at different scales (i.e. the further you zoom away from the Earth's surface, the clusters will condense into fewer clusters, and the closer you zoom in, they will separate into more clusters) this study collected photos working at a 20-mile eye altitude zoom level. At this distance, only clusters were selected, not individual photos, as multiple photos indicate interest in a location and multiple users photographing and uploading in a location demonstrates consensus (Alivand and Hochmair 2013, Dunkel 2015, Hochmair 2010). When saving the cluster, the embedded title provided by the user and metadata comes from the most popular photo (most viewed or liked/favorited photo) within the cluster. The resulting data points saved from the cluster locations thus represent interest in a place, but not necessarily the photo itself. This process was repeated all over Pennsylvania, working county by county, using the right-click "save to my places" command within Google Earth. Then each county was exported as a .kml file by right-clicking on "My Places", then "save my place as…", then "save to .kml" and named for the county. After all counties were inventoried, we added all of the county .kml files back into Google Earth and exported a master .kml file for the entire state. The master file contained 7309 photo location points in total.

We then applied a 1km buffer to the point locations to help document and describe the physical context of the photo locations using 2011 National Land Cover Dataset (NLCD) (30-meter resolution) from United States Geological Survey (USGS). Using the Geospatial Modelling we calculated the representative area of each land cover for each of the 7309 1 km buffers. Using the Geospatial Modelling Environment (GME) isectpoly (intersect polygons with raster) function offers a benefit over traditional spatial joins and similar tools in ArcGIS, which don't include overlapping polygon areas in the calculations. Percentage of land use land cover were calculated within the 1-km buffers and classified by the majority land cover type found within their respective buffer.

In addition to evaluating the physical context of photos, we classified and categorized metadata included in the photos to more fully integrate into the broader Appalachian LCC pilot study. Simply, we categorized user provided titles for all 7309 photos. The goal was to categorize the images using a classification system based the key categories in the National Register of Historic Places. We chose to emulate these existing categories because the National Register of Historic Places is a well-known and long established program used to coordinate public and private efforts to identify and protect America's historic and archaeological resources. Initial categories included The Arts, Infrastructure, Religion, Economy, Society, Education, Military, Environment, and Transportation. These were amended to add a Scenic category (to catch images whose subject looks out over a mixed landscape from a vantage point, typically a long-distance view) and Ephemeral (to catch images whose subjects are fleeting, such as weather, seasons, etc.). Environment was also divided into Human Environment and Natural Environment to help understand the nuances between environments and landscapes which are clearly touched by people and those which appear more "natural". Images were classified by their titles, initially using a key word search, and manually for those that did not fall into the keyword search. Untitled images (704) and those images whose titles were not intuitively descriptive were visually inspected and classified according to their subject matter.

Results

Patterns in the data

Using 2010 census data, 3019 images fell within areas classified as urban and the other 4200 were in non-urban areas. Figure 1 shows the point density for the distribution of the photos, and units of density are points per square meter represented in 500-meter pixels.

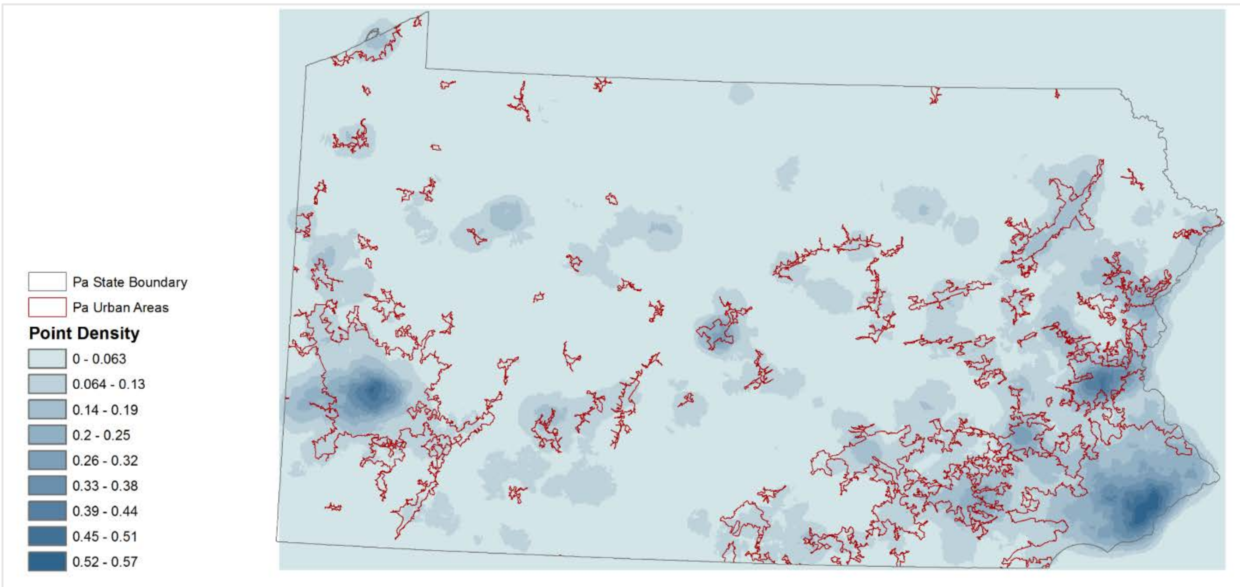


Figure 1 - Point density of photos in Pennsylvania areas and delineation of urban areas

Comparison with the classifications of the National Land Cover Dataset (NLCD) shows overwhelmingly that people are taking photos in areas classified as forest land cover. 52.41% are classified as deciduous forest, with 1.80% mixed forest and 0.33% evergreen forest for a combined 54.54% total forest classification. The next highest category is developed open space, such as parks, at 10.63%. All results are shown in Table 1. Interestingly, even when we separated urban and non-urban areas according to the 2010 census data, deciduous forest is still the highest ranking land cover type. When separated, developed open space and developed low and medium density areas are where most photos are being taken. In non-urban areas, deciduous forest is first, followed by hay/pasture areas and cultivated crops. Figure 2 shows the geographic distribution of all of the photo buffers and their dominant land cover types. Development is represented in the reds, pinks, and purples, and these aggregate in the urban areas. The length of the Susquehanna River is clearly displayed in blue for open water.

Table 1 - Percent Land Cover Type: Urban vs. Non-urban

	Urban	Non-Urban	All
Deciduous Forest	33.77%	72.89%	52.25%
Developed, Open Space	19.50%	0.64%	10.59%

Cultivated Crops	7.21%	9.24%	8.17%
Developed, Low Intensity	14.34%	0.06%	7.59%
Hay/Pasture	5.34%	9.64%	7.37%
Developed, Medium Intensity	11.67%	0.03%	6.17%
Open Water	3.68%	2.43%	3.09%
Developed, High Intensity	3.79%	0.00%	2.00%
Mixed Forest	0.16%	3.62%	1.79%
Evergreen Forest	0.03%	0.67%	0.33%
Herbaceous	0.03%	0.20%	0.11%
Shrub/Scrub	0.08%	0.03%	0.05%
Woody Wetlands	0.00%	0.12%	0.05%
Barren Land	0.05%	0.03%	0.04%
Emergent Herbaceous Wetlands	0.05%	0.03%	0.04%
Developed, Medium Intensity; Deciduous Forest	0.03%	0.00%	0.01%
Developed, Open Space; Deciduous Forest	0.03%	0.00%	0.01%
Developed, Open Space; Developed, Low Intensity	0.03%	0.00%	0.01%

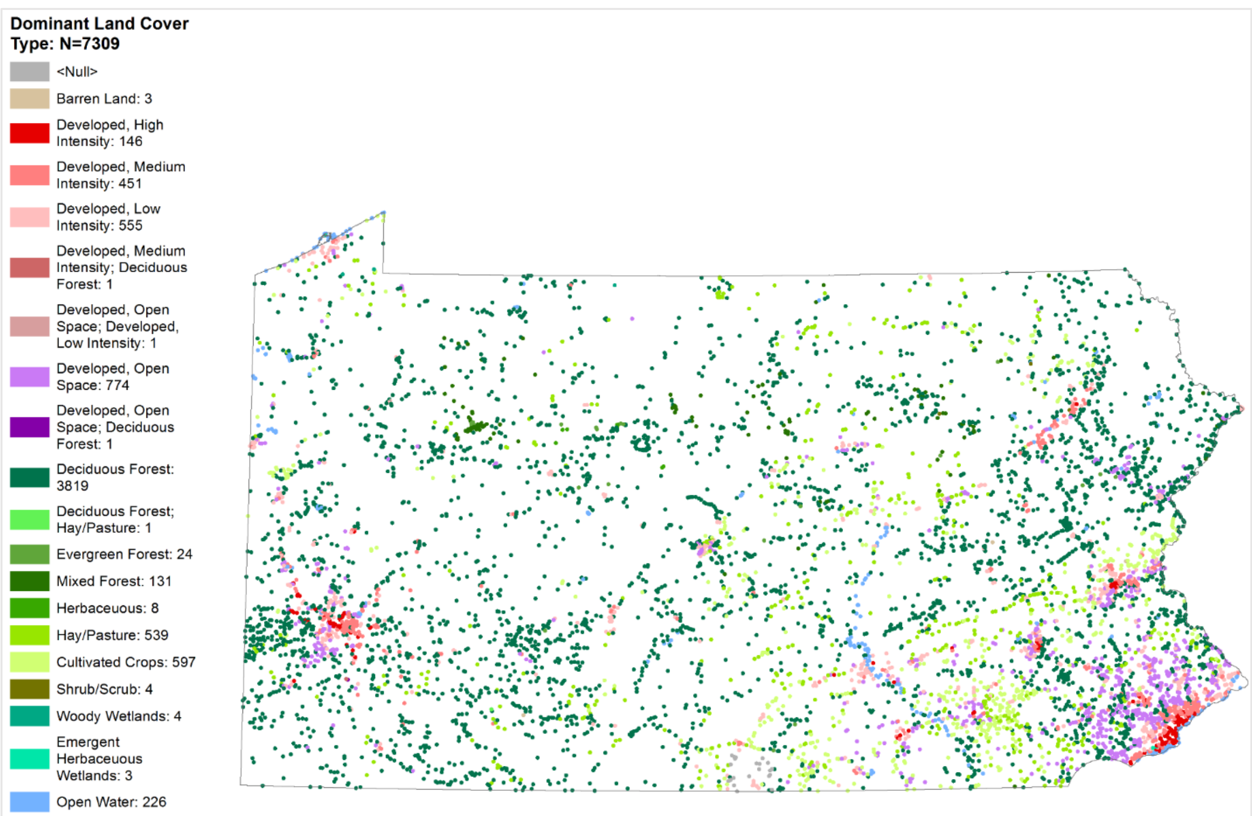
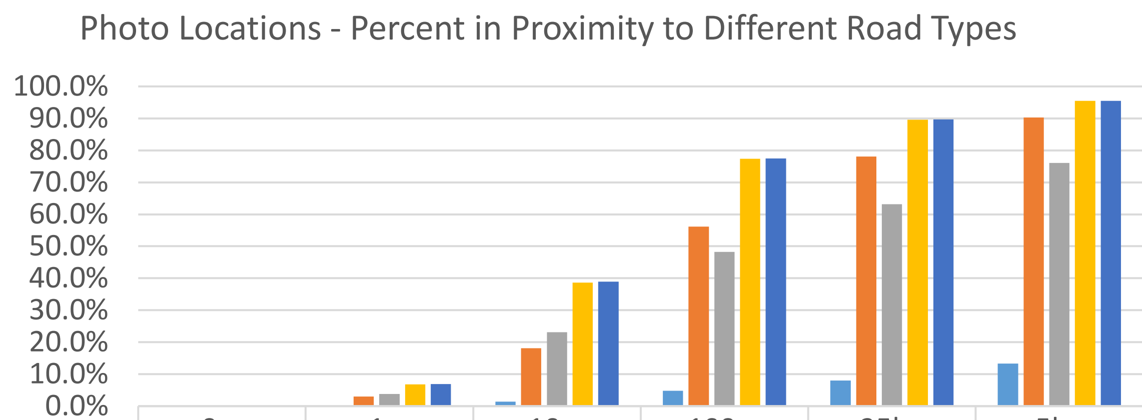


Figure 2 - Distribution of photos and land cover type in Pennsylvania.

Another interesting pattern that emerged is that of access. Table 2 and Figure 3 show that photos rarely exist in areas far from roads. Specifically, 95.5% of all photos occur within .5 kilometers of a road. This equates to about 4 blocks or an 8-minute walk.

Table 2 - Photo Locations - Percent in Proximity to Different Road Types



	0m	1m	10m	100m	.25km	.5km
Unpaved	0.0%	0.2%	1.5%	4.8%	8.0%	13.3%
Local	0.0%	3.0%	18.1%	56.1%	78.0%	90.2%
State	0.0%	3.8%	23.2%	48.2%	63.1%	76.1%
Improved	0.0%	6.8%	38.7%	77.3%	89.6%	95.5%
All	0.0%	6.9%	38.9%	77.4%	89.7%	95.5%

Unpaved Local State Improved All

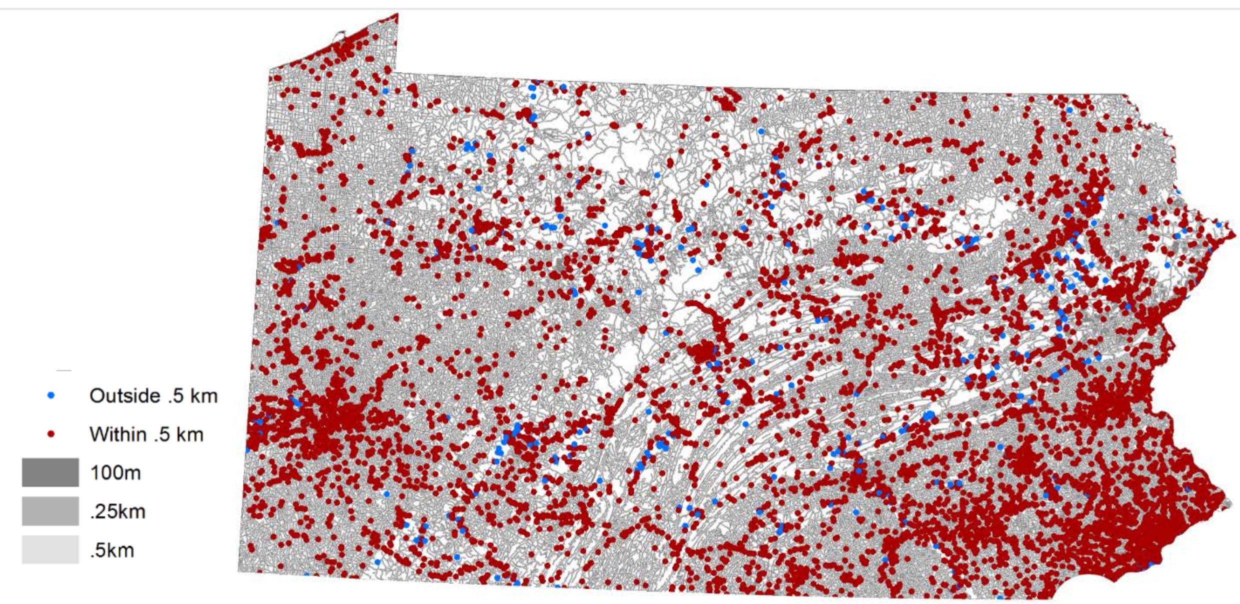


Figure 3 - Photo proximity to roads

The textual analysis also yielded interesting results. While we would expect a high number in the "natural environment" environment category, as the geographic distribution and land use analyses show us, we did not expect transportation to be the second highest category. Table 3 shows the category percentages and for clarification, Table 4 shows the breakdown of the number of photos into categories and subcategories.

Table 3 - Textual Analysis Results

18.48%	18.34%	17.21%	14.93%	8.09%	5.95%	5.23%	3.77%	3.62%	2.21%	1.52%	0.66%
Natural Environment	Transportation	Human Environment	Cultural	Economic	Religion	Infrastructure	Ephemeral	Scenic	Education	The Arts	Military

Tracking impacts

Knowing what the "on the ground" impacts are, how they are affecting the people of the place, and where these impacts are occurring is a very important piece in conservation. Since some problems occur at the regional scale, it is often difficult to have current data to work with that covers an entire affected area. One way to coalesce impact data across a region is to crowdsource it. FrackTracker Alliance and its website fractracker.org use crowdsourced photography and videos to document impacts caused by unconventional shale gas development in the U.S. and other countries. The volunteered media is sorted by theme (e.g. air quality concerns, rigs, water impoundments, pipelines, etc.) or by location such as state or country. While these photos are not georeferenced, they do have locational information available in their descriptions so at least municipal level location can be determined for impact assessment. Information such as this can be combined with the photographic preference data to see where spatial overlaps occur and aid in designing a conservation plan.

Discussion

Findings

As is common in much of scenic conservation research and literature, natural or seemingly natural areas and greenery seem to be preferred. The geospatial analysis of the photos showed that deciduous forest is the most photographed land cover type in the state of Pennsylvania, whether you are looking at urban or non-urban areas. In urban areas, developed open space (parks and similar) are second. In non-urban areas, people photograph and share hay/pasture and cultivated crops (the bucolic scene) second and third. When compared to the textual analysis, this makes more sense, as the natural environment category was the most popular. This category includes forest and vegetation, but something that would not be visible at the NCLD 30-meter scale is the water (the most popular sub-category in the textual analysis) that likely is found in forested areas. The next steps for this work would be to combine and cross-validate the geographic and textual analyses.

A finding that was not expected was the popularity of transportation within the textual analysis. 35% of this are pictures of roads themselves, many obviously taken from a vehicle. These included streets and intersections, highways, and images specifically titled as “xxxx Street (or Road, Boulevard, etc.)”. Further research needs to go into understanding why roads are seemingly so important and frequently photographed. In relation to roads, the geographic distribution of photos indicates that roads and thus access is very important when it comes to people visiting a location and taking a photo. As mentioned before 95.5% of all photos are taken within 5 kilometers of a road. This equates to about 4 blocks or an 8-minute walk, which tells us, that if people cannot drive to a location, they are unlikely to visit it and photograph it. This has several implications for conservation. First you can say if people cannot visit or see something, they will not value it. Whyte (1968) notes this similarly in his work saying “...the greenery. There is too much of it (274).” Referring to open spaces needing to be seen to be valuable. On the other hand, limiting vehicular access to an area prevents many people from visiting it which can be a good thing for sensitive landscape areas and habitats.

Showing preference and prioritizing conservation efforts

Simply stated, if you are given a large area and wish to prioritize its visual amenities for conservation, the locations with the most crowdsourced photos (from unique contributors, that is) are where time and effort should be focused. An example of this from a related project (Goldberg 2015) looked at the viewshed of the Loyalsock Trail, a historic 60-mile hiking trail in central Pennsylvania. This trail is in the midst of Marcellus shale development. It spans two counties, eight municipalities, and two conservation regions, the Pennsylvania Wilds and the Endless Mountains Region. The total viewshed for the trail, at a distance of 5-miles, covered 113,743 acres of land. This is a huge undertaking trying to organize people and resources over such a large span. To focus the limited resources, crowdsourced photos along the trail were analyzed and the areas with multiple photos were kept. From that, those with the most photos and the most external views from the internet were put in rank order. This method would allow for the sub-viewsheds along the length of the trail to be dealt with individually and in order of scenic and cultural importance to the region (Figure 4).

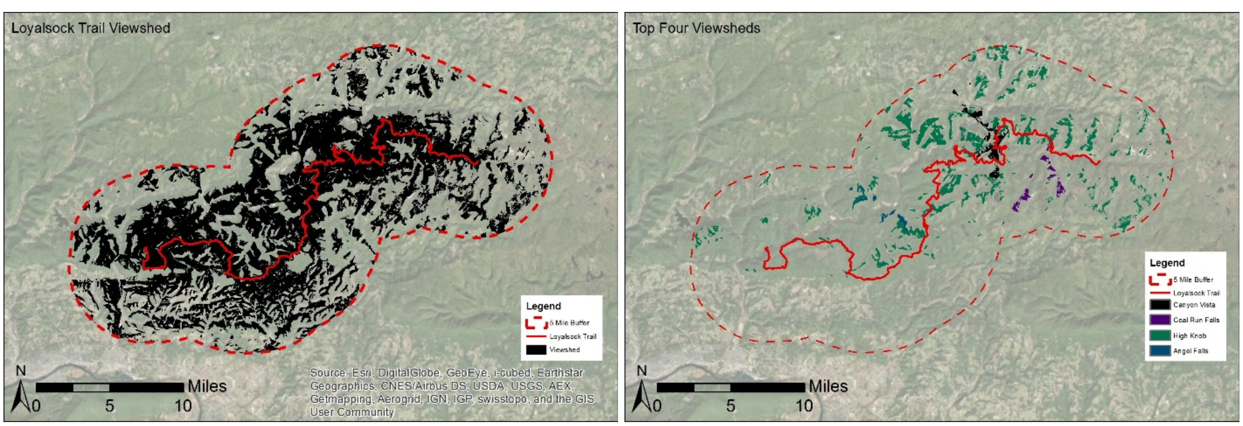


Figure 4 - Loyalsock Trail: Entire Viewshed and Top Four Sub-viewsheds

Possible Application

One potential application is to see how areas of Pennsylvania that are visually and culturally important are being impacted by energy development. The map below (Figure 5) shows point density of Marcellus shale gas well development and photo distribution as well as the location of wind farm installations. This example shows where overlaps of densely energy-developed areas and frequently photographed areas exist. This rough analysis quickly allows focus to be drawn to the area in the northeastern part of the state where both densities are high. This region is known as the Northern Tier or the Endless Mountains region and is highly valued for its rolling hills, beautiful forests, and bucolic scenes, but as we see here, these valued areas and scenery are at risk from shale gas development.

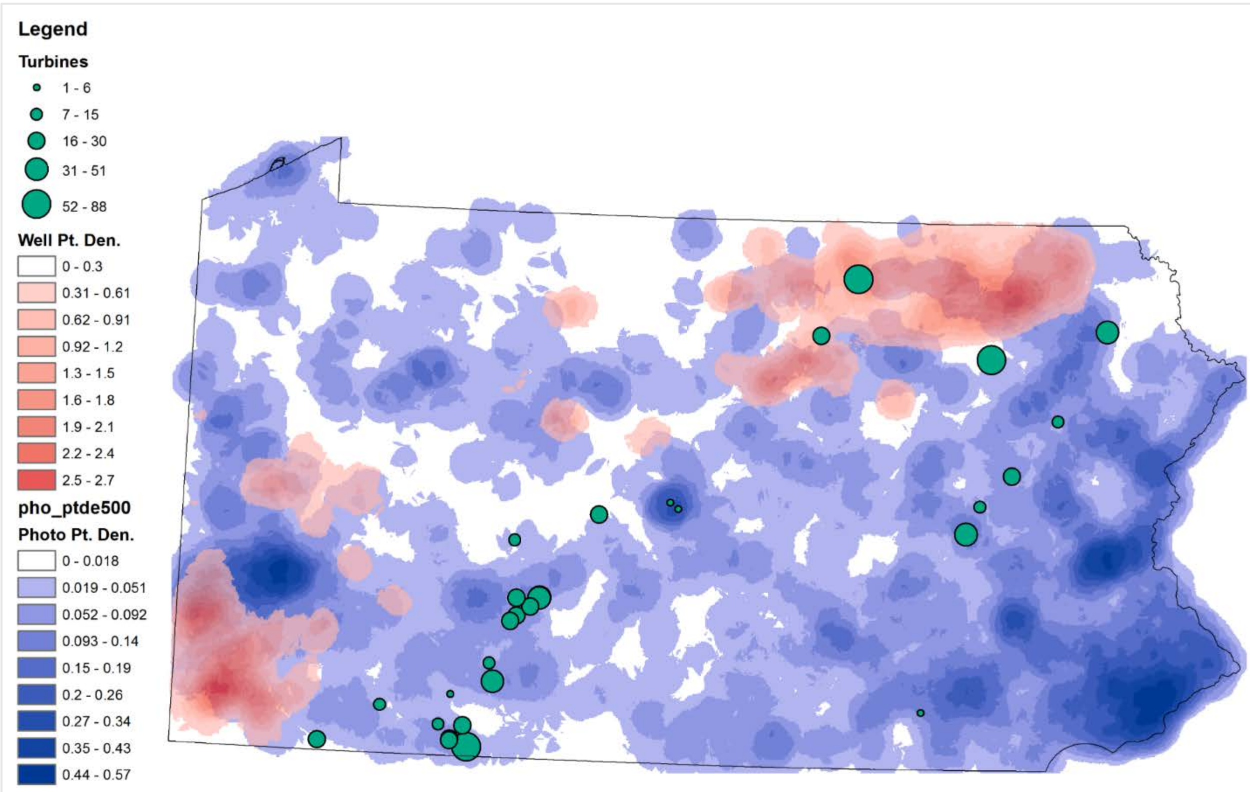


Figure 5 - Marcellus shale gas well and photo point density overlay

Conclusions

This paper demonstrates several forms of crowdsourced data and their utility and versatility in visual resource planning and conservation. As this study shows, crowdsourced photos can reveal where people are visiting and photographing in a landscape. The next step of subsequent sharing to social media indicates that they are valuing these photo locations. Repeat photographs in a particular location indicate consensus among those visiting, seeing, and sharing these visual and cultural landscapes and amenities. Crowdsourced data does have its faults. It is a convenience sample and may not represent the opinion or views of all stakeholders, particularly those without access to transportation, technology, or social media. The data is not always perfect and may include incorrectly located photos, missing or incomplete metadata, or subjects that are unclear to the researcher without further explanation. Conversely, big data is just that, large data sets, inexpensive or free for use in a multitude of analyses. Crowdsourced data, particularly photographs, are valuable tools in the process of visual conservation design and planning.

Table 4 - Textual Classification Index

Natural Environment	Water	627	Cultural	House	321	Human Environment	Park	280
	Waterfall	133		Town/City	319		Trail	211
	Vegetation	116		Recreation	241		Farm	156
	Forest	103		Ruins	42		Barn	100
	Animals	89		Memorial	28		Agriculture	83
	Geology	79		People	22		Countryside	68
	Mountains	61		Monument	21		Dam	65
	Field	38		Festival	17		Building	41
	Nature Preserve	35		Civic Center	14		Reservoir	29
	Valley	16		Object	13		Structure	27
	Wetland	14		Cultural	9		Domestic Animals	26
	Island	13		Visitor Center	6		Cabin	25
	Disaster	9		Cultural/Historical Society/Center	5		Yard	25
	Beach	5		Historic Site	5		Object	23
Transportation	Road	470		Historic/Cultural District	4		Decay	14
	Bridge	288		Historical Marker	4		Disaster	14
	Covered Bridge	152		Plaque	4		Fountain	9
	Railroad	150		Archaeological Site	3		Garden	9
	Tunnel	47		Political	2		Fair grounds	8
	Air	45		mound	1		Dump	6
	Transportation	30	Economic	Business	201		Square	6
	Gas Station	28		Restaurant	99		Lighthouse	5
	Train	26		Hotel	81		Wall	5
	Vehicle	26		Industry	66		Human Environment	4
	Canal	23		Store	62		Courtyard	2
	Boat	21		Mill	60		construction	1
	Dock	10		Quarry	12		Greenhouse	1
	Parking Lot	7		Bank	5		Interior	1
	Port	4	Religion	Place of Worship	271		Plaque	1
	Disaster	1		Cemetery	148		Wrong	1
Infrastructure	Sign	113		Religious Symbol	7	Ephemeral	Sunset	81
	Energy	100		Religion	4		Snow	53
	Firehouse	24		Plaque	1		Autumn	39
	Hospital	23	Scenic	Vista	262		Weather	31
	Telecommunication	21	Education	School	72		Sunrise	23
	Post Office	17		Education	66		clouds	15
	Courthouse	15		Library	9		Rainbow	13
	Fire Tower	15		Schoolhouse	8		Winter	9
	Water Tower	13		Arboretum	4		Moon	5
	(Storm)water management	9		Plaque	1		Spring	4
	Town Hall	9	The Arts	Art	37			
	Utilities	6		Architecture	27			
	Prison	4		Museum	18			
	Police	3		Theater	15			
	Springhouse	3		Statue	11			
	Senior Living	2		Arts	2			
	Turnpike Commission	1	Military	Military	38			
	plaque	1		Memorial	10			

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