# VISUAL QUALITY ASSESSMENT AT LOWER MUSKEGON WATERSHED

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## ABSTRACT

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Planners, designers, governmental agencies, and citizens are interested in evaluating environmental quality. However, environmental quality is often quite intangible and difficult to be described quantitatively. Nevertheless, the hypothesis for this research is that: one can predict landscape aesthetic qualities of the Lower Muskegon Watershed by producing a statistically validated landscape visual quality map, meaning that a generated predictive map of visual quality is highly concordant with real images in the watershed. To construct the predictive map, photos were taken in the study area, their visual quality was measured with an equation developed by Burley (1997), then matched to land-uses on the map, and thus the land-uses had a visual quality score across the study area. With another set of photographs from the study area, the scores of the photographs were compared with the predictions of the map, employing Kendall's Coefficient of Concordance. The results suggest that the predictions (land-use map based scores) and the real photographs are in concordance and significant to a high (95%) confidence level, which supports the hypothesis.



Key Words: Environmental Psychology, Landscape Architecture, Geography, Landscape Planning

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## 1. Introduction

For generations, people have been in pursuit of two conflicting goals. On the one hand, people seek to make our life physically easier, consequently with the results include rapid industrial development, high energy demands, and increased traffic. On the other hand, they have growing concerns about degeneration of natural environment, including water, air, lands, living species, and urban sprawl. Like water, land, and air pollution, visual pollution in the environment is also a concern. A series of legislative acts were initiated to protect natural aesthetic resources, for example, The National Environmental Policy Act, The Scenic Rivers Act, The Wilderness Act, and Road Beautification Act (Tang, 2007; Zube et al., 1982).

The problem with assessing landscape aesthetics and environmental quality is that landscape is often quite intangible and it is difficult to be described quantitatively. However, investigators have explored approaches to evaluate the value of landscape aesthetics by numerous mathematical methods. Legislative Acts have stimulated the evolution of manuals and experiments for assessing and managing landscape resource and scenic quality (Zube et al., 1982). Many governmental institutes and organizations have produced manuals and guidelines to assess and manage landscape resource, for example, Visual Management System (VMS) from US Forest Service (USFS, 1973), Visual Resource Management (VRM) from Bureau of Land Management (BLM, 1980), and Landscape Resource Management (LRM) from US Soil Conservation Service (Yu, 1988a). Environmental planners and designers are also greatly interested in developing methods and procedures to evaluate and predict the visual and ecological quality on wild and scenic rivers, scenic highways, scenic, and recreational parks, trials, and wetlands (Burley, 1997).

Visual quality assessment is one approach for landscape professionals to analyze existing conditions and proposed treatments. The approach often requires the use of photographic images to assess the visual quality of the landscape. Photographs have been tested in many studies, and investigators have demonstrated that photographs could be used as substitutes for site visits, as there is no perceived variance between photos and real landscape (Boster, 1974; Zube, 1974). Besides landscape planners and professional resource managers, a significant number of individuals, including ecologists, geographers, environmental experts and psychologists are engaging in landscape perception and assessment research, and all of them have introduced different sets of methods and models from their disciplines (Burley, 1997; Yu, 1988b; Zube et al., 1982). Today, four popular paradigms are universally recognized: the expert paradigm, the psychophysical paradigm, the cognitive paradigm and the experimental paradigm (Kaplan and Kaplan, 1989; Kaplan et al., 1989; Yu, 1988; Zube et al., 1982). Landscape perception and assessment is often considered as a function of the interaction of humans and the landscape (Zube et al., 1982; Zube, 1975). Besides those four paradigms, there is an increasing trend that more and more people engage in mapping visual quality because of the growth of spatial model and remote sensing. This project focuses on the connection concerning visual quality and mapping.

## 2. Literature Review

Both public and experts show intense enthusiasm for landscape values, but no general standardization of landscape values exists (Taylor et al., 1987). Many people tended to utilize their own discipline to develop tools and methods to measure landscape aesthetics and ecological values while ignoring existing data and methods from others (Burley, 1997; Brown, 1991; Vining and Steven, 1986; Zube et al., 1982; Latimer et al., 1981; Malm et al., 1981;). Meanwhile there is little agreement on how to evaluate landscape (Zube et al., 1975). After discussion and exploration on the topic of landscape assessment for several decades, four paradigms were identified on the basis of theoretical models and respondent participation: expert, psychophysical, cognitive, and experiential (Kaplan and Kaplan, 1989; Kaplan et al., 1989; Zube et al., 1982; Yu, 1988b; Taylor et al., 1987; Daniel and Vining, 1983; Porteous, 1982). In the expert paradigm, assessments are done by highly skilled experts, such as landscape planners and designers, forestry managers and ecologists. In the psychophysical paradigm, assessing models derive from landscape stimulus features by public respondents. In the cognitive paradigm, the core issue is to understand meanings of landscape by terms, such as legibility, coherence, mystery, complexity, and smoothness (Taylor et al., 1987). And the experimental paradigm emphasizes human-landscape interaction (Yu, 1988b; Taylor et al., 1987).

### 2.1. The Expert Paradigm

Expert assessment of landscape quality is divided by two general traditions: fine art tradition and ecological tradition (Taylor et al., 1987; Daniel and Vining, 1983). Laurie (1975) and Carlson

(1977) indicated that experts who are through their professional training are far superior judges of landscape quality than general public. In the expert paradigm, four elements; form, line color and texture are often described as dominance elements to assess scenic quality. In addition, expert paradigm often takes ecological principle into account to assess landscape quality. For example, Smardon's experiment (1975) on inland wetland and Leopold's experiment (1969) on evaluating river corridor aesthetics demonstrated the importance of ecological tradition.

The expert approach has generally dominated the professional practice, including land use planning, forest management, and correlative legislation, and has been accepted by governmental institutes and organizations (Zube et al., 1982; Taylor et al., 1987). Manuals and guidelines to assess and manage landscape resource, have been developed by the organizations, for example, Visual Management System (VMS) of The U.S. Forest Service (USFS, 1973), Visual Resource Management (VRM) of Bureau of Land Management (BLM, 1980), Visual Impact Assessment (VIA) of Federal Highway Administration, and Landscape Resource Management (LRM) of The U.S. Soil Conservation Service (Yu, 1988b). Management agencies explore expert ways of rating landscapes for resource management, but their purposes vary. For instance, VMS of The U.S. Forest Service and VRM of Bureau of Land Management target on natural landscape, and aim to establish rational measurements by assessing the natural resources, including forest, mountain, and water (USFS, 1973; BLM, 1980); LRM of The U.S. Soil Conservation Service targets on country landscape; and VIA of Federal Highway Administration aims to assess influence of human activities, such as construction and traffic, on landscape.

Leopold (1969), a pioneer of the expert paradigm, utilized ecological and human use factors to assess riverscape aesthetics. His procedure used a rating system for scenic beautification while considering specific physical and ecological criteria. His model hypothesized an intense positive correlation between “landscape interest” and “degree of naturalness” (Taylor et al., 1987), which indicated that human use would lower the scenic rating scores. Linton (1968) and Fines (1968) tried to assess landscape aesthetics by categorizing landscape types and land forms, and then generated general scenic rating criteria. Both of the two sets of their criteria reflect a preference for wild and rural landscape. The U.S. Forest Service developed three basic sets of criteria: dominance elements, dominance principles, and variable factors to evaluate landscape quality (Taylor et al., 1987). Dominance elements consist of form, line, color, and texture, which are basic components of landscape perception; dominance principles include contrast, sequence, axis, convergence, codominance, and enframernent; and variable factors include atmospheric, light, atmospheric conditions, seasons, distance, observer position, scale, and time (USFS, 1973). As might be implied by the above examples, the expert paradigm is a serial categorizing and rating process while the criteria are based on both fine art tradition and ecological tradition. The advantage of expert paradigm is that this approach needs simple photos or site ratings and involves only a few trained persons. However, the weakness is that landscape quality assessments are only done by skilled experts, there might be some gaps between public and expert preferences. The expert paradigm is a milestone in landscape assessment and a stimulus for the development of alternative approaches, such as psychophysical paradigm.

### 2.2. The Psychophysical Paradigm

Different from the expert paradigm, landscape assessment in the psychophysical paradigm depends upon experiments with respondents rather than relying upon the opinion of experts. The primary idea of psychophysical paradigm is to understand landscape as stimuli to respondents (Taylor et al., 1987). Since it is implied that the landscape serves general public, it is believed that the psychophysical paradigm is an efficient and direct way to test public preferences on appealing landscape. The psychophysical paradigm utilizes stimulus-response assumption, which is derived from psychology, to test response on landscape aesthetics, and then to generate public perception on landscape quality (Taylor et al., 1987). The method is to transform individual respondent's ratings to standard scores to a predictive general equation.

The modern psychophysical paradigm originated from Elwood Shafer's landscape preference model (Lee and Burley, 2008; Burley, 1997; Carlson, 1977; Shafer and Tooby, 1973; Shafer et al., 1969). Shafer attempted to understand "why is one landscape preferred more than another" by series of experiments (Shafer et al., 1969). Shafer's work involved placing a grid to measure variables and having respondents rate photographs. He built predictive models concerning landscape preference (Taylor et al., 1987). His model (Shafer and Tooby, 1973) presented quantitative variables derived from photographs of landscape which were significantly related to public preference. In this case "assessment" means measuring people's perceptions of natural environments. Shafer's model could be considered as a "physical attributes" predictive model because the variables in his model are all physical elements such as vegetation, sky, water. However, Shafer's model was questioned by some later studies (Bourassa, 1991; Carlson, 1977; Weinstein, 1976), because equation based assessment on visual quality is lacking formal theory to explain interaction between variables measured in the photos and the preferences of respondents (Burley, 1997). For example, Carlson criticized Shafer's method and assumption on his research of quantifying scenic beauty; and he suggested certain alternatives to Shafer's assumption, which involved expert opinions and non-formalist approaches (Carlson, 1977).

Daniel and Boster (1976) developed "Scenic Beauty Estimation" (SBE) method, which involved a standardized testing procedure. In this procedure, forest quality and quantity is measured, for example, downed wood, tree diameter, deadwood, and low-level vegetation. They chose the term "scenic beauty" rather than "natural beauty", because "natural" would exclude many components, and "beauty" could be more than visual (Daniel and Boster, 1976). SBE method asked respondents to score landscape photographs on a 1 to 10 scale according to their own criteria, while the photographs taken in random directions in the forest are presented in a random sequence to avoid partial sampling procedure (Daniel and Boster, 1976). Then statistical techniques were employed to test and analyze the reliability and validity of SBE data. SBE showed promise as an efficient and objective way for assessing scenic beauty, and for predicting the aesthetic consequences of alternative land uses. In addition, Daniel had explored mapping the "scenic beauty" for road systems and road settings (Daniel and Boster, 1976; Daniel, 1977), based on those SBE scores.

Besides SBE, Law of Comparative Judgment (LCJ) is another technique to utilize psychophysical theory to evaluate landscape preference (Buhyoff et al.,1982). In LCJ experiment, respondents are required to compare a set of photographs to generate tables of landscape measures. Buhyoff and his colleagues set up multiple regression models to assess vista landscape, while dependent variable is public preference and independent variables include forest area, mountain area, and flat ground area. Although most researchers focused on studying natural forest landscape, Buhyoff and his colleagues assessed quality of urban green space as well (Buhyoff et al., 1984). Buhyoff and his colleagues established a mathematical model from two aspects: like Daniel's work, they assessed landscape elements during site visits and established relational models based on public preferences; secondly, they directly measured dominance components on photographs, for example, vegetation area in the photos, and then established correlation between these components and public estheticism (Buhyoff et al., 1981). Buhyoff's study on urban green space showed that less large tress are more preferred as high scenic quality than more small tress. Experiment has proved that group consensus values derived from the Law of Comparative Judgment psychophysical scaling procedure is excellent, and provided evidence of robustness of LCJ procedure (Buhyoff et al., 1984). However, both the SBE and LCJ methods could be fairly time consuming in the judgments collection and data processing, and heavily rely on high speed computers (Buhyoff et al., 1984).

After early pioneering experiments on psychophysical paradigms, photographs had been tested in many studies and proved to be appropriate substitutes for site visits, as there is no perceived variance between photos and real landscape (Boster, 1974; Zube, 1974). Nevertheless, drawings of landscape should not be used in preference surveys (Smardon et al., 1986; Boster, 1974; Zube, 1974). Although Shafer's model is questioned by many researchers, people from different disciplines attempt to develop their own predictive preference equations based on Shafer's model to assess scenic quality (Burley, 1997; Brown, 1991; Vining and Steven, 1986; Latimer et al., 1981; Malm et al., 1981;). Even today, the expert paradigm is still in an exploration phase, as no expert could promise his or her method is the "canon".

For transportation planning and design, Jon Burley developed a visual and ecological environmental quality model that explains 67 percent of respondent preference to predict human preference (Burley, 1997). Besides physical variables in grid measuring, he added an "environmental quality index" in his equation. This equation has also been employed frequently in surface mine reclamation assessment and landscape evaluation (Lu, et al., 2010; Lee and Burley, 2008; Burley, 2006; Burley 1997). For example, Lee and Burley (2008) employed this equation to measure two sets of photographs which were from 1980 and 2005 to compare landscape changes after 25 years of reclamation in Plymouth, Minnesota. Burley's model was initially developed as a universal model across North America and illustrated its use for transportation planning and design. According to those experimental results, his method is applicable in many areas of natural landscape, from scenic road designs to post-mining areas. In addition, Noffke and Burley (2004) used GIS based land-use data to substitute for photographs to assess visual quality in Grand Traverse County, Michigan. This experiment suggests the application of a remote, off-site method to measure landscape visual quality.

### 2.3. The Cognitive Paradigm

Although their criteria are different, both expert paradigm and psychophysical paradigm assess physical components of landscape to evaluate scenic quality. However, investigators were unsatisfied with only using “Physical Attributes” models. Thus, they began exploring other relative domains, for example, the cognitive paradigm.

Human-landscape interaction is emphasized in the cognitive paradigm. The core idea is that humans are selecting landscapes that have value to them. The cognitive paradigm tends to search for meanings and cognizance associated with people’s preference on scenic beautification (Taylor et al., 1987). Instead of using physical landscape attributes or variables, cognitive paradigm emphasizes landscape cognitive variables, such as legibility, coherence, mystery, complexity, smoothness, density, and degree of naturalness, in predicting visual quality (Terry, 1994; Kaplan and Kaplan, 1989; Kaplan, 1987). Stephen Kaplan, Rachel Kaplan and Appleton stressed the important role that human evolution played in the experience of landscape (S. Kaplan, 1979; R. Kaplan, 1979; Appletion, 1975). Stephen Kaplan considered that in order to survive or live more safely and more comfortably, individuals should understand living spaces and exterior spaces; individuals should also keep on acquiring, judging and predicting information (S. Kaplan, 1987). Thus, in the landscape aesthetics assessment process, two terms are identified: one is “making sense”, which focuses on suitable orientation of landscape; the other is “involvement”, which focuses on challenge and stimulation (S. Kaplan, 1979). “Making sense” could be immediately understood as “coherence”; and also be inferred as “legibility” (Kaplan et al., 1989). “Involvement” immediately related to complexity (richness, intricate, numbers of different elements, and inferential related to mystery (promise of new but related information) (Kaplan et al., 1989). Mystery, which is a key element in cognitive model, emphasizes an exploring process of the observers and points to the endless opportunity to see new things, for example, the next hill or brooks behind the trees.

Several researchers in the cognitive paradigm showed great interest in cross-cultural experiments for landscape perception. Zube and his colleagues (1973; 1976) did several cross-cultural experiments, and found that in some of their experiments there were significant differences between River Valley residents and college students; and in some of their experiments there were high correlation of landscape preference, for example, between residents of Australia and college students. By assessing photographs of lake landscapes within cross-cultural groups, Yu (1987) summarized that the expert group has intuition in evaluating basic landscape elements associated with ecological features, while the public group is mostly influenced by beauty in forms.

Some researchers have been involved in studies of the relationship between personality and landscape perception. By series of experiments, Craik (1975) identified fourteen personality types which might influence landscape perception. Little (1975) emphasized both "thing" and "person" as personality dimensions.

In addition, unlike so many methodological experiments in the expert paradigm and in the psychophysical paradigm, many cognitive researches utilized survey questions or adjective checklist as techniques for studying (Taylor et al., 1987). For example, in Craik's (1975) study on San Francisco Bay Area, the respondents checked many terms describing landscape, such as active, dark, and bushy. A landscape preference was created based on the checklist.

In the later studies, in order to avoid disadvantages of language expression of psychological tests, Ulrich (1981) and his colleagues began to use more standard scientific test techniques, for example, electroencephalograph (EEG) and electrocardiograph (EKG), to measure emotional reactions objectively. Ulrich considered that the influence of natural scenes was not only as aesthetic objects, but also directly affected human's other physiological and psychological reactions. His experiments proved that natural landscape scenes would significantly accelerate patents' recovery rate and positively influence them; but urban scenes would result in sadness for patents (Ulrich, 1979; Ulrich, 1981).

We could see that the cognitive paradigm was gradually developed by Appleton, Kaplans, Craik, Ulrich and other scholars to form a theoretical system, including evolution, aesthetic concept, and emotional theory to integrally understand landscape. The problem with the approach is that cognitive constructions are difficult to establish. For example, how could one measure coherence? It is a difficult construct to establish.

### 2.4. The Experiential Paradigm

In contrast with the expert paradigm, the psychophysical paradigm and the cognitive paradigm that have already confirmed the subjective effect human-beings caused in the assessment of landscape aesthetics. Moreover, the experiential paradigm addresses behavior effects: considering human's landscape evaluation as expression of individual's personality, education, background, and interest (Yu, 1987). In the experiential paradigm, human-beings are not only considered as observers but also participants of landscape (Taylor et al., 1987). As active participants, humans view the landscape as a kind of experience. The landscape would gain meaning when it is experienced.

At the same time, the experiential paradigm also employed psychological measurement, investigation and survey to record human's perception and evaluation on the landscape, but it differed from the psychophysical paradigm. In the psychophysical paradigm, individuals are often only required to rate the landscapes or compare them; while in the experiential paradigm, besides rating process, individuals are also required to describe their own experiences, perceptions, feelings on particular landscapes in detail. The purpose is to analyze background and circumstance behind particular landscape values (Yu, 1987).

The experiential paradigm is not considered as a method to assess landscape, as it does not study the quality of landscape; thus, the experiential paradigm rarely directly offers effective information to landscape planning and management. As a result, the experiential paradigm is powerless when compared with the other paradigms.

### 2.5. Comparison of the Four Paradigms

Some studies summarized and compared these different domains or paradigms of landscape perception. In 1989, Kaplan et al. (1989) reported that they examined and compared four domains: Physical Attributes, Land Cover Types, Informational Variables, and Perception-based Variables to assess their relative benefit and deficiency in explaining environmental preference. Their results suggested the importance of utilizing different predictor domains, rather than relying on any single one, since their merits vary according to different study backgrounds. Some researchers also analyzed and summarized four popular paradigms: the expert paradigm, the psychophysical paradigm, the cognitive paradigm and the experimental paradigm to offer help in choosing appropriate methods (Tang, 2007; Yu, 1988b; Taylor et al., 1987; Zube et al., 1982). Each paradigm has its own strength and weakness, and might be suitable for different situations: the expert paradigm describes landscape from the professional perspectives and could be applied in planning, design and management decision; the psychophysical paradigm is rated mainly on physical variables and associated with public participation; the cognitive paradigm emphasizes understanding meanings of landscape (legibility, coherence, mystery, complexity, smoothness and so on); and the experiential paradigm emphasizes human-landscape interaction (Taylor, et al., 1987; Yu, 1988b). In short, the expert paradigm and the psychophysical paradigm focus on landscape management practice (Terry, 2001; Yu, 1988b); while the cognitive and the experiential seek to understand the importance of valued landscape to people. Those paradigms have paralleled a long-standing debate in the philosophy of aesthetics (Terry, 2001; Yu, 1988b).

In general, each of the above four paradigms takes a unique approach and target on landscape assessment. Nevertheless, if the landscape aesthetics process, as a system, is considered, it is apparent that all different approaches are complemented rather than incompatible. For example, the expert paradigm ignores the subjective function while the experiential paradigm emphasizes human-beings.

### 2.6. Mapping Visual Quality

Because of the development of spatial modeling techniques, landscape visual quality assessment has begun to work on a broader dimension: (1) integrating spatial models with assessment, and (2) associating with ecological quality assessment. As Terry (2001) mentioned, technological development such as remote sensing, three-dimensional geographic information system (GIS), and advanced environmental modeling have improved the ability to measure ecologically relevant landscape features, which has the potential to meet the urgent need of shifting toward more comprehensive ecosystem management. Consequently, traditional visual quality assessment, including expert and perception-based approaches, would be challenged by both technological improvement and the emergence of landscape ecology.

Many studies have offered well-grounded evidence to support the validity of using computer-based spatial modeling to assess landscape visual quality (Germino et al., 2001; Dramstad et al., 2006; Bishop and Hulse, 1994; Crawford, 1994; Aamir and Gidalizon, 1990).

In early time, Brush (1979) and his colleague measured land use change in the Northwest to illustrate the impact of urbanization on scenic quality. Aamir and Gidalizon (1990) used the expert paradigm for quantitative evaluation of landscape visual absorption capacity (VAC), and then used these data to output computer-printed maps in several regions with various geographical characteristics in Israel. This method was found to be easy and effective to apply. Bishop is a pioneer with integrating the use of GIS with the traditional method (prediction equation) to assess landscape visual quality. The results of Bishop and Hulse's (1994) experiment on Oregon suggested that there existed considerable potential for use of GIS combing with a predictor equation to map visual quality and that the mapped value at all locations would match an assessment made by experts. Crawford (1994) used remote sensing to assess landscape visual quality and replicated an experiment in Cook's river, where the traditional method was used and combined with extensive fieldwork to assess visual quality. The result of this study demonstrated the feasibility of using remotely sensed data in the assessment of landscape visual quality and showed the considerable savings in time and work. Dramstad (2006) tested map-derived indicators of landscape structure in agricultural land with visual landscape preferences and found significant positive correlations between preferences and spatial metrics. En-Mi Lim and his colleagues (2006) tested three-dimensional computer graphic made with virtual reality modeling language (VRML) as a stimulus for landscape assessment. The results indicated that VRML images could be used as an effective stimulus for landscape assessment both on the Internet and in the laboratory.

Some studies have proved that GIS based assessment for visual quality would serve well even at a large extent, such as scenic region or highway (Qin, 2008; Steinitz, 1990). Germino (2001) used GIS to estimate viewshed properties at larger extents and extend depth and naturalness to assess the value of scenery at Rocky Mountain because small scale approaches of this type are impractical. Qin (2008) used GIS to measure the scenic quality of the highway landscape and attempted to explain how landscape features relate to visual perception of drivers. This study illustrates the advantage of using GIS to measure visual quality at a broad and linear area.

In addition, using spatial models to assess landscape visual and ecological quality also closely relates to tourism management. Steinitz (1990) used a regression model based on site photographs and GIS to map visual preference and, meanwhile, incorporated ecological values in planning for sustainable landscapes in Acadia National Park. This research established levels of sensitivity to landscape management of Acadia National Park because of the impact of the growing number of visitors (Steinitz, 1990). A GIS based methodology was developed by Kilskey (2000) for mapping recreation terrain suitability using recreation terrain suitability indices (RTSI) in the North Columbia Mountains of British Columbia. The mapping process includes four steps: identifying suitability variables, developing spatial criteria, weighting factors and overlaying analysis. The RTSI mapping offered a spatial approach to resource use and recreation management. Freeman and Buck (2003) developed an ecological mapping methodology in the Dunedin city, New Zealand. In their experiment, the map is the first attempt to record all natural land uses, and then GIS was used to map the urban habitats and store the habitat data (Freeman and Buck, 2003). Combined mapping at a detailed level and at a broad level was chosen as a final version to output ecological maps. Ayad (2005) integrated remote sensing with GIS to assess visual changes in a developing coastal area of Egypt and succeeded in detecting several changes in the attributes, and mapping the magnitude of those changes. Yasser also suggested that the tourism resource in Egypt might be undermined if there is no consideration of scenic value assessment in tourism management (Ayad, 2005). Mouflis and his colleagues (2008) assessed the ecological, landscape and visual impacts of marble quarries on the island of Thasos, Greece by mapping quarries and landscape changes. In this experiment, remote sensing, landscape metrics and viewshed analysis were employed to monitor the landscape dynamics (1984-2000) of marble quarries (Mouflis et al., 2008). The results indicated that the visual impact of the quarries degraded the aesthetic impression of Thasos as a touristic island.

Some researchers are extremely interested in assessing and mapping agricultural landscape. Nassauer and Corry (2004) developed normative scenarios to anticipate and affect agricultural landscape changes in Iowa. In their experiment, three distinct scenarios were proposed with different emphases, including value of agricultural production, value of water quality and value of biodiversity. They indicated their scenarios as a tangible goal for future landscape predictions.

Picuno and his colleagues (2011) employed GIS software and three-dimensional land modeling with solid extrusion and an overlap of the photographic images to examine the variation in the visual perception of agricultural land in southern Italy. The results of these stimulations could be used for detection and positioning of green house distribution and helpful in management of the agricultural landscape. To map traditional cultural landscape in the Mediterranean area, Cullotta and Barbera (2011) used three different scales of analysis to examine how to select appropriate data-sets of interest. At the most detailed level, traditional cultural landscapes were identified through an overlaying procedure and a detailed regional land-use map of both agricultural and forestry practices in the Mt. Etna area. The highly diversified land-use patterns in Mediterranean cultural landscapes advocated conducting further technical and scientific research while avoiding subjective elements in the mapping process.

Based upon the literature above, many researchers have explored varied approaches to measure visual quality and make landscape visual quality maps of particular areas. However, there are few experiments to validate those visual quality maps. This research attempts to make a landscape visual quality map of "Lower Muskegon Watershed", which can be also statistically validated.

## 3. Method

### 3.1. Research Progress Diagram

Figure 1 illustrates the research procedure used in this study.

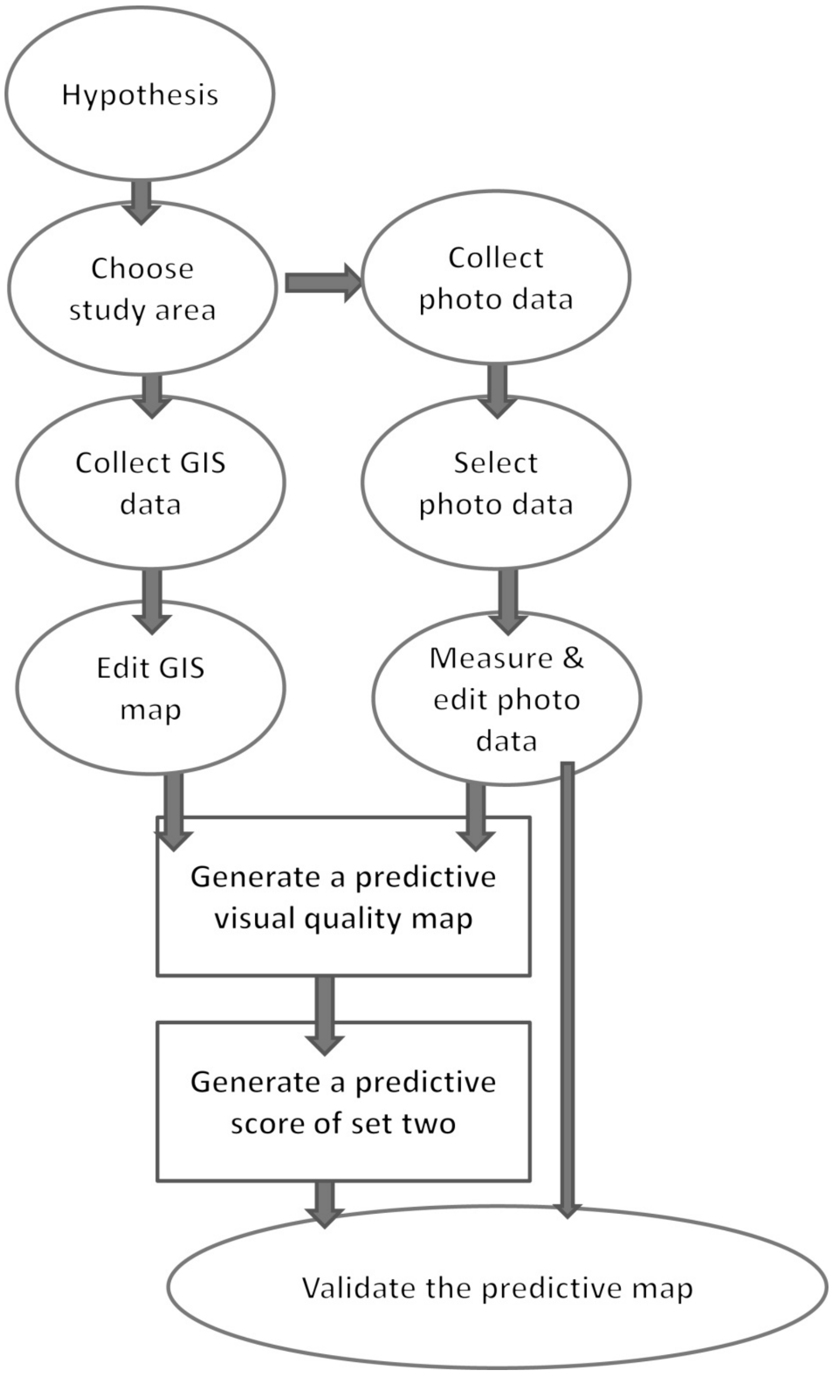


**Figure 1: Research progress diagram**

To assist planners and managers to assess landscape resources at Lower Muskegon Watershed, this research hypothesizes: one can predict landscape aesthetic qualities of the Lower Muskegon Watershed by producing a statistically validated landscape visual quality map, meaning that a generated predictive map of visual quality is highly concordant with real images in the watershed.(This research defines scores generated from Burley's Equation 1 as real scores and scores generated from the predictive map as predictive scores.)

### 3.2. Study Area

Michigan is located in the Great Lakes Region of the United States of America, with plentiful inland lakes and river resources. Currently, a large portion of population lives in the southern part of the Lower Peninsula but the Upper Peninsula is also important for tourism and natural resources.

A watershed, or a drainage basin, is the area of land where surface water from rain, melting snow and underground water drains into the same place. John Wesley Powell, scientist geographer, defines watershed as "that area of land, a bounded hydrological system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community" (Worster, 2009).

Muskegon River Watershed is one of the largest watersheds in the State of Michigan and spans across nine counties: Wexford, Missaukee, Roscommon, Osceola, Clare, Mecosta, Montcalm, Newaygo and Muskegon. There are several reasons that the Lower Muskegon Watershed was chosen as the study area: (1) it is composed of several land cover types to study; (2) updated information is readily available; and (3) it is nearby and fit within the study area of Burley's Equation 1 (1997). Since the late 1800s, Muskegon River Watershed drainage and riparian vegetation were decimated by logging, constructing of dams, and forest fires (O'Neal, 1997). During the 1900s, the expansion of urban and agricultural land use, accompanying with nutrient, sediment, and chemical pollution have significant negative effects on the biological community (O'Neal, 1997). Presently, people begin to consider limiting human influence on crucial habitats and repairing the ruined environmental condition.

In this study, the Lower Muskegon Watershed (Figure 2) includes six counties: Muskegon County, Lake County, Mecosta County, Montcalm County, Newaygo County, and Osceola County. To examine our hypothesis, two crucial questions are additionally asked:

(1) What kinds of landscape are more preferred according to "Burley's Visual Quality Equation" in the Lower Muskegon Watershed?

(2) Are predictions (land-use map based scores) and the real photograph scores in concordance and significant to a high confidence level?

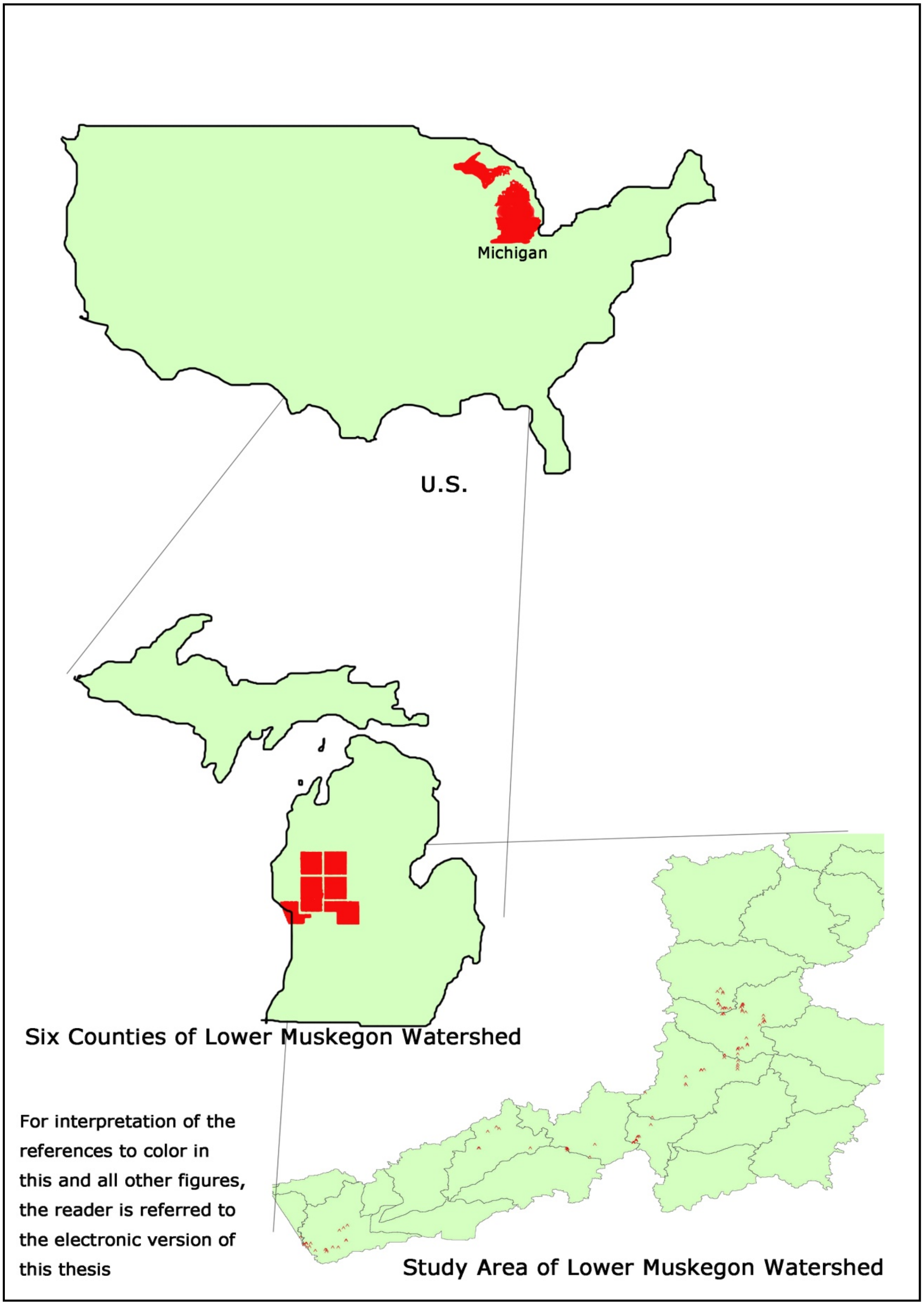


**Figure 2: Geographic location of Lower Muskegon Watershed**

## 3.3. Collecting Data

The photos data in this study were taken by the author from site surveys on Lower Muskegon Watershed in May and August of 2010. In May and August 2010, 131 photographs from Lower Muskegon Watershed were recorded, and each of them was positioned and tagged on the map of Lower Muskegon Watershed by Global Positioning System (GPS). Although the photo data were acquired in different times of summer, there is almost no recognizable seasonal difference. The objective and principle to collect photographs is trying to obtain different types of landscapes, and across the study area. Typical recorded photos may contain such physical attributes as people, wildlife, water, roads, flowers, vegetation, buildings, facilities and nonvegetated substrate across urban savanna, farmland, forest, and watery areas. Two sets of 30 photos were chosen from the original 131 photos to analyze. In the following study steps, set one would be used to create a predictive landscape visual quality map while set two was employed to compare with predictions and validate the predictive map.

The basic GIS map data in this study were downloaded from a database of Grand Valley State University. The project of "Sustainable Futures for the Muskegon River Watershed" from Grand Valley State University provides all the "Updated 1998 Land Use Data" in Lower Muskegon Watershed of six counties: Muskegon, Lake, Mecosta, Montcalm, Newaygo, and Osceola counties. By merging all the land use data of these counties, a land-use map of Lower Muskegon Watershed was generated (Figure 3).

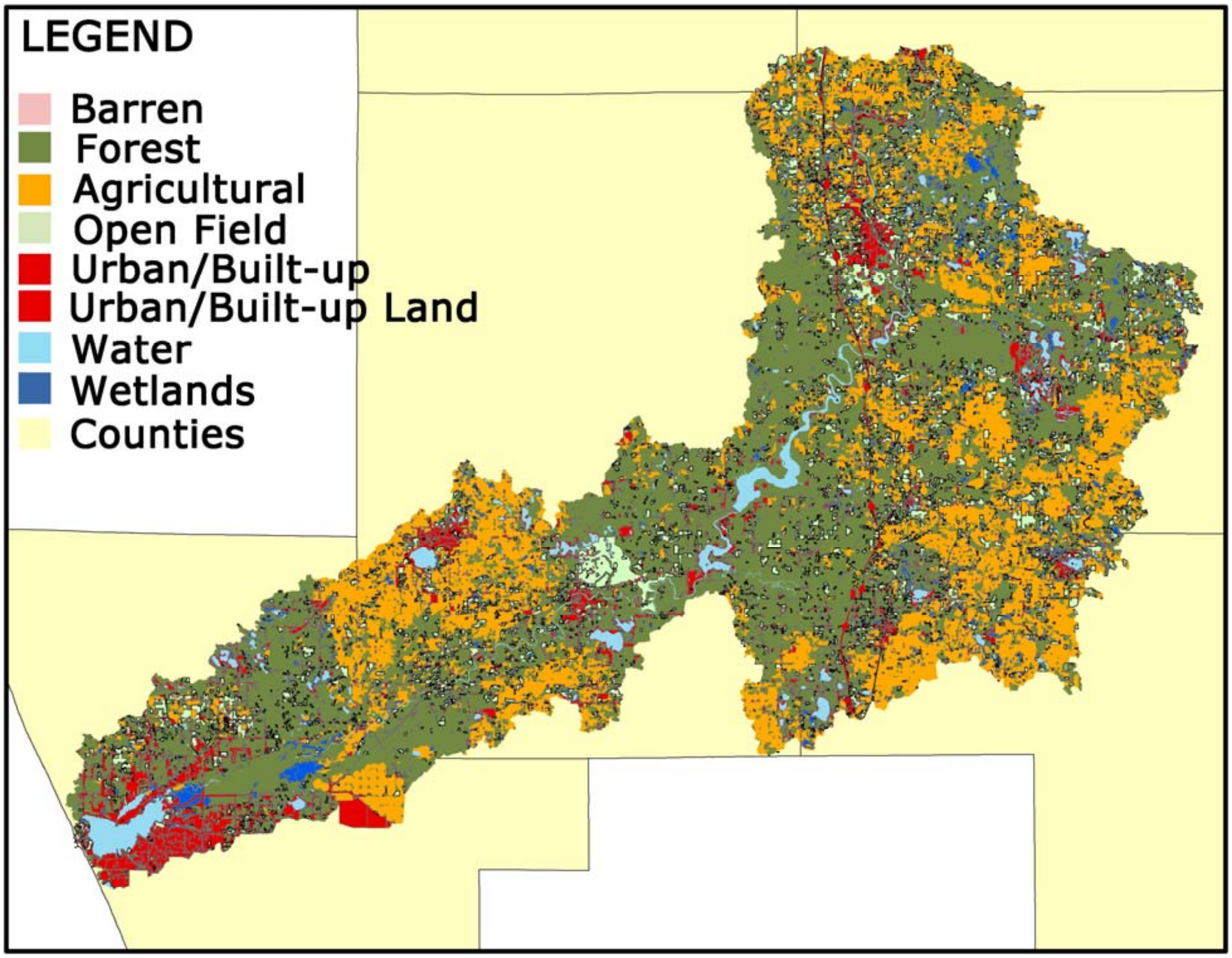


**Figure 3: Land-use map of Lower Muskegon Watershed**

## 3.4. Analysis Techniques

**Table 1: Burley's Equation 1** (Burley, 1997)

| |
|---|
| Y= 68.30 - (1.878*HEALTH) - (0.131*X1) - (0.064*X6) + (0.020*X9) + (0.036*X10) + (0.129*X15) - (0.129*X19) - (0.006*X32) + (0.00003*X34) + (0.032*X52) + (0.0008*X1*X1) + (0.00006*X6*X6) - (0.0003*X15*X15) + (0.0002*X19*X19) - (0.0009*X2*X14) - (0.00003*X52*X52) - (0.0000001*X52*X34) |

**Table 2: Independent variables** (Burley, 1997)

| **Variables** |
|---|
| HEALTH= environmental quality index (Table 3.3) |
| X1= perimeter of immediate vegetation |
| X2= perimeter of intermediate non-vegetation |
| X3= perimeter of distant vegetation |
| X4= area of intermediate vegetation |
| X6= area of distant non-vegetation |
| X7= area of pavement |
| X8= area of building |
| X9= area of vehicle |
| X10= area of humans |
| X13= area of herbaceous foreground material |
| X14= area of wildflowers in foreground |
| X15= area of utilities |
| X16= area of boats |
| X17= area of dead foreground vegetation |
| X19= area of wildlife |
| X30= open landscapes = X2+X4+(2*(X3+X6)) |
| X31= closed landscapes = X2+X4+(2*(X1+X17)) |
| X32= openness = X30-X31 |
| X34= mystery = X30*X1*X7/1140 |
| X52= noosphericness = X7+X8+X9+X15+ X16 |

This study utilized Burley's experimental method (Burley, 1997; Lee and Burley, 2008) to measure photos. Each of the 30 photos from set one and set two was measured according to the Equation 1 by Burley (1997), which is based on physical variables and environmental quality index. The predictive model, where the equation explains 67 percent of respondent preference, contained total area of noospheric features and total area of motorized vehicles; presence of humans, wildlife, utility structures, and foreground flowers; total area of distant nonvegetation landscape features such as mountains and buttes; perimeter of intermediate nonvegetation; total area of foreground vegetation; and openness, mystery, and environmental quality index; with an overall p-value for the equation <0.0001 and a p-value<0.05 for all regressors (Burley, 1997).

**Table 3: Environmental quality index** (Burley, 1997)

| Environmental Quality Index | |
|---|---|
| Variable | Score |
| A. Purifies Air | +1 0 -1 |
| B. Purifies Water | +1 0 -1 |
| C. Builds Soil Resources | +1 0 -1 |
| D. Promotes Human Cultural Diversity | +1 0 -1 |
| E. Preserves Natural Resources | +1 0 -1 |
| F. Limits Use of Fossil Fuels | +1 0 -1 |
| G. Minimizes Radioactive Contamination | +1 0 -1 |
| H. Promotes Biological Diversity | +1 0 -1 |
| I. Provides Food | +1 0 -1 |
| J. Ameliorates Wind | +1 0 -1 |
| K. Prevents Soil Erosion | +1 0 -1 |
| L. Provides Shade | +1 0 -1 |
| M. Presents Pleasant Smells | +1 0 -1 |
| N. Presents Pleasant Sounds | +1 0 -1 |
| O. Does not Contribute to Global Warming | +1 0 -1 |
| P. Contributes to the World Economy | +1 0 -1 |
| Q. Accommodates Recycling | +1 0 -1 |
| R. Accommodates Multiple Use | +1 0 -1 |
| S. Accommodates Low Maintenance | +1 0 -1 |
| T. Visually Pleasing | +1 0 -1 |
| Total Score __________ | |

In Burley's Equation 1 (Table 1, Table 2), there is a set of regressors (regressors are the variables from Table 2) with negative coefficients. This set of regressors positively relate to visual quality (Burley, 1997). They include the presence of immediate vegetation and distant nonvegetation, the presence of wildlife, presence of flowers and openness (X1, X6, X14, X19 and X32 from Table 2). These regressors are perceived as positive enhancement by respondents.

There is also a set of regressors with positive coefficients (Burley, 1997). This set of regressors negatively related to visual quality (Burley, 1997). These regressors include the presence of vehicles, humans, utility structure and overall noospheric features (X9, X10, X15 and X52 from Table 2). This means that the more humans, vehicle, building and artificial structures in a photograph, the worse the visual quality is.

There is a third set of regressors to be considered: neutral variables (Burley, 1997). Typical neutral variables are sky, clouds, sun, moon, water, ice, snow and so on. They affect the presence of both positive and negative variables. The more area these neutral variables occupy in a photograph, the more likely the score is close to a neutral value, which is 70.

To analyze the visual quality scores of set one and set two, statistical analysis for our research is executed in Microsoft EXCEL 2007 for Windows XP. As mentioned above, the real scores of set two were generated according to Burley's Equation 1. And the predicted average scores of set two were generated from the real scores of set one. Then, the real scores of set two and the predicted average scores of set two were ranked from 1 to 30, with the highest score receiving 1 and the lowest score receiving 30.

The two columns of scores were compared using Kendall's Coefficient of Concordance (*W*) (Daniel 1978), to test for similar agreement. Suppose that score *i* is given the rank $r_{i,j}$ by judge number *j*, where there are in total *n* (30) scores and *m* (2) judges. Then the total rank given to score *i* is

$$R_i = \sum_{j=1}^{m} r_{i,j} \tag{1}$$

and the mean value of these total ranks is

$$\bar{R} = \frac{1}{2}m(n+1) \tag{2}$$

The sum of squared deviations, S, is defined as

$$S = \sum_{i=1}^{n}(R_i - \bar{R})^2 \tag{3}$$

and then Kendall's *W* is defined as (Kendall, 1939)

$$W = \frac{12S}{m^2(n^3 - n)} \tag{4}$$

The test statistic *W* is between 0 and 1. If *W* is 0, there is no overall trend of agreement among the respondents. If *W* is 1, the responses might be regarded as essentially random. Intermediate values of *W* suggest a degree of concordance among different responses.

## 4. Results

### 4.1. Mapping Visual Quality

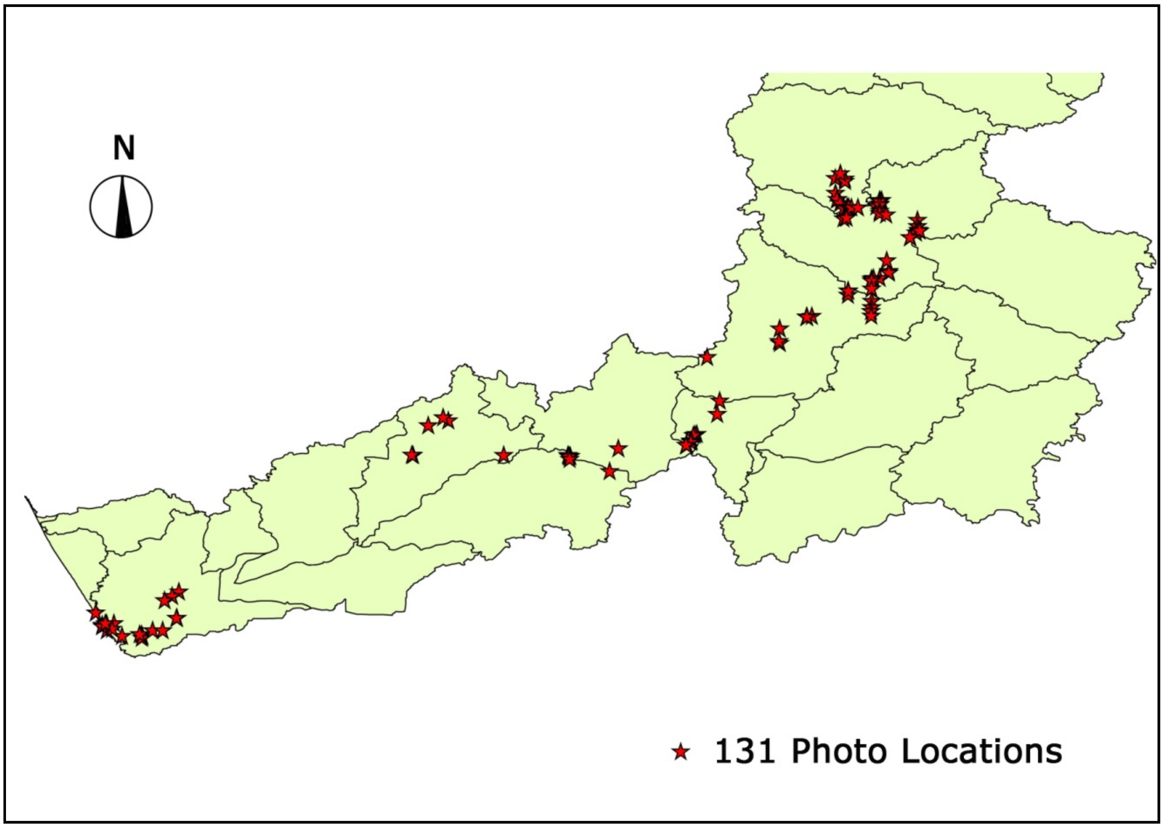


**Figure 4: Locations of 131 photos at Lower Muskegon Watershed**

The methodology generated a series of figures and tables. The collected 131 photographs were marked in the map to illustrate their locations (Figure 4). As shown in Figure 5 and Figure 6, the locations of set one and set two were recorded in this experiment.

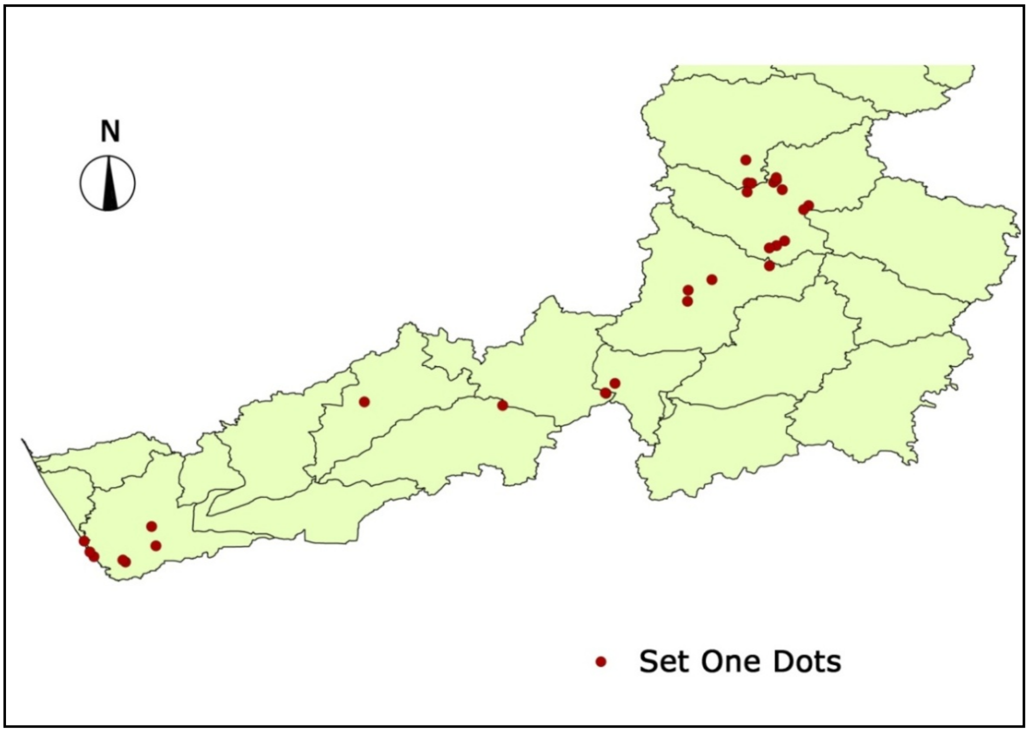


**Figure 5: Locations of set one**

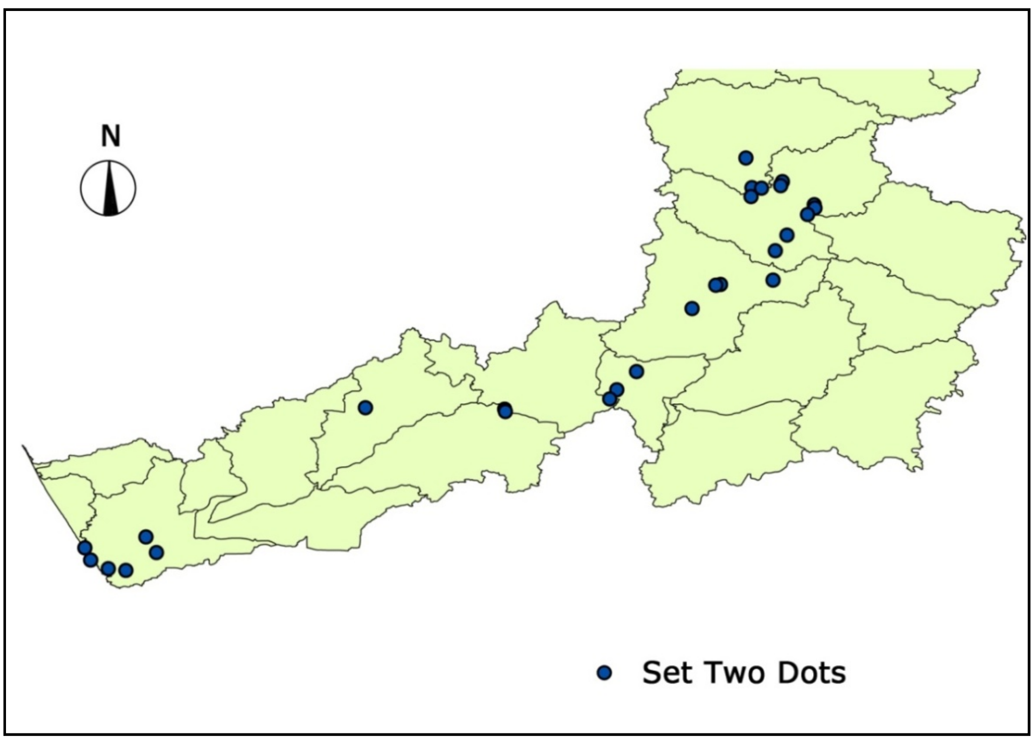


**Figure 6: Locations of set two**

**Table 4: Visual quality score of set one and set two**

| Visual Quality Score | | | | |
|---|---|---|---|---|
| | **Set One** | | **Set Two** | |
| **NO.** | **Land Use Type** | **Score** | **Land Use Type** | **Score** |
| 1 | Urban Savanna | 64.15325 | Urban savanna | 72.91732 |
| 2 | Farmland | 47.2868 | Farmland | 60.12997 |
| 3 | Water | 49.29968 | Water | 54.04903 |
| 4 | Industrial | 83.06227 | Industrial | 93.2968 |
| 5 | Farmland | 45.02445 | Farmland | 43.3638 |
| 6 | Water | 52.4 | Water | 44.4542 |
| 7 | Forest | 52.4952 | Forest | 52.3262 |
| 8 | Farmland | 64.63812 | Farmland | 51.06412 |
| 9 | Water | 52.89468 | Water | 42.1124 |
| 10 | Farmland | 51.5882 | Farmland | 51.93535 |
| 11 | Downtown | 78.67512 | Downtown | 80.84248 |
| 12 | Farmland | 53.00983 | Farmland | 48.79608 |
| 13 | Forest | 59.414 | Forest | 56.192 |
| 14 | Forest | 54.4982 | Farmland | 55.29468 |
| 15 | Farmland | 62.12048 | Forest | 48.2258 |
| 16 | Water (Pier) | 57.97836 | Water (Urban Savanna) | 72.98182 |
| 17 | Farmland | 42.2612 | Farmland | 59.01933 |
| 18 | Forest (Road) | 65.97347 | Forest (Road) | 54.71145 |
| 19 | Water | 49.628 | Water | 50.506 |
| 20 | Water (Bridge) | 54.47212 | Water (Dam) | 61.07647 |
| 21 | Industrial | 107.2581 | Industrial | 107.805 |
| 22 | Downtown | 80.44573 | Downtown | 81.84413 |
| 23 | Farmland | 63.35648 | Farmland | 41.91216 |
| 24 | Urban savanna | 64.24578 | Urban savanna | 67.92477 |
| 25 | Water | 48.944 | Water | 46.87449 |
| 26 | Urban savanna | 68.00453 | Urban savanna | 73.11433 |
| 27 | Water | 49.55917 | Water | 48.7268 |
| 28 | Downtown | 72.85386 | Downtown | 83.52013 |
| 29 | Water | 55.013 | Water | 48.1872 |
| 30 | Forest | 58.262 | Water, Road and Forest | 68.89192 |

Table 4 lists the visual quality scores for two sets of 30 images based on Burley's Equation 1.

The 30 photos from set one were divided into 6 groups: downtown, industry, urban savanna, farmland, water and forest by their attributes (land use) and then each group derived a mean score by calculating the average (Table 5).

**Table 5: Visual quality mean scores of set one by land use**

| **Visual Quality Mean Scores of Set One by Land Use** | | | | | | |
|---|---|---|---|---|---|---|
| **Attribute** | **Downtown** | **Industry** | **Urban Savanna** | **Farmland** | **Water** | **Forest** |
| | 78.67512 | 83.06227 | 64.15325 | 47.2868 | 47.2868 | 52.4952 |
| | 80.44573 | 107.2581 | 64.24578 | 45.02445 | 52.4 | 59.414 |
| | 72.85386 | | 68.00453 | 64.63812 | 52.89468 | 54.4982 |
| | | | | 51.5882 | 57.97836 | 65.97347 |
| | | | | 53.00983 | 65.97347 | 55.013 |
| | | | | 62.12048 | 54.47212 | |
| | | | | 42.2612 | 48.944 | |
| | | | | 63.35648 | 49.55917 | |
| | | | | | 55.013 | |
| | | | | | | |
| Average | 77.3249 | 95.16019 | 65.46785 | 53.6607 | 53.83573 | 57.47877 |

From Table 5, it was found that farmland and water are the two most preferred landscapes in Lower Muskegon Watershed. As shown in Table 5, the mean score of farmland landscape is 53.6607 and the mean score of water landscape is 53.83573, both of them are positively preferred landscapes. Figure 7 illustrates a typical farmland landscape with few artificial utilities with the score of 53.00983. Figure 8 illustrates a typical water landscape with score of 49.628.

**Figure 7: A typical image of farmland**
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**Figure 8: A typical image of water**
**— Copyright © 2010, Di Lu**

Forest landscape, with the mean score of 57.47877, and urban savanna landscape, with the mean score of 65.46785, are positively preferred landscapes as well, but not as good as farmland and water. Figure 9 illustrates a typical forest landscape, with score of 52.4952, while Figure 10 illustrates a typical urban savanna landscape, with score of 64.15325.

**Figure 9: A typical image of forest**
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**Figure 10: A typical image of urban savanna**
**— Copyright © 2010, Di Lu**

There are also negatively preferred landscapes, such as industry landscape, with the mean score of 95.16019, and downtown landscape, with the mean score of 77.3249. Figure 11 illustrates a typical downtown landscape, with score of 80.44573, while Figure 12 illustrates a typical industry landscape, with score of 107.2581.

**Figure 11: A typical image of downtown**
— **Copyright © 2010, Di Lu**

**Figure 12: A typical image of industry**
— **Copyright © 2010, Di Lu**

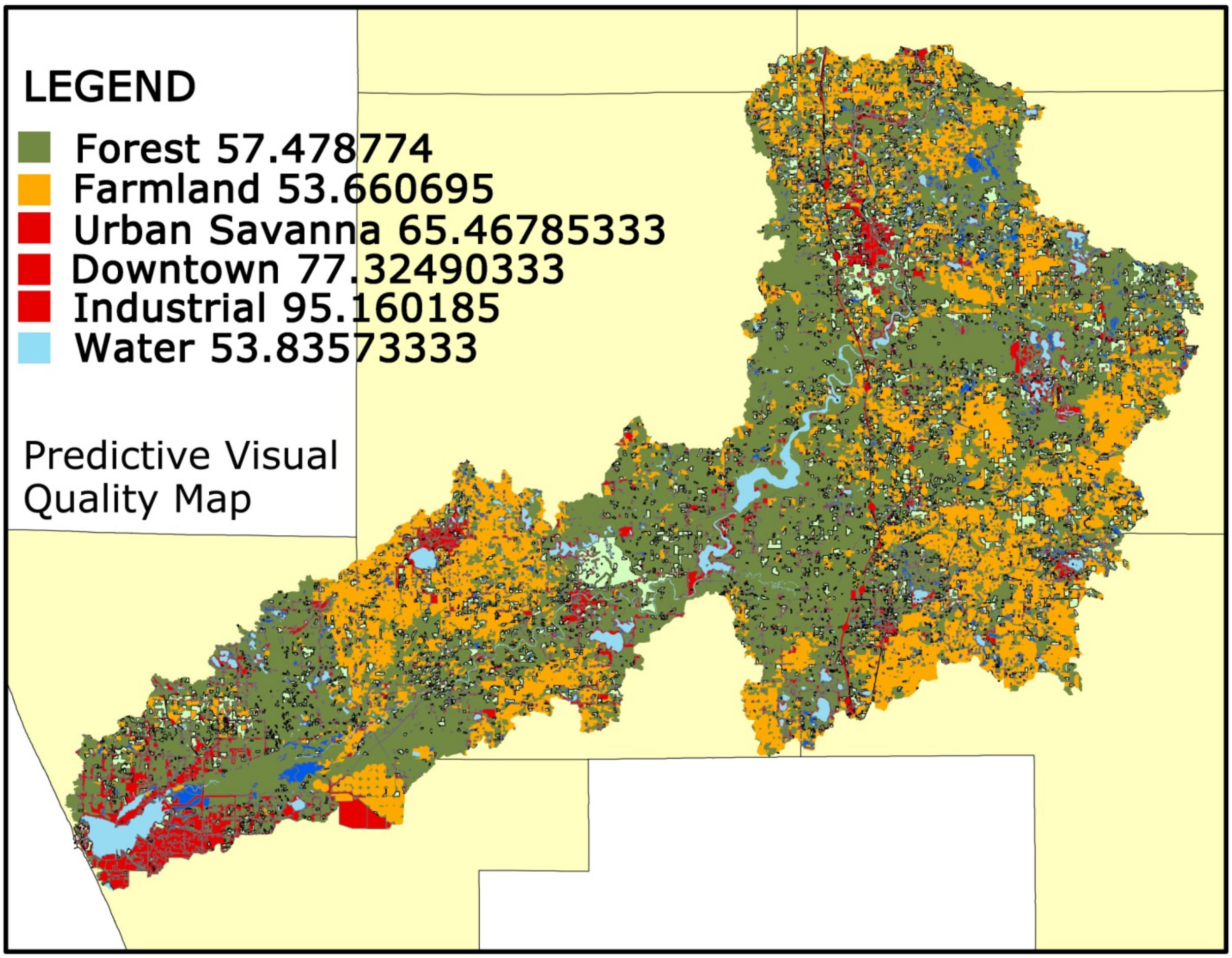


**Figure 13: Predictive visual quality map**

A predictive visual quality map of Lower Muskegon Watershed (Figure 13) was generated. Table 5 shows that there are six corresponding predictive scores according to the six various land-use types. To help validate this predictive map, the predictive scores of set two (Table 6) were generated based on the predictive visual quality map. For example, Figure 14 is a farmland landscape image and it acquired a predictive score of 53.660695.

**Table 6: Predictive scores of set two**

| NO. | Score | NO. | Score | NO. | Score |
|---|---|---|---|---|---|
| 1 | 65.46785333 | 11 | 77.32490333 | 21 | 95.160185 |
| 2 | 53.660695 | 12 | 53.660695 | 22 | 77.32490333 |
| 3 | 53.83573333 | 13 | 57.478774 | 23 | 53.660695 |
| 4 | 95.160185 | 14 | 53.660695 | 24 | 65.46785333 |
| 5 | 53.660695 | 15 | 53.660695 | 25 | 53.83573333 |
| 6 | 53.83573333 | 16 | 65.46785333 | 26 | 65.46785333 |
| 7 | 57.478774 | 17 | 53.660695 | 27 | 53.83573333 |
| 8 | 53.660695 | 18 | 57.478774 | 28 | 77.32490333 |
| 9 | 53.83573333 | 19 | 53.83573333 | 29 | 53.83573333 |
| 10 | 53.660695 | 20 | 53.83573333 | 30 | 58.92745 |

**Figure 14: A farmland image with a predictive score of 53.660695 — Copyright © 2010, Di Lu**

## 4.2. Validating the Map

**Table 7: Real score and predictive score of set two**

| Set Two Image NO. | Real score | Real score Ranking | Predictive Score | Predictive Score Ranking |
|---|---|---|---|---|
| 21 | 107.805 | 1 | 95.160185 | 1.5 |
| 4 | 93.2968 | 2 | 95.160185 | 1.5 |
| 28 | 83.52013 | 3 | 77.32490333 | 4 |
| 22 | 81.84413 | 4 | 77.32490333 | 4 |
| 11 | 80.84248 | 5 | 77.32490333 | 4 |
| 26 | 73.11433 | 6 | 65.46785333 | 7.5 |
| 16 | 72.98182 | 7 | 65.46785333 | 7.5 |
| 1 | 72.91732 | 8 | 65.46785333 | 7.5 |
| 30 | 68.89192 | 9 | 58.92745 | 10 |
| 24 | 67.92477 | 10 | 65.46785333 | 7.5 |
| 20 | 61.07647 | 11 | 53.83573333 | 17.5 |
| 2 | 60.12997 | 12 | 53.660695 | 26 |
| 17 | 59.10933 | 13 | 53.660695 | 26 |
| 13 | 56.192 | 14 | 57.478774 | 12 |
| 14 | 55.29468 | 15 | 53.660695 | 26 |
| 18 | 54.71145 | 16 | 57.478774 | 12 |
| 3 | 54.04903 | 17 | 53.83573333 | 17.5 |
| 7 | 52.3262 | 18 | 57.478774 | 12 |
| 10 | 51.93535 | 19 | 53.660695 | 26 |
| 8 | 51.06412 | 20 | 53.660695 | 26 |
| 19 | 50.506 | 21 | 53.83573333 | 17.5 |
| 12 | 48.79608 | 22 | 53.660695 | 26 |
| 27 | 48.7268 | 23 | 53.83573333 | 17.5 |
| 15 | 48.2258 | 24 | 53.660695 | 26 |
| 29 | 48.1872 | 25 | 53.83573333 | 17.5 |
| 25 | 46.87449 | 26 | 53.83573333 | 17.5 |
| 6 | 44.4542 | 27 | 53.83573333 | 17.5 |
| 5 | 43.3638 | 28 | 53.660695 | 26 |
| 9 | 42.1124 | 29 | 53.83573333 | 17.5 |
| 23 | 41.91216 | 30 | 53.660695 | 26 |

In Table 7 the real scores ranked from high to low, with 107.805 assigned as the highest score and 41.91216 assigned as the lowest score; while the predictive scores ranked according to corresponding original image numbers and their attributes. Each column of scores has an associated ranking. In Kendall's Coefficient of Concordance, a W value of 0.851112347 was generated. A corresponding Chi-Square table was consulted to determine if the derived value for Chi-Square was significant ($p \leq 0.05$) at twenty-nine degrees of freedom (Daniel, 1978). Since the derived value of 49.36451613 is greater than the table value of 42.55697, the null hypothesis was rejected and the hypothesis that the two sets of numbers are in concordance ($p \leq 0.05$) was accepted. It was determined, through statistical analysis, that the relationship of predictions (land-use map based scores) and the real photographs are in concordance and significant to a high (95%) confidence level.

## 5. Discussion

The findings on visual quality assessment at Lower Muskegon Watershed are consistent with many previous studies (Lee and Burley, 2008; Burley, 1997; Yu, 1988; Kaplan, S., 1979; Shafer, et al., 1969): in general, natural landscapes are more preferred than highly disturbed human landscape.

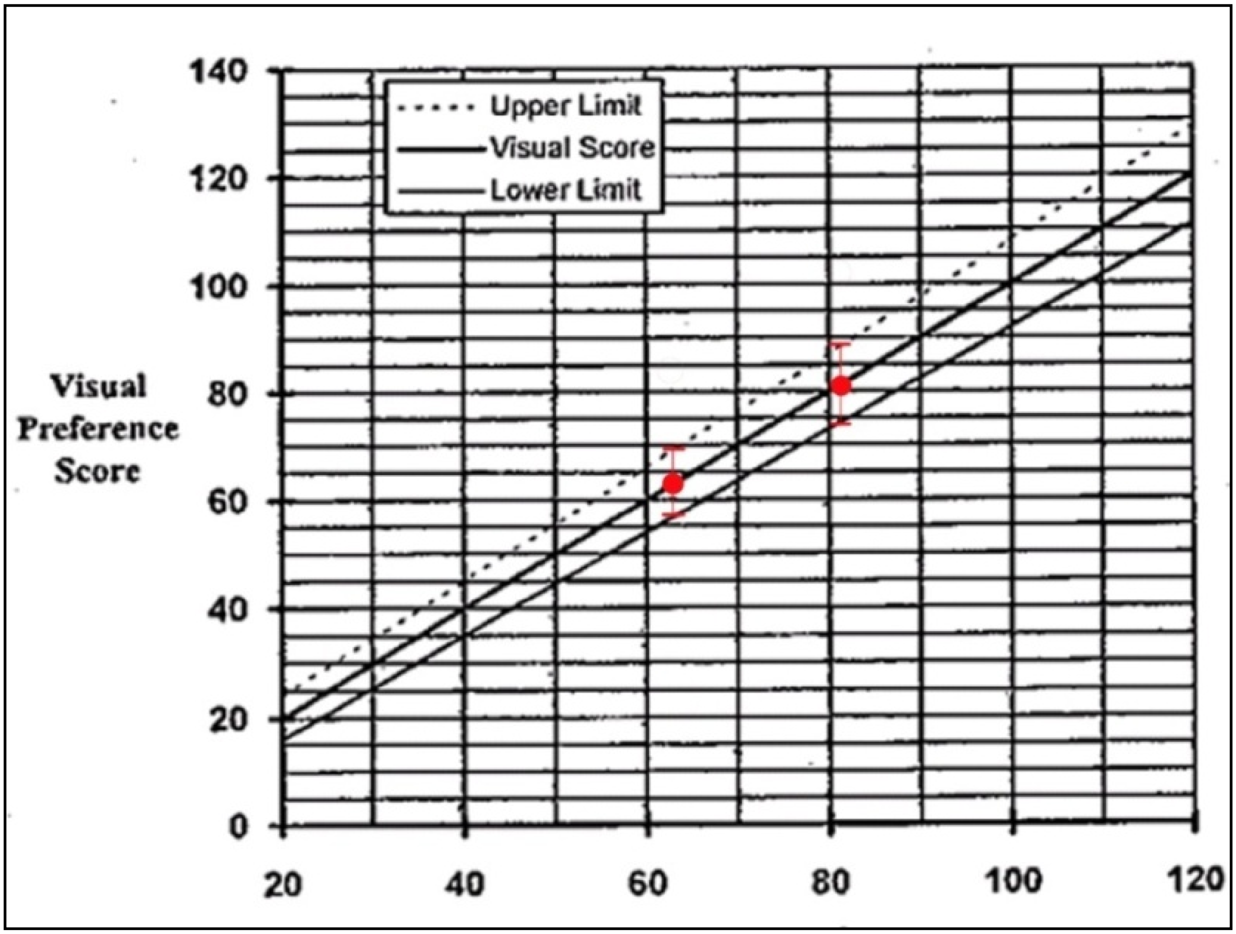


**Figure 15: Graphs of 95% confidence tails for visual preference scores: the 95% confidence scores for Figure 5.2 (63.35648) and Figure 5.3 (80.44573)**

It is possible to compare various photographs by constructing a plot of the predicted mean score for a statistical equation and then calculating the 95% confidence tables for the mean scores (Burley, 1997). A graph was constructed to illustrate the confidence plots (Figure 15). Comparisons between scores from various images were made horizontally by determining whether there is an overlap between the two tails (Burley, 1997). The confidence tails for Figure 16 and Figure 17 do not overlap in Figure 15, and thus it is possible to conclude the two images are significantly different.

As shown in Figure 16 and Figure 17, a farmland image (63.35648) has a better score in visual quality assessment than a downtown image (80.44573) because of less artificial structures and more natural elements. It also indicated humans' preference for rural and natural landscape.

**Figure 16: A typical downtown image with the score of 80.44573 — Copyright © 2010, Di Lu**

**Figure 17: A typical farmland image with the score of 63.35648 — Copyright © 2010, Di Lu**

The predictive visual quality map suggested that each random landscape image that is taken from Lower Muskegon Watershed, and is qualified for each of the six land use types, would easily have a predictive score of visual quality. For example, Figure 18 illustrates a random farmland image with a predictive score of 53.660695. Even if a random photograph consists of mixed land use types of landscape, there would be a predictive averaged score for it. Figure 19 is another example of a mixed land use image.

**Figure 18: A random farmland image with the predictive score of 53.660695 — Copyright © 2010, Di Lu**

**Figure 19: A random mixed image of urban savanna, water and forest with the predictive average score of 58.92745**
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In this research, many more photo samples could be taken to create a landscape visual quality map; but for this research I was more interested in determining if only a few (30) number of images would generate significant results. The reason was that by using fewer photos, this research could examine the methodology to test for significant concordance (95%) under less than ideal conditions and save money and time. Thus, only 30 pairs of images were chosen but with high variation (from rural to urban landscape) to test the ability of the methodology in assessing landscape visual quality. The results suggest that this methodology works.

Additionally, many previous investigations demonstrated the validity of using surveys, such as respondent groups in landscape evaluation experiments (Chen et al., 2009; Burley, 1997; Yu, 1988; Buhyoff et al., 1984; Daniel and Boster, 1976; Boster, 1974; Zube, 1974). Nevertheless, in this experiment, no respondent group was employed to evaluate landscape images, although the equation utilized (Burley's Equation 1) was generated from a respondent group study (Burley, 1997). It might be faster and more objective if this experiment does not involve people-based surveys. Another issue in this experiment is the accuracy and reliability of these studying photographs. Possible incomplete and bias photographs might influence the structure of this study. A systematic way of taking photographs was used in this study: including assessing near view visual quality, median view distance and horizontal viewshed (Chen et al., 2009; Clay and Marsh, 2001). Thus, as presented in this study, a defined method for shooting pictures would make this research highly reliable and reproducible.

In the context of landscape planning and design, landscape visual quality assessments are sometimes considered not important because they lack substantial evidences or due to their subjectivity (Ewald, 2001). The GIS based land use-map might be used in this context to facilitate a reinforcement of visual quality assessment dealing with aesthetic depreciation. The result of this experiment suggests that a GIS based land-use map could serve in visual quality assessment as well as in the professional practices of landscape planning. Land-use maps could be used to measure landscape quality instead of real images. With the help of GIS based land-use maps, initial site surveys might be reduced. Designers and planners are able to use predictive equations and GIS data during the early design phase. However, predicting site-assessed visual quality does not mean that replacing public and expert assessment is advocated.

In an environmental impact assessment, visual quality assessment is an important factor as well. Many of the environment impact properties could not be measured easily because these indicators are very subjective. With the help of GIS based land-use maps to predict potential visual impact, it might supply a quantitative method for environmental impact assessment. For example, as it is known that the predictive visual quality score of farmland is significantly better than the predictive score of industry in Lower Muskegon Watershed. If the developers initiate to build a factory at a farmland area of Lower Muskegon Watershed, it is obvious that the report of visual impact assessment would be negative according to the predictive model presented in this study.

The results of the experiment could also help managing viewsheds. A viewshed is an area of land, water, or other environmental element that is visible to the human eye from a fixed vantage point. In this paper, the area covered by each recorded photograph is defined as a viewshed. An example of four images and the direction of the viewsheds is shown in Figure 20. As well as illustrated in this example, all the photo data collocated and located in this paper could be used for later viewsheds management research.

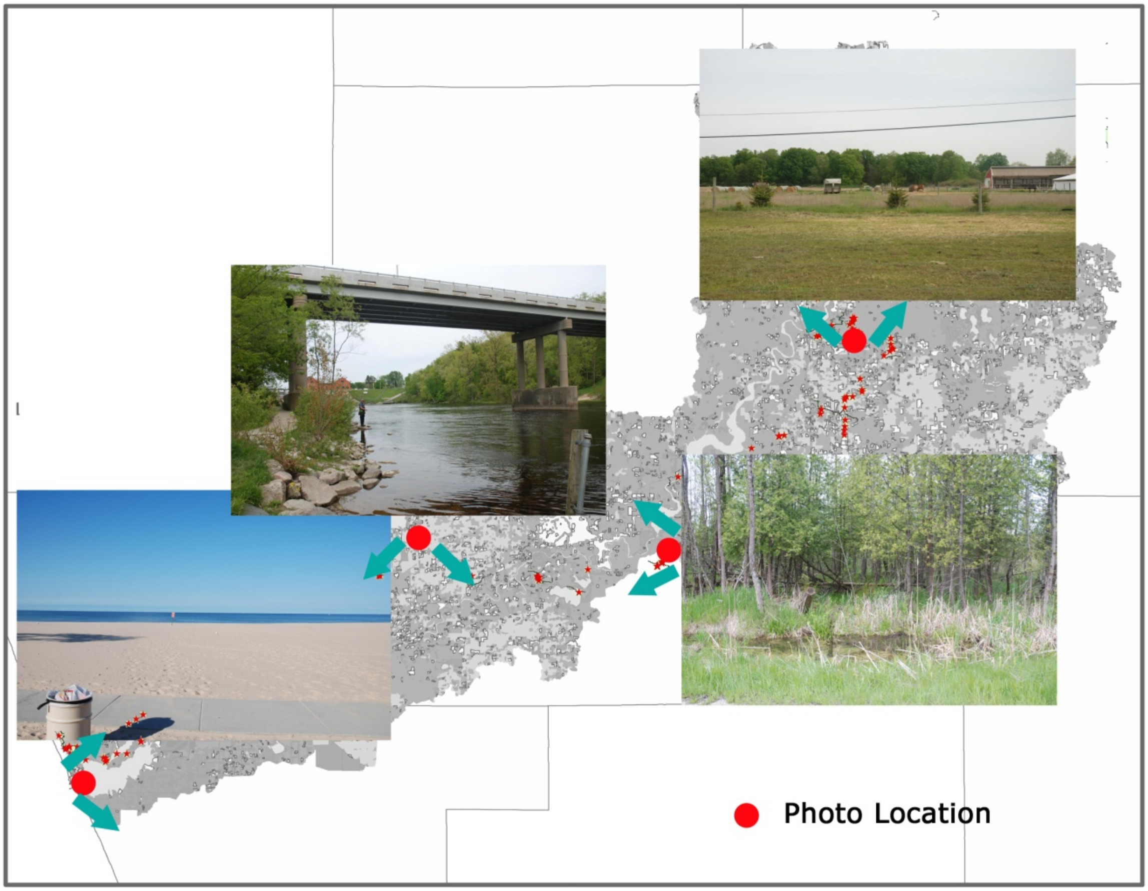


**Figure 20: Images representing directions associated with viewsheds**

Some people might wonder why this research was extremely interested in predicting landscape visual quality rather than predicting ecological quality. The reason is although it seems that ecological arguments might provide the most fundamental and convincing supports to a new plan or design, practical projects are more likely to be justified in terms of their aesthetic potential. Besides, the present study incorporated some ecological elements. The "environmental quality index" in Burley's Equation 1 demonstrated that this research has taken into account environmental, economic and social aspects already rather than only considering visual aspects to evaluate the landscape.

## 6. Limitation

Although the potential for GIS-based land-use map seems endless, the limitations of land-use map in visual quality studies are obvious as well. In this research, the land-use map which has been chosen with only six categories: farmland, forest, water, urban savanna, industry, and downtown. It is not sure, if a land-use map has more than these six categories or a photograph is with a special landscape type, if it would still be an effective way to predict landscape visual quality. For example, a typical photo taken from the Grand Canyon (Figure 21) might not work in this experiment because that special landscape type is not included in the land-use map of Lower Muskegon Watershed, although Burley's Equation 1 was generated all across U.S. (Burley, 1997). Sometimes, land-use map based scores are confused in adjacent areas, for example, in an image containing a mix of farmland, water and forest. It is not always accurate or reliable to use the average score as the predictive score of mixed landscape. In addition, land-use map based scores could easily cover a wide area of research sites; however they could not be assigned to a specific view or place. In those situations, site visits would become crucial: photographs corresponding to land-use maps should be recorded and measured to solve those problems.

**Figure 21: A typical photo of the Grand Canyon**

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In addition, there are also some limitations in the current equation, especially with "environmental quality index". As "environmental quality index" is a subjective test, human sense would significantly influence the results. It is entirely possible that various respondents might perceive visual quality differently. For example, if a person extremely likes an industrial property, his perception on this property would be more positive than others. Meanwhile better and more independent variables are expected for this equation.

While this research has some limitations, the methodology presented in this article might provide some inspirations in the landscape assessment and management in the Lower Muskegon

Watershed. For example, landscape planners could use the land-use map created in this study to predict landscape visual quality or landscape change in the Lower Muskegon Watershed. However, the methodology does not necessarily support the use of the predictive equation in other areas. Some studies have shown that there is a relationship between landscape aesthetics and visual impact of objects relevant to their scale (Shang and Bishop, 2000). Further experiments could be carried out on a broader scale, such as the whole area of Michigan or North America. This paper also raises some questions regarding future research:

(1) How would the results be affected if more updated GIS data is used in the research? Current work is under the "Updated 1998 Land Use Data", which is somewhat dated.

(2) Seasonal and annual changes in the landscape should be considered. This research only assessed photographs in the summer while the studying area is full of leafed vegetation. How would the results be affected if studying images were recorded during the winter?

## 7. Conclusion

In the era when sensitivity to land use and visual quality value is exponentially growing, landscape stewards ought to analyze and utilize potential and possible implications within the existing condition. Visual quality assessment is but one way for landscape planners to analyze existing environments. In some cases, deep site survey would be costly in terms of money and time. With the easy access to GIS based land-use maps, there is an increasing need to determine how land-use maps could serve to provide cost-effective landscape visual quality assessment and predictive models. The present study is an attempt to explore potential use of land-use maps in predicting landscape visual quality. The study identified that land-use map based predictive scores and real photograph scores are in concordance and significant to a 95% confidence level. Although there are still some limitations in this research, at a minimum, a science based statistical test to compare images and several theories might explain the existing model. It is hoped that the quantitative method presented in this paper might provide some insights in future planning and management at Lower Muskegon Watershed.

# Appendix

Figure 22: Set one NO.1
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Figure 23: Set one NO.2
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Figure 24: Set one NO.3
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Figure 25: Set one NO.4
— Copyright © 2010, Di Lu

Figure 26: Set one NO.5
— Copyright © 2010, Di Lu

Figure 27: Set one NO.6
— Copyright © 2010, Di Lu

Figure 28: Set one NO.7
— Copyright © 2010, Di Lu

Figure 29: Set one NO.8
— Copyright © 2010, Di Lu

**Figure 30: Set one NO.9**
**— Copyright © 2010, Di Lu**

**Figure 31: Set one NO.10**
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**Figure 32: Set one NO.11**
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**Figure 33: Set one NO.12**
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**Figure 34: Set one NO.13**
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**Figure 35: Set one NO.14**
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**Figure 36: Set one NO.15**
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**Figure 37: Set one NO.16**
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**Figure 38: Set one NO.17**
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**Figure 39: Set one NO.18**
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**Figure 40: Set one NO.19**
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**Figure 41: Set one NO.20**
**— Copyright © 2010, Di Lu**

**Figure 42: Set one NO.21**
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**Figure 43: Set one NO.22**
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**Figure 44: Set one NO.23**
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**Figure 45: Set one NO.24**
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**Figure 46: Set one NO.25**
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