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Ecology of Scale in Visual Landscape Assessments

Richard K. Sutton
University of Nebraska-Lincoln, rsutton1@unl.edu

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ABSTRACT:

Background readings on scale plus twenty-three visual landscape assessment studies from 1968 to 2006 were examined to understand the nature and use of scale and its relationship to the visual environment. The objectives of this study were to: 1) describe the concept of scale as applied to visual assessments, 2) review scale use in selected visual assessments, and 3) identify issues that need further research to better integrate scale into visual landscape assessments and landscape ecological theory.

Basic concepts and features relating observers with landscape and scale required defining scale, bounding visibility, perceiving scale, seeing hierarchically, and visualizing grain and extent.

Finally, it recommends further research for defining, recognizing, and incorporating scale into visual landscape studies should: 1) explicate use of absolute and relative scale, 2) compare traditional and multi-scalar, hierarchical approaches, 3) examine and revise the current reliance on substitution of distance for extent or scale, 4) compare space/mass interactions, not simply masses, to determine visual grain, 5) design research protocols in which psychophysical metrics correlate more logically with eco-physical metrics.

KEYWORDS: Absolute scale, Relative scale, Grain, Extent, Hierarchy
1.0 INTRODUCTION

Scale is a familiar term to landscape architects. It is one of many visual relationships taught in introductory studios to help designers perceive, order, and explain how they structure landscapes. Zube (1984) has noted that moving between scales such as the region and the site is one of four requirements for a general theory of landscape assessment. Scale also emerges as a central organizing theme in landscape ecology (Wiens, 1992; Turner et al., 2001; Wu and Hobbs, 2002; Wu and Li, 2006). As recent studies (e.g., Palmer, 2004; Fuente de Val et al., 2005; Dramstad et al., 2006) attempt to connect visual quality of landscapes with their ecological structure, it becomes more important to understand the role of scale.

In early visual landscape studies, scale was considered as a variable and a potentially important area of investigation (Zube et al., 1975; Fabos et al., 1975); little research on it has ensued. Wu et al. (2006) note that environmental planning and design rarely apply scale theory. Landscape architect, Richard Stiles (1994), proposed that there is a lack of research on space, scale, and visual quality. Visual assessment studies, however, continually find a spatial (and hence an implied scale) component present (Gobster and Chenoweth, 1989; Kaplan, 1979). Furthermore, Gobster (1993), Nassauer (1997), Eaton (1997), Tveit et al. (2006), and Gobster et al. (2007) have suggested understanding scale is a variable that produces visual and aesthetic qualities of and impacts on landscape.

The objectives of this study were to: 1) describe the concept of scale as applied to visual assessments, 2) review scale use in selected visual assessments, and 3) identify issues that need further research to better integrate scale into visual landscape assessments and theory. Together, the objectives represent an examination of scale as a set of distinct relationships between humans and their physical and visual environment that emerge as a kind of “ecology of scale.”

2.0 BASIC CONCEPTS OF SCALE
2.1 Definitions of Scale

Forman and Godron (1986) define scale as “the level of spatial resolution perceived or considered”. Laurie (1986) defines scale simply as the relative size of some thing or entity compared to some other thing or entity. Grinde and Kopf (1986, p. 329) distinguish two types of scale absolute and relative. Absolute scale compares size to a standard such as a human, whereas relative scale relates entities and their context. Several other definitions of scale in a visual context reported by Grinde and Kopf (1986, p. 331) present similar definitions for relative scale. Landscape architects often use cartographic scale or map scale (Silbernagel, 1997) or the human body (i.e., absolutes) but they also refer to the apparent size of some object or space relative to its context (Motloch, 1991; Bell, 1993) Relative scale best captures the dynamic aspects of human scale perception, but there are several complicating factors such as boundary visibility, hierarchical structure, spatial grain and extent

2.2 Bounding Visibility

Perceiving land results in landscape. If one cannot see land, that is, if it is not visible due to darkness or fog or some opaque occluding barrier, then one is blind to landscape surfaces (Gibson 1986). So visibility is a basic ingredient of assessing landscapes and their relative scale (Felleman 1979, 1982; Higuchi, 1983; Tveit et al., 2006).

Landscape ecologists explicitly and deliberately determine the boundaries of a study area and the size of the units measured with in it. The overall boundary has been called variously scope or extent and the measured units have been called resolution or grain (Turner and Gardner, 1991; Schneider, 1994; Kosslyn, 1994; Ahl and Allen 1996). Boundary and scale also become basic to visual landscape studies. Litton (1968) observed that our sense of scale is directly attributed to the boundaries or extent of what we see. In a corollary to Litton’s observation, De Veer and Burrough (1978) note arbitrary, fixed boundaries are important.
Boundaries get our attention (Litton and Tetlow, 1978; Kaplan and Kaplan, 1989).

2.3 Perceiving Scale

In a remarkable study, Coeterier (1994) investigated the relationship of spatial size and spatial distance in perceptions of space in Dutch landscapes. Importantly, the number and quality of the relationships both contributed to perceiving size and distance. He concluded that human size and depth, or distance represented unique processes and used different cues or the same cues differently. Space perception integrated distance and size (Coeterier 1994 p. 333). This occurs because our perceptual faculties appear to automatically integrate visible landscapes (Gibson 1986) and scale is one of those integrative mechanisms (Watzek and Ellsworth 1994). Sculptor and artist, the late Robert Smithson has said something similar to Coeterier, “Size determines an object, but scale determines art… Scale depends one’s capacity to be conscious of the actualities of perception” (Holt 1979). Humans readily and easily make judgments about the perceived sizes of individual parts or features of landscapes and have adapted to quick perhaps subconscious reaction to our physical context to survive in an uncertain world.

In many environmental perception and visual landscape studies, scaling applies to the observer’s ability to subconsciously understand different relationships within a landscape and his or her tendency to quickly scale up and scale down as a normal act of perception (Sutton 2011). This is borne out by Gibson’s (1986) explanation of seeing in perspective.

Seeing Hierarchically

James J. Gibson’s career as a psychologist spanned over 50 years, during which he attempted to understand humans as perceptual creatures embedded in our environment. Gibson, (1986) brought together and revised many of his earlier theories on how we understand the world in which we live. His observations regarding scale come from two broad concepts articulated in that book. The first explains how we see hierarchically in a hierarchical world. The second
involves invariants in the visual array that humans use to understand where they are and how we use invariants to find our way around.

To Gibson (1986) a place is contained within in a larger place and differs from that of a Cartesian coordinate point. He describes surfaces of boundaries that effect visibility and thus control and filter information from the surrounding ambient array. These surfaces can be detailed as to their texture and “…units of texture are generally nested [e.g., hierarchical] within one another at different levels of size” (p 28).

Not only does he describe the physical world as nested, but how or our eyes, head and body move and adjust give us additional information about distance. What we see of the earth’s surface occur in a range of size, derives from the visual angles of those features and is not the same as earthly features (Gibson 1986). According to Gibson we innately see hierarchically and derive information about the landscape by interpreting and using nested optical angles.

Gibson describes the concepts of variant and invariant structure in the environment. The most common and critical invariants are the horizon and the texture of the earth’s surface. Using relative comparison Gibson (1986) explains hierarchically nested objects have constant size relationship, as does an individual object. For example, he stated, “equal amounts of texture for equal amounts of terrain suggests that both size and distance are perceived directly” (p. 162).

We basically apply scale hierarchically. For example, when size hierarchical constancy or scale continuity abruptly breaks, the landscape view becomes less harmonious (Bell 1993). Since naturally occurring patterns display a visual hierarchy, they become important features of visual scaling (Bell 1993). Seeing in scale musts include surrounding objects or spaces as context.

Hierarchy theory attempts to describe and explain relationships between objects, spaces, time and processes in the context of their complex human, ecological and physical systems (Whyte, 1969). Cognitive scientists (Ahl (in Ahl and Allen, 1996), Kosslyn, 1994; Gibson,
1986) and landscape ecologists (Allen and Hoekstra, 1992; Turner and Gardner, 1991; Allen and Starr, 1982) have used hierarchies to examine the importance of scale. Landscape ecologists are concerned with scale and hierarchies because the objects and processes they study may vary with scale. Setting the scale for an investigation or sampling of physical landscape is an important early step, and one that must be explicit. Researchers who use scale as an investigative scheme in landscape ecological analyses apply hierarchy theory to order the scale changes (Allen et al., 1993; Wu and Li, 2006).

Tveit et al. (2006), propose a nested, hierarchical scheme of visual scale, dimensions (visibility, openness and grain size), attributes (topography, vegetation, and man-made obstacle), and indicators (viewshed size, viewshed form, depth of view, degree of openness, grain size and number of obstructing objects). Because human perception of landscape is an ecological, hierarchical, multi-scaled process and it requires us to constantly scale up and scale down.  

2.4 Visualizing Grain and Extent

Since landscape ecologists must be explicit about the scale at which they study a phenomenon of interest, they carefully select grain and extent. In some cases (e.g. Hyman et al., 1991) different scales (and thus different grains and extents) were selected to study the range of relationships between small tree seedlings and the larger migrating deer that browsed on them. In sampling a biotic environment, for example, whales and plankton, the size of the overall net is the extent and the size of the net’s mesh is the grain. If you wish to sample plankton, a 1-meter by 1 meter net may be an adequate extent, but a 1 cm opening in the net is a grain size that would not allow you to collect such a small organism as plankton. On the other hand, the net would not be nearly large enough to capture something like a whale. In both cases an improper hierarchy of relationships between net size and mesh size or extent and grain gives little hope of meaningful sampling.
This analogy holds with human observation of the landscape, because our moment-to-moment views become visual samples. In visual studies Gibson (1986), supports the idea of choosing grain and extent because he explains that no fixed unit works in every situation. He proposes that we vary the scale of investigation to fit the entity of interest and that we be explicit when we describe the relationships between parts at a lower, subordinate level. Subordinate in visual landscape assessment should be thought about as the space where the observer resides and that space, once chosen, represents the dominant visual grain. This space is smaller than the total observable landscape; it is near to us and we respond more quickly to it, yet it is contained and nested within the larger context or extent. Encompassing such a space is the general context of what one views; for example, the interaction between landscape spaces occurs at the next higher, super-ordinate level (i.e.,). It can be thought of as the larger and more inclusive circumstance exhibiting strong containment.

Using the relative concepts of grain and extent the complexity of a landscape view and its visual scale becomes more than an absolute, background-middleground-foreground triad (e.g., Shafer et al. 1969) or nested view windows (e.g. Fuente de Val et al. 2005). For each separate view there are different indicators of grain and extent and observers directly and automatically distinguish a hierarchy of grain and extent.

2.5 Summary of the Basic Concepts of Visual Scale

A landscape must be visible before its scale can be judged and described. Scale appears to be interpreted in two ways, first as a comparison to an absolute size such as a human and second, as a relative between an object or space and its context. Absolute scale depends strongly on sensing size that, in turn, we substitute for distance. The concept of relative scale includes absolute scale and invoking relative scale requires multi-scalar perception within a hierarchy suggested by an environment and interpreted as a unique place by an observer. Use of relative
scale has come about by moving and learning in a 3-dimensional world where the context constantly changes.

Humans readily react to sizes of individual parts or features of landscapes (Coeterier 1994). For way finding we rely on invariants such as the horizon and surface texture. Allen and Hoekstra (1992, p. 87) agree, saying, “[H]uman perception of landscapes is probably the result of selective pressures. It is reasonable to suppose we have been selected to perceive the world in a way that allows prediction. Prediction comes easier in familiar circumstances. Since changes in scale change perception radically, it would be of advantage [to humans] to perceive in a way that recognizes patterns that occur at multiple scales; then the world remains familiar even under scale changes.” (emphasis added). Placing the visual world into hierarchical relationships such as the nesting of absolute scale within relative scale aids human navigation and survival. The structure and composition of landscape reveal subordinate and super-ordinate entities defined and delimited by boundaries that suggest grain and extent.

3.0 LINKING LANDSCAPE, SCALE AND VISUAL STUDIES

Landscape ecologists clearly define scale and explicitly use it in structuring their studies. Wu and Li (2006) summarize and organize the concepts of scale. Those concepts will be covered here in abbreviated form, but the reader is encouraged to see the original work for more detail. Wu and Li discuss three aspects of scale: characteristic scale, scale effects and scaling where characteristic scale is part of a phenomenon’s essential nature. As observed by humans, scale effects are changes in outcomes based on changes in scale, and scaling extrapolates information from one scale to another. In Figure 1, Wu and Li (2006) break scale into a hierarchy of (1) dimensions, (2) kinds and (3) components. The discussion below reframes Wu and Li’s concepts for the visual landscape.

The most general level of their conceptual hierarchy deals with the dimensions of scale,
that is, space, time and organizational level. Space and time scale studies (e.g., Delcourt and Delcourt, 1988) are straightforward, connected and widely used and understood. An organizational level perceived by a researcher has inherent time and space scales associated with it. Large events cover more space and return more slowly, whereas smaller events are contained within and often constrained by larger events in time and space (Whyte, 1969) as nested hierarchies such as those described above by Gibson (1986).

When an individual confronts landscape, selection of organizational level would also probably occur quickly and with minimal deliberation. For example, moving down a hierarchical level brings more detail and smaller temporal or spatial units. Movement, whether it is the scanning eye or the walking human, essentially activates and links humans, their perceptive minds, and the environment (Gregory Bateson in Harries-Jones, 1995). Assuming an elevated view (what Litton (1968) calls “observer superior position”) shifts the observer up in level and thus scale, allowing comprehension of larger units of landscape. In short, moving up in a landscape increases the area of one’s view scale and scale (Bell 1993).

Next Wu and Li (2006) describe what they call kinds of scale. First, intrinsic scale is “the scale on which pattern or process actually operates.” In the case of visual landscape studies
Figure 1. Concepts of Scale (After Wu and Li, 2006).
intrinsic scale may closely match their second kind of scale, observational scale, because, “. . .
the observed scale of a given phenomenon is the result of the interaction between the observer
and the inherent scale of the phenomenon” (p. 7). “Selection of the strata [levels] in which a
given system is described depends upon the observer, his knowledge and interest in the operation
of the system . . . stratification is an interpretation of the system” (Whyte 1969, p. 32).

Although hierarchies can be conceptualized as levels that decompose into subordinate
levels or compose to super-ordinate levels, they are not mere aggregations but holistic,
identifiable units interpreted or defined by the observer. In their view, ecologists Allen and
Hoekstra (1992) explain the hierarchical role of the observer as first deciding what the structure
may be then applying that decision to what is seen in the environment. The role of the observer is
central to understanding scale. His or her decision may be long and deliberate in a research study
or quick and subconscious by an observer.

Wu and Li’s (2006) observational scale often coincides with the scale at which samples
are measured or data is modeled or analyzed. They describe these as experimental scale and
modeling/analysis scale. Of importance to visual landscape studies is what they call the policy
scale that acknowledges the context of local, regional and national planning regulations. For
visual landscape studies it might be a region (e.g., Zube, 1970; Litton and Tetlow, 1978) or a
discrete public land management unit (e.g., USDA 1995). Summarizing these ideas about kinds
of scale Wu and Li (2006) note a sequence in which proper observation and analysis allow
detection of the phenomenon’s characteristic scale in turn allowing appropriate scale of
experimentation and modeling resulting in planning and management at a scale of the problem at
hand.

Finally at a more detailed, basic level Wu and Li discuss components of scale that
include: cartographic scale, grain, extent, coverage and spacing. Cartographic scale is familiar as a ratio of a map’s distance to that same distance in the real world and applies absolute scale (See Silbernagel, 1997). Wu and Li (2006, p. 9) use a definition for relative scale from Meentemeyer (1989) where “relative scale [is] the relationship between the smallest distinguishable unit and the extent of the map, which can be expressed simply as the ratio between grain and extent.” However, sole reliance on map extent unnecessarily restricts the concept of relative scale as previously described in this review from Bell (1993) and Motloch (1991) and for visual landscape studies compromises observational and intrinsic scales.

Coverage and spacing have to do with sampling in time and space and may affect capture of the appropriate characteristic scale. Grain and extent are basic elements of scale represented by the net size and mesh size described earlier. Wu and Li (2006) note that the grain size must be smaller than the phenomenon of interest yet include its range. Observation of an environment can be thought of as a quick, subconscious and ongoing visual sampling.

3.1 Comparing Visual Studies to Concepts of Scale

First, what might be considered a visual landscape study? Some refer to them as landscape assessments (Brown and Itami, 1982; Daniel and Vining, 1983; Sutton, 2011), scenic assessments (Schauman, 1988) scenic resources (Zube et al., 1975), scenic analyses (Litton and Tetlow 1978), visual resource analyses (Brown, 1994), view quality (Germino et al., 2001), visual quality assessments (Schauman and Pfender, 1982; Crawford, 1992), landscape values (Zube, 1987), visual preferences (Kaplan and Kaplan, 1989; Dramstad et al., 2006), aesthetic preferences (Gobster and Chenoweth 1989), landscape perceptions (Palmer, 2003) or scenic beauty estimates (Daniel and Boster, 1976; Daniel 2001). Simply put, visual landscape studies examine the landscape as an environment visible to and valued by humans. A scene is seen; a vista is viewed and most importantly humans perceive the quality of their physical landscape.
Human reactions may be functional, (way-finding, Kaplan and Kaplan, 1989; sustenance or safety, Appleton, 1975); ethical, (stewardship, Nassauer 1995) or (aesthetic, Gobster and Chenoweth, 1989; Hammit et al. 1994) and they imply an interest in quality (Daniel and Boster, 1976; Palmer, 2003).

Twenty-three visual landscape studies (Table 1) were examined for how they addressed scale linkage and correspondence with Wu and Li’s (2006) conceptual structures. Many others were reviewed but not included because of space limitations. Some of the twenty-one selected are more conceptual than applied; only detailed, published studies were used in which scale, hierarchy, or space were featured. A discussion of each study follows below.

Review of Visual Landscape Studies

Influenced by Gibson (1966) Litton’s (1968) description and analysis of western U.S. forests set the foundation for the USFS visual resource management system. He noted the role of landscape in travel and recreation, proposed graphical and verbal landscape descriptions, related resource management and visual management and proposed future research.

Litton was keenly aware of the role that scale plays in the experience of landscape. His factors: distance, observer position, form, spatial definition, light and sequence all touch on it. Distance zones, observer position, and spatial definition all tie landscape space to the viewer. Regarding the organization of distance zones, Litton clearly does not see them as static and separate (as they have often been presented since) but to “be examined and [related] to landscape” (p. 3) as in a hierarchy. It can be inferred that he was using the component of extent when he discussed visual limitations (p. 17) or visual penetration (p. 38) and grain when

Table 1. Studies reviewed for concepts and use of scale in visual landscape assessment. The left column lists the studies chronologically and the right column lists them alphabetically.

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Using landscape scenes, Shafer et al. (1969) completed one of the first quantitative analyses of structural landscape features and human preference. Using ten variable “landscape zone predictors” they performed a multiple regression in which six variables accounted for 66% of the variation from respondent’s preferences for the scenes.

Although scale is not specifically discussed, space and hierarchy are addressed indirectly by the nature of the landscape zone predictors: 1) perimeter of immediate (foreground) vegetation, 2) perimeter of intermediate (middleground) non-vegetation 3) perimeter of distant (background) vegetation, 4) area of intermediate vegetation, 5) area of water (if present) 6) area of distant non-vegetation. These zones represent complex relationships between space and materials that, in essence, create a hierarchy of space and mass.

The study methodology reminds one of the cell or raster based depiction of land use and
land cover by landscape ecologists, except that Shafer et al.’s (1969) views of landscape were horizontal (i.e., chorological sensu Zonneveld, 1990) not an overhead vertical view studied on a map or aerial photo. The grain was literally a gridded mesh overlain on the photo, whereas extent was the entire 8” x 10” black and white photo a smaller sample of the viewshed. The same size grid mesh was used for close, intermediate and far areas with out regard to scale.

Litton et al. (1974) created a clear spatial hierarchy and implied scales for identifying and classifying the aesthetic qualities of natural water bodies to aid its planning, design and management. Beginning at the regional level they described Landscape Units defined by invariant topographic boundaries within which nested the Setting Unit and the Waterscape Unit. Furthermore, those units include lower levels called Expressions.

Zube et al. (1975) reviewed seven visual landscape studies from the North Atlantic Region to understand the public reactions. They concluded, “Grain, spacing, evenness and naturalism are negatively related which suggests that as these dimensions increase, scenic resource value decreases” and “two sizes of view dimensions [area of view and length of view] are positively related to scenic resource value which suggests that as area or length of view increases scenic resource value increases.” And finally, they found that “… the viewer inferior position enhances scenic quality more than viewer superior position” (p. 166). Their summary “findings from the regression analyses of the last study [Zube et al. 1974] suggest that better prediction [of scenic resource quality] may be possible if attention is given to stratifying the landscape on the basis of scale of the view area and/or on the extent of the naturalism or the impact of man” (p. 167).

Coeterier and Dijkstra (1976) report on several coordinated experiments and studies that became part of a comprehensive ecological and economic model of hedgerow change in the Netherlands. Because they postulated scale might be a critical feature impacted by hedgerow
removal, they sought to determine the significance of the hedgerow landscape on residents’ perceptions and values and evaluated models of hedgerow removal for visual impact. They found among other things that apparently residents found no difference between space and space-forming objects, that is, the landscape was considered as a whole and not as separate parts. Secondly they found that the resident respondents saw three levels of space and scale: 1) small-scale areas, 2) transitional areas neither big nor small and 3) large-scale areas. Finally, small-scaled landscapes were more preferred. To date, this study has completed the most extensive and integrated examination of scale and its impact on human responses. A follow-up study sought to examine changes over time after hedgerow removal by looking at their location, length, density and the space-scale. Coeterier and Dijkstra (1976) define space-scale as “the degree of openness of the space” (p. 438) and for evaluation their respondents used a semantic scale differential that ranged from open to closed.

DeVeer and Burrough (1978) reviewed a decade of Dutch landscape assessments detailing four methods with variations for describing, classifying and mapping landscape space and structure. The first is the “compartment” approach in which a space is conceptualized as a concave bowl with vegetative, topographic or urban elements as boundaries roughly equivalent to the concept of viewshed. The second features concentric zones surround a centered viewer at 500 and 1200 meters based on “breadth of view”. According to DeVeer and Burrough (1978) the 500 meters is an arbitrary distance, but the 1200 meters approximates the distance at which an object has visible detail. (Note the similarity but not coincidence with zones from Litton, 1968; Higuchi, 1983; Felleman, 1982) Users of distance zones acknowledge that the distances are modified by weather and season. A third approach parsed the landscape into cells of 125 X 125 meters or larger in conjunction with both the compartments and breadth of view. The grid approach can be thought of as utilizing a chosen cell size (absolute scale) as a grain, but extent is
not explicitly defined or used. A fourth method was specialized for and localized to flood plains of large rivers.

Litton and Tetlow’s (1978) study of the visual aspects of the Northern Great Plains landscape reflects an evolution in their thinking about scale. Their inventory was based on 1) study of previously developed landscape analysis methods and their terminology; 2) examination of high altitude imagery and topographic maps as sources of visual information; and 3) field observation. Criteria included characteristics and patterns of landform, vegetation cover, water, and land use. They add two levels, Continuity and Province, above the landscape Unit and make scale a descriptor of each hierarchical level. The broad Continuity level is defined by major invariant structure composed of mountain chains. The province has sufficient extent and visual unity to stand out clearly as an island within the Continuity” (p. 44). “The Scale of the Unit – its size or area compared with other landscapes—is not wholly dependent upon the observer’s perception of immediate enclosure with positive physical boundaries and the presence of clear internal views” (p. 52). However, it is extensive enough that it cannot be seen as a whole by the observer. “[When] the proper scale for a Setting is determined by the scenic element itself” (p. 61), visual scale shifts from relative to absolute. Extent as a concept interchanges with distance-of-view.

The work of Stephen Kaplan (1979) (1987) and Rachel Kaplan (1985), and their colleagues (e.g., Brown et al., 1986; Brown and Itami, 1982; Herzog, 1984; Kaplan et al., 1972; Kaplan et al., 1989, Kaplan, 1977; Pitt 1976) is much too voluminous to cover in detail here. The reader is referred to Kaplan and Kaplan (1978), (1989) and Kaplan et al. (1998). Stephen Kaplan (1987) presents an “ecological” model based on human evolution. The Kaplans and their associates have not specifically studied scale, though space as distance and extent have been examined. Stephen Kaplan (1979) using content identifying methodology found that the
following spatial configurations appeared from respondents’ preferences for landscape scenes: open undefined scenes, spacious, but well structured scenes, enclosed scenes, and blocked views.

Talbot et al. (1987) and Talbot and Kaplan (1986) studied preferences for landscape size. These sizes were estimated by the respondents and not set by the researcher. They concluded that size had little if any relationship to preference. However, they did not measure the boundary distance or boundary relationships determined by a viewer. They also discuss size and perception of space and puzzle at why some scenes appeared to be smaller than they were even when the scenes were obviously sub-divided and linked sub-spaces of various sizes. They appear to be confounding the space-grain and the distance of view. They mention extent but use it in the same sense as distance of view. Kaplan and Kaplan (1989) later defined extent as, “connectedness and scope” (p. 184).

Higuchi’s (1983) work measured culturally important landscape views in Japan, defining and deconstructing the physical relationships that delimit visual relationships. His seminal work mostly focused on absolute scaling of the “of short-distance views, middle-distance views and long-distance views” (p. 12). Following Gibson, (1966) he posited a relationship between the distance views based on the perception of trees and the texture of their parts. A tree reads as a whole unit in short-distance views, at middle-distance view based on the outline and its relationship with the context provided by surrounding trees, topographic positioning and atmospheric haze and in long-distance view relationships, trees simply collapse into the internal texture of topographic features such as a hillside or peak. Higuchi modified the absolute scale of zone distance by giving a range noting the importance of background to visual order.

In summarizing the visual structure of landscapes Higuchi (1983) produced (Figure 2) three hierarchical charts (Figures 6.1, 6.2, and 6.3, p 88). Chart 1 relates the area of visibility to 1) degree of sunlight, 2) distance, 3) angle of incidence [of the view], 4) angle of elevation [of
the view], and 5) angle of depression [of the view]. Spatial occlusiveness is related to 1) distance, 2) textural density gradient and 3) angle of incidence [of the view]. Finally, spatial depth is related to a hierarchy of 1) distance, 2) angle of incidence [of the view], 3) angle of elevation [of the view]. While Higuchi never uses the words “spatial hierarchy” or “scale” to describe the features of his investigation, those concepts are none-the-less embodied in his discussion of visual structure.

Hull and Buhyoff (1983) measured the impact of distance on viewer preferences for scenes. Selecting photographs of landscapes with open foregrounds, they varied the viewer distance to two topographic boundaries, one a low hill and the other, a main ridge of the Appalachian Mountains. Results from their multiple regression analysis show a non-monotonic (i.e., quadratic) relationship between view distance and the scenic beauty estimates of observers. The curved line bowed slightly upward at either end, indicating that scenic beauty was greater for close views and for distant views of the first hill. They concluded that distance as a variable may represent composite effects and that may have been scale effects.
Figure 2. Hierarchy of spatial characteristics (After Higuchi, 1983).
Iverson (1985) described the visual magnitude of landscape scenes as distance, aspect, and slope. He used nested view angles (see Gibson, 1986; Higuchi, 1983) of the human eye to determine the visual magnitude. Interestingly his description of a proposed logging clear cut, accounted for a scale factor in a superior way to the gridded photograph of Schafer et al. (1969) and in doing so created a de facto hierarchy of size.

Gimblett et al. (1985) studied spatial constructs of landscape such as screening, distance of view, spatial definition, (enclosure and openness) physical accessibility and the radiant (i.e., backlit) forest backdrop on Kaplans’ (1979) cognitive variable, mystery. They theorized screening and radiant forest scenes affected the promise of information, while physical accessibility, distance of view and spatial definition affected opportunity for involvement. Gimblett et al. (1985) don’t specify a hierarchy of space, but note Litton’s background, middleground and foreground relationship. They rely on distance (of view) as a key affect on mystery and conclude that as it increases mystery decreases.

Schauman (1988) examined space in rural Whatcom County, Washington as an important dimension of scale. In the background material for their study, her team devised a hierarchical scheme of classifiers where “visual patterns . . . appear as discrete units” and modifiers operating at a lower level that “are visual elements which appear in conjunction with, but not necessarily contiguous to, a visual unit. The modifiers chosen represent two scales of special visual elements which . . . change our perception of the countryside landscape” (p. 233).

Hammitt (1988) surveyed the preferences of tourists for scenic rural vistas along the Blue Ridge Parkway. Factor analysis of preferences for 96 photos, depicting vistas from three geographical sections of the parkway, grouped into four types (with associated preference means on a 1 to 5 scale): Water vistas (4.6, 4.12), Multi-ridged Vistas (3.96, 3.75), Pastoral Vistas (3.68, 3.60, 3.57, 3.46), and Un-maintained (3.19, 2.99). However, a different interpretation
could easily evoke a strong spatial and scalar theme. Perhaps larger scale, as suggested by the number of ridges or heterogeneity of pasture and field boundaries, increased extent and, hence, preference or smaller scale, suggested by smaller grain and defined by encroaching foreground vegetation, decreased scale and hence preference ratings.

In a later examination of that data using factor analysis and regression, Hammitt et al. (1994) predicted nearly 76% of the variation in preferences for the Blue Ridge Parkway scenes. In order of importance, the prediction variables were: area of sky, area of largest ridge, area of water, area of obstructing vegetation and area of rolling plateau. Area of moving water, linear perimeter of ridgeline, and area of rolling plateau positively affected their visual preference estimate, while area of foreground vegetation detracted.

Using forested landscapes in east Texas, Ruddell et al. (1989) attempted to establish links between psychophysical predictors and psychological theory by measuring scenic beauty affects in visual penetration of various forest sites. They state that the spatial configuration or openness or distance of view used in many visual landscape studies would not work in dense forest stands with short distance views. Their regression model predicted 37% of the scenic beauty scores and was the greatest with 7 variables. Whether near view or distant view, their study shows that spatial configuration has an important impact on scenic beauty.

Coeterier’s (1994) study began to explain why Talbot and Kaplan’s (1986) respondents may have “misperceived” the size of landscape spaces. He discussed some of the psychological and cognitive processing needed to explain spatial configuration’s impact on preference for landscape scenes. Scale integrates lineal distance and spatial size.

Coeterier (1996) reviewed eight dominant attributes (unity, use, abiotic, biotic, time, spatial, management and sensory) that Dutch residents used to evaluate landscapes. The spatial arrangement of the Dutch landscape cut across and integrated all eight attributes and was based
on 1) open space size and form, 2) landform heights 3) ground plane texture and micro-relief and
4) composition of objects. He describes the eight attributes as perceived, but first and more
importantly the attributes were viewed as integrative parts of a whole.

Palmer and Lankhorst (1998) examined six Dutch regions and attempted to model and
correlate spaciousness as defined by woodlands, hedgerows and building and urban masses with
ratings of spaciousness by respondents. They used existing GIS layers depicting landscape
structure in a 125 km$^2$ study area. They used two major models, one based on a 250 m x 250
meter GIS raster cell and one based on a 500 meter x 500 meter raster cells that they call
resolution and this review calls “grain”. Field checking found some of 500 x 500 sized cells as
“poor representation of actual spatial conditions” (Palmer and Lankhorst, 1998, p. 73), declaring
it too coarse to capture the spatial conditions. The 250 x 250 meter grid model was then
modified by allowing its spaciousness rating to be changed contingent upon rating of
neighboring cells brought better agreement between respondents’ ratings and ratings generated
by the model.

Germino et al. (2001) used GIS and viewshed analysis to compare planimetric and
panoramic (horizontal) sources of physical landscape data such as: view area, depth [of view],
relief, landcover, diversity, and edge. Their study site included thousands of square miles in
southwestern Wyoming, possessing distant views to mountains. They validated that images
generated by draping landcover on GIS topography displays for surrogate landscape perspectives
created excellent simulations when compared with similar video footage. They found
perspective effects influenced by the relationship of foreground and background; “greater
foreground relief was associated with smaller areal extents…[and] greater diversity of landcover
was associated with higher values for edge, and more relief in the view was associated with
Perhaps the most important conclusions of Germino et al. (2001) were that “the planimetric output commonly used to evaluate viewshed properties was not suitable for analyses of the landcover viewed from the ground level” (p. 79) and that “while the planimetric approach appeared superior for quantifying the dimensions [configuration] (areal extent, relief depth) of viewsheds, the panoramic computer simulations were superior for representing the composition (landcover, diversity, edge) of views observed at ground level” (p. 81). (Emphasis added.)

Palmer (2004) continued to connect landscape ecological theory and technique with a study of the visual landscape in Dennis, Massachusetts. He briefly reviewed landscape ecological concepts that might be applicable to visual landscape studies and noted, “In order to frame a landscape ecological study, one must consider the ecological appropriateness of the landscape’s extent, grain and elements, all which gain meaning and consequence from an organism of concern” (p. 203). He defines extent in two ways, first from With (1994, p. 25) “as the largest scale that an organism perceives” and second, from Kolasa and Rollo (1991, p. 7) as “the range at which a relevant object can be distinguished from a fixed vantage point”. The organism is the perceiver in both these very different definitions of extent. Palmer considered extent to be a neighborhood or a viewshed—very different concepts. Later Palmer (2004, p 207), without discussion or ecological justification, selected the 225 km$^2$ Town of Dennis study site as the study extent.

Next Palmer (2004) reviews definitions of grain as “size of individual units of observation” (McGarical and Marks, 1995, p. 7), “the finest resolution at which the organism perceives spatial heterogeneity” (With, 1994, p. 25), and “the distance or area to which a species is sensitive in carrying out its functions” (Forman and Godron, 1986, p. 182). Again without discussion of these three differing definitions he selects the last one and equates it to a residential lot. Later in the study a grain size of 30 meters is selected, conveniently just about the size of a
quarter acre lot. He justifies the 30-meter grain/lot size as being a division of the land most familiar to the resident. (It also happens that 30 meters was the cell sizes of the GIS base.)

Fuente de Val et al. (2005) attempted to connect landscape visual quality (preference) and landscape spatial pattern. Using two Mediterranean landscapes, one in Spain and the other in Chile, they compared ratings of 11 descriptors (scenic beauty, coherence, legibility, complexity, mystery, perspective [observer position], diversity, risk [hazard, sensu Appleton, 1975], color diversity, pattern, and patch shape) from photographs of landscape scenes. Nine indices of landscape pattern (number of patches, patch diversity, patch richness, evenness, interspersion, contagion, fractal dimension, visibility, and relief) were calculated for three scales depicted in the scenes. Respondents rated the landscape scenes; experts calculated the indices for three set “windows” or distance zones along the earth’s surface from the viewpoint. The window sizes were: (1) ‘foreground’—500 x 500 meters covering .25 km$^2$ (2) ‘mid-ground’—1000 x 1000 meters covering 1 km$^2$, and (2) ‘background’—5000 x 5000 meters covering 25 km$^2$. Criteria for selection of the window sizes were not discussed.

Dramstad et al. (2006) examined “whether map-derived [planview] indicators of landscape structure . . . are correlated with visual landscape preferences” (p. 465). Twenty-four photographs of landscapes within the 1 km$^2$ landscape inventory of the Norwegian 3Q program were rated for preference by a group of students (n=38) and local residents (n=53). The viewsheds (seen area) depicted in the photos were translated on to the 1:12 500 scale land use and cover maps. For this seen area nine metrics that included landscape content and configuration were calculated: total [seen] area (m$^2$), number of land [use] types, number of patches, heterogeneity index, Shannon’s diversity index, open area (m$^2$), percent openness, grain size of open areas, and length of edge.

The heterogeneity index was a specialized measure giving “the proportion of points that
are on different land [use] types.” … The “minimum heterogeneity value is zero, when all points fall on the same land type (large-scale) The “maximum value is one, when points in every pair fall on the different land types (small-scale landscape with a high degree of spatial division)” (Dramstad et al., 2006 p. 470). Grain size is a measure of “the number of patches of open land types divided by the total area of open land” (Dramstad et al., 2006, p. 470). The visual reason given for using grain size in relation to total open area was that “landscape elements such as a narrow hedge or grass bank between two fields (i.e., that divide the landscape into more patches) may change the visual impression of a landscape, even though total area of a more open landscape may be almost identical” (Dramstad et al., 2006, p. 470). (See Figure 3.) The preference scores for scenes were then correlated with the landscape metrics calculated for the seen areas. Several significant correlations were seen between preferences for a scene and the number of land (use) types, the number of patches and Shannon’s diversity index. They found “the total area of the viewsheds was positively correlated with the total open area, length of edge, and number of patches and negatively correlated with grain size” (Dramstad et al., 2006, p. 471).

Several components of scale appeared in the study. The variable, grain-size, brings into focus grain as a space seen by humans (e.g., Motloch, 1991, p. 110) sub-divided by edges that were not visual barriers (open or closed views). Furthermore, the viewshed approach attempted
Figure 3. On this rural stage does the foreground ditch create a smaller space? As a part of a *trompe-l’oeil* rural landscape, the viewer decides whether visual grain and extent reach the ditch, the trees or the horizon.

...to connect the total of what was seen of the landscape in the photographs of landscape scenes (called “viewshed”) with the landscape metrics. The viewshed represented a de facto extent.

Summary

What do the *Dimensions, Kinds, and Components of Scale* tell us about scale when examining visual landscape assessments? Since all of the studies chosen for review had a spatial component, it is not surprising that all had implicit or explicit concepts of space. Eight of the studies implied a connection with time and three specifically controlled for seasonal landscape effects. Eight studies employed hierarchies with some type of nesting: six of the studies used Background-Middleground-Foreground (B-M-F), three used Close-Far, two used Small-Transitional-Large, one used three unspecified distance zones and one implied an unspecified hierarchy.
The reviewed visual studies utilized mostly intrinsic, observational approaches though some had an experimental aspect that was tied to kinds of scale. As applied experiments, fifteen of the studies used or tested hypotheses or models and nineteen attempted to use their findings for design, planning, or management policies. As with much of biological landscape ecology work, visual landscape studies are strongly applied. While the dimensions and kinds of scale were widely utilized by researchers in the visual studies, components of scale, especially grain and extent, were explicitly used by only a few, though eleven of the studies or implied grain or extent. European researchers (Coeterier and Dijkstra, 1976; Fuente de Val et al., 2005; Dramstad et al., 2006) have begun to define and use more specific components of scale that are now spurred on by EU policies aimed at preserving rural landscape structure and amenity.

Table 2 summarizes each study’s use of Dimensions, Kinds and Components of Scale (after Wu and Li, 2006). Some studies such as those by Kaplan and Kaplan and their associates were grouped.

4.0 RESEARCH ISSUES TO BETTER INTEGRATE SCALE INTO VISUAL ASSESSMENTS

In addition to placing the studies within Wu and Li’s (2006) larger framework as noted above, this paper also identifies other scale-based issues important for visual assessments of landscape and needing further study.

Earlier in this paper, while defining scale in ecology and landscape assessments it became apparent absolute scale and relative scale need to be explicitly identified by visual researchers as is done by biological landscape ecologists. Gibson’s (1986) work as an environmental psychologist confirms that as ecological beings our perception is multi-scalar and nested hierarchically.

Table 2. Scale concepts present in twenty-one visual assessment studies sorted by use of components of scale especially grain and extent.
Table 2. Concepts present in twenty-one visual assessment studies sorted by their use of components of scale.

<table>
<thead>
<tr>
<th>Citation</th>
<th>Dimensions of Scale</th>
<th>Kinds of Scale</th>
<th>Components of Scale</th>
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<tbody>
<tr>
<td>Dramstad et al. (2006)</td>
<td>√ Space</td>
<td>Intrinsic</td>
<td>Grain</td>
</tr>
<tr>
<td>Fuente de Val et al. (2005)</td>
<td>√ √ Time</td>
<td>Experimental</td>
<td>Extent</td>
</tr>
<tr>
<td>Coeiter &amp; Dijkstra (1976)</td>
<td>√ √ Implied</td>
<td>Folicy</td>
<td>Sample spacing</td>
</tr>
<tr>
<td>Palmer &amp; Lankhorst (1998)</td>
<td>√ √ Nested</td>
<td>Implied</td>
<td>Map scaling</td>
</tr>
<tr>
<td>Zube, Pitt &amp; Anderson (1975)</td>
<td>√ √ Nested</td>
<td></td>
<td></td>
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<tr>
<td>Germino et al. (2001)</td>
<td>√ √ 3 Distance Zones</td>
<td></td>
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<tr>
<td>Hammitt (1988)</td>
<td>√ √ B-M-F</td>
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<td>Hammitt et al. (1994)</td>
<td>√ √ B-M-F</td>
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<td>Litton (1968)</td>
<td>√ √ B-M-F</td>
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<tr>
<td>Coeiter &amp; Dijkstra (1994)</td>
<td>√ √ Small-Transitional-Large</td>
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<tr>
<td>Hull &amp; Buhyoff (1983)</td>
<td>√ √ Close-Distant</td>
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<td>De Veer &amp; Burrough (1978)</td>
<td>√ √ Nested</td>
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<td>Gimblett et al. (1985)</td>
<td>√ √ B-M-F</td>
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<tr>
<td>Litton &amp; Tetlow (1978)</td>
<td>√ √ Nested</td>
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<td>Schaffer et al (1969)</td>
<td>√ √ B-M-F</td>
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<tr>
<td>Kaplan, R Kaplan, &amp; associates 1972-1989</td>
<td>√ √ Close-Far</td>
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<tr>
<td>Higuchi (1983)</td>
<td>√ √ B-M-F</td>
<td></td>
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<tr>
<td>Iverson (1985)</td>
<td>√ √ Nested</td>
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In visual landscape studies, absolute scaling (using a set standard) has been applied to perception of distance (Iverson 1985). Litton (1968) used the following standard for distances relating to foreground, middleground and background foreground: 0.40 to 0.80 km (0 to 1/4 or 1/2 mi), middleground: 0.80 to 4.83-8.0 km (1/2 to 3-5 mi), background: 4.83-8.0 km to infinity (3-5 mi to infinity) but did believe they could be modified. Felleman (1982, p. 258) notes the U. S. Forest Service says that these distance zones are “based on experience in the western U.S. and [applied] with a caution . . . [zones] must be determined on a case by case basis, as with any distance zoning.” Felleman (1982) went on to establish his own distance zone limits at 0.8 km (fore), 1.6 km (mid) and 3.5 km (back), for an eastern Great Lakes visibility study. Higuchi (1983) (Figure 2) used 140-360 meters (.08-.23 mi) and 3300-6600 meters (2.04-4.1 mi) as the break point between short distance and mid-distance and mid-distance and long distance respectively depending on cues from deciduous or evergreen vegetation.

Impacts on relative scaling (object, space, or object/space to their context) occur as we move not only laterally in the landscape, but also vertically. When we become elevated above and detached from the surroundings below, and if our view is not blocked, by moving into a cloud or enclosure within a tree canopy, two things happen, we see farther by now peering over the tops of former boundaries. Second, and coupled with the first, we can view the surfaces below in a revised relationship, seeing more of their tops and sides and less of their bottoms. Central features of elevated viewpoints make horizons more important and reveal and command ground planes. In sum, the observer also sees more of the surrounding landscape context.

Before enacting visual assessments protocols with variables impacted by scale, it seems reasonable to establish how absolute and relative scale are being used and to see just what variability might be apportioned to differing scale relationships. For example, Hull and Buhyoff (1983) began to examine them in their closely controlled experimental work and their approach
could be expanded with investigations of explicit levels of absolute and relative scale, how humans react and the impacts on perceived visual quality.

4.2 Research Need #2 Grain and Extent as Components of Scale

While Tveit et al. (2006, p. 242) propose a less detailed definition of visual scale as, “the perceptual units that reflect the experience of landscape rooms, visibility and openness.” What seems to be missing from the visual landscape assessment methods reviewed (Table 1) is an operational concept for relative scale. It could be adapted from landscape ecology where, grain and extent (resolution and scope) are used hierarchically to define scale. What would need to be resolved, however, is that landscape ecologists’ interests most often revolve around objects. As long as it is made clear that objects cannot be seen without intervening spaces and that spaces result from defining objects, then the care and rigor that biological landscape ecologists bring to defining grain and extent might be applied to visual landscape studies. It also means bringing an observer into the process as done by Kaplan (1979). For example, in visual landscape studies, grain could be conceptualized as the size of the space (however large) occupied by the viewer. Researchers should answer just what is the size range of such a space, if any, that a viewer perceives and how has a study related that space to the defining boundaries?

Grain and extent linked in a hierarchical relationship might be used to gauge relative scale (Sutton, 2011). Though it involves careful consideration. For example, selecting 30 m² as a lot (and grain) size as does Palmer (2004), fails to for account other visible landscape boundaries or compartments (De Veer and Burrough, 1978; Palmer and Lankhorst, 1998) thus locks the viewer into an absolute scale of space much like the set distance zones described above. For visual landscape studies, grain might best be put into operation by controlling for and varying the bounded space. Doing so accommodates human multi-scalar perception, but violates biological landscape ecologists’ need to standardize control grain size.
Furthermore, extent might be conceptualized as the visible spaces beyond the boundaries of a perceived envelope of space or thought of as the context in which that space is nested hierarchically (Sutton, 2011). While these conceptualizations make sense to most landscape architects’ understanding of space, they may not be thought of as universal among all humans (Sutton, 2011). For visual landscape studies, initial research is needed to examine the efficacy of a dynamic, interacting hierarchy of grain and extent to determine scale.

4.3 Research Need #3 Understanding the Relationship of Visual Extent and Distance of View

Many researchers assessing visual landscapes confuse the conception of scale as merely distance or distance of view. They collect and examine data without stating what was their net and mesh size. For example, they do not acknowledge that to understand scale in visual landscape studies, there must be some level of extent for comparison with grain and lacking it, the observer is left simply with the grain he or she occupies.

Hull and Buhyoff’s (1983) empirical study concluded that distance of view as a variable is not singular and may represent composite effects. Coeterier’s (1994) work begins to explain some of the cognitive processing needed to explain spatial configuration’s impact on preference for landscape scenes. From his work, scale can be surmised to play a role integrating distance and spatial size, two aspects of configuration of scale.

Palmer and Lankhorst (1998) struggled with modeling landscape space. When they assumed that “landscape enclosure or spaciousness is represented by the sum of the wooded and urban areas or the total area filled with landscape objects” (p. 68), they appear to be using a percolation model (Turner et al., 2001) based on visibility in which what is detected of spaciousness is modified by objects with in the landscape. However, simply filling a space (or grid cell) with opaque objects may or may not affect its spaciousness if, 1) the objects are closer or further away from the observer (i.e. locus of photographed view) in a 250 m x 250 m cell, 2)
the objects occur on the cell’s perimeter, or 3) there are openings in the array of objects at the edge of the cell. The last situation likely led to their creation of a more predictive modified model using what they call a neighbor effect, though Palmer and Lankhorst (1998) offer no explanation tied to any theory why their modified model was better. The root of the problem may be the substitution of spatial distance for scale.

Misunderstanding potential importance of spatial extent also occurred in work by Ruddell et al. (1989). They didn’t, but if we did conceptualize their work as having both a grain and extent component, their study scenes could be described a small-grained and limited in extent. They found that degree of spatial enclosure was significantly related to scenic beauty in photos. However, there may not have been great enough range of differing extents to support the constrained examples of enclosure. A reviewer of this paper has suggested that an observer who knows the area may in fact supply more spatial information about the scene by remembering the extent of a circumscribed landscape setting. Remembrance and inference, however, require some higher-level cognition (e.g. recall, pondering and judgment), not in line with Gibson’s (1986) direct, automatic and subconscious reactions. Perhaps careful screening of questions for the study participants could have controlled for the impact of such remembering.

Palmer (2004) uses viewsheds to help delimit boundaries. Though he also relies on viewer memory and inference by selecting the political boundary of Dennis, MA as the extent. While indeed a (political) boundary, the city limits of Dennis, MA, may or may not be strongly visible and thus irrelevant to visual studies proffering direct visual stimuli as photographs of landscape scenes.

Research on visual qualities that controlled for differences in grain and extent might eliminate the current use of distance-of-view as a substitute for scale or extent.

4.4 Research Need #4 Relevance and Interaction of Space and Mass in Understanding Spatial
Scale

Humans perceive spatial wholes defined by edges of massive patches, but may not perceive such a patch as a whole. This is a difficulty similar to understanding landscape spaciousness (Coeterier, 1994) or where landscape objects occupy and dominate a cell in Palmer and Lankhorst (1998). Kaplan (1985, p. 174) notes, “The task of visual assessment and visual resource management, then, must focus on the organization and pattern of spaces and on the interpretations of these spatial characteristics in terms of human functioning.” (Emphasis added.)

Dramstad et al. (2006) begin to address this issue when they operationalized a concept they call “space-grain”. Grain-size measures “the number of patches of open land types divided by the total area of open land” (p. 470). The reason given for visualizing grain size in relation to total open area was that, “landscape elements such as a narrow hedge or grass bank between two fields (i.e., divid[ing] the landscape into more patches) may change the visual impression of a landscape, even though total area of a more open landscape may be almost identical.” (See Figure 3.)

Landscape architects are quite familiar with the space versus mass and space and mass conundrum. If one concentrates on the masses of boundary one simply sees an object’s edge or possibly an object in space. On the other hand one can be cognizant of the mass while primarily focusing on the shape, size, quality etc. of the space as Dramstad et al., (2006) begin to do with “space-grain” concept. Because of its concrete simplicity, the first approach, mass awareness, is inherent in raster-based delineation, or becomes embedded in biological landscape ecologists’ definition of scale. For example, Turner et al. (2001) say, “grain is the finest spatial resolution with in a given data set” (p. 43). A reviewer of this paper noted that Turner et al.’s (2001) concept of scale and grain dealt in objects (i.e. masses) down to one pixel. However this paper posits that space and mass interact and thus more visual information emerges for the viewer.
Humans with our hierarchical perception (Gibson 1986) likely evolving in relationship to a hierarchical physical environment, can easily understand and react to space while still remaining cognizant of the embedded masses. If we could not do so finding our way would be difficult if not impossible.

Researchers need to devise concepts, methods and measures, like space-grain that acknowledge, parse, and account for variation in space and mass and its human perception.

4.5 Research Need #5 Resolving the Chorological Nature of Visual Landscape Assessments with the Topological Nature of Psycho-physical Landscape Metrics

Chorological versus topological is a more generalized problem of the space/mass interaction. While much can be gained from exploring the use of psychophysical measures, researchers should understand and use logical typing so that the metrics are believable. For example, Germino (2001), Palmer (2004), Fuente de Val et al. (2005), and Dramstad et al. (2006) attempt to apply landscape ecological metrics garnered directly from plan view or even remotely sensed sources to directly gauge preference for visual landscapes. Palmer’s knowledge of human landscape perception (Palmer 1986) should be used to translate landscape ecological concepts into visual and spatial terms. Humans require an envelope of space in order to perceive mass (Recommendation #4 above). Lacking that space impacts perceptual and preference outcomes (Ruddell et al. 1989, Kaplan, 1979, Kaplan and Kaplan 1989).

Visual studies are chorological (Zonneveld, 1990), horizontal, subjective and multi-scaled perspectives (Gibson 1986). Conversely, landscape metrics are topologic, vertical (Zonneveld, 1990), objective, one-scaled and 2-dimensional. Germino et al. (2001) have shown there is poor correspondence between landscape metrics from eye level and planimetric views. Therefore, if one attempts to directly correlate landscape preference with landscape metrics, you may be altering scale effects, scaling up or scaling down (Wu and Li, 2006) without knowing it.
Humans have the ability to learn and integrate knowledge about their surroundings. Since most humans (excepting pilots) do not and have not widely experienced the world from above, it stretches credibility to use vertical views to create perceived environmental qualities. Perhaps the way around this would be to create ecological indices from the horizontal perspective scenes. Early studies (Shafer et al., 1969) started in this direction and it might be possible to use viewsheds as samples for metrics created from plan view while correlating them with the scene used to generate the viewshed. This is a technique Dramstad et al. (2004) appear to be using.

4.6 Summary of Recommended Research Inputs for Ecology of Scale in Visual Landscape Studies

As suggested by studies in this review the five inputs below are recommended for further research to define, recognize, and more fully incorporate scale into visual landscape studies:

1) explicate use of absolute and relative scale
2) compare traditional and multi-scalar, hierarchical approaches
3) examine and revise the current reliance on substitution of distance for extent or scale
4) compare space/mass interactions, not simply masses, to determine visual grain
5) design research protocols in which psychophysical metrics correlate more logically with eco-physical metrics.

In the last forty years visual landscape studies have indeed become more ecological. They are, in fact, simultaneously ecological and psychological, because humans inhabit and respond to landscape structure, function, and change. Future studies and theory must continue to become more cognizant of scale factors because the hierarchical structure of the landscape interacts with a hierarchical system of human sensory perception to create information, much of it dealing with environmental and landscape quality.
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