ECOLOGY OF SCALE IN VISUAL ASSESSMENTS

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Abstract.—Background readings on scale plus 21 visual landscape assessment studies 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 vis-à-vis landscape ecological scale, and 3) identify issues that need further research to better integrate scale into visual landscape assessments and landscape ecological theory. 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 reliance on substitution of distance for extent or scale; 4) compare space/mass interactions, not simply masses, to determine visual grain; and 5) design research protocols in which psychophysical metrics correlate more logically with eco-physical metrics.

INTRODUCTION

Scale is a familiar term to landscape architects. One of many visual relationships taught in introductory studios, it helps 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 (Turner et al. 2001, Wu and Li 2006). As studies (e.g., De la Fuente de Val et al. 2005, Dramstad et al. 2006, Palmer 2004) attempt to connect visual quality of landscapes with their ecological structure, it becomes more important to understand the role of scale.

Wu et al. (2006) note that environmental planners and designer rarely apply scale theory. Visual assessment studies, however, continually find present a spatial (and hence an implied scale) component (Gobster and Chenoweth 1989, Kaplan 1979). Furthermore, Gobster (1993), Gobster et al. (2007), Nassauer (1997), and Tveit et al. (2006) 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 compared to landscape ecological scale, and 3) identify issues that need further research to better integrate scale into visual landscape assessments and theory. Together, the objectives examine scale as a set of distinct relationships between humans and their physical and visual environment that emerge as a kind of "ecology of scale."

BASIC CONCEPTS OF SCALE

Forman and Godron (1986) define scale as "the level of spatial resolution perceived or considered." 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 (Fig. 1). Relative scale best captures dynamic aspects of human scale perception, but several factors such as boundary visibility, hierarchical structure, spatial grain, and extent must also be considered.

Bounding Visibility

Perceiving land results in landscape. *Not* seeing land due to darkness or fog or some opaque occluding barrier, one is blind to landscape surfaces (Gibson 1986). So visibility is a basic ingredient of assessing landscapes and their scale (Felleman 1979 and 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

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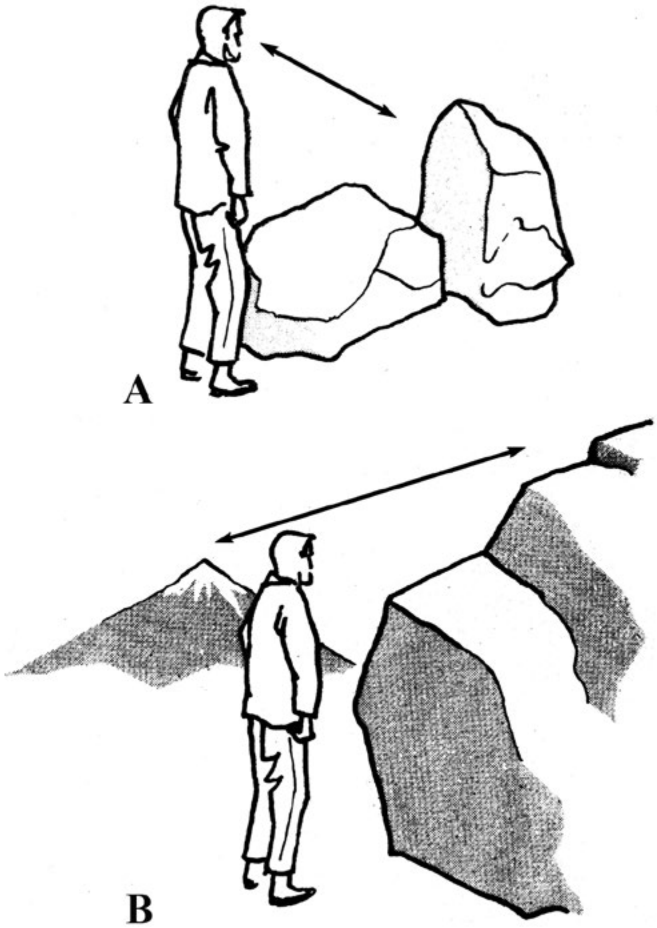

Figure 1.—Example of A) absolute scale—where comparison is to a known standard (e.g., human body); and B) relative scale—where comparison is to its context. Image from USDA Forest Service 1973.

or grain (Ahl and Allen 1996, Turner and Gardner 1991). 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 that arbitrary, fixed boundaries are important. Boundaries get our attention (Kaplan and Kaplan 1989, Litton and Tetlow 1978).

Perceiving Scale

Coeterier (1996) 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 contribute to perceiving size and distance. Coeterier concluded that human size and depth, or distance clues, represent unique processes and use different cues or the same cues differently. Space perception integrates distance and size (Coeterier 1994). 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). 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.

Seeing Hierarchically

Gibson (1986) explains how we see hierarchically in a hierarchical world using what he called "invariants in the visual array" to find our way around. To Gibson (1986), a place is contained within a larger place and differs from a Cartesian coordinate point. He describes surfaces of boundaries that affect visibility, controlling and filtering information from the surrounding ambient array. These surfaces can be detailed as to their textures and "… units of texture are generally nested [e.g., hierarchical] within one another at different levels of size" (p 28). Accordingly, we innately see hierarchically and derive information about the landscape by interpreting and nesting optical angles. He states, "Equal amounts of texture for equal amounts of terrain suggests that both size and distance are perceived directly" (p. 162). We apply scale hierarchically, so seeing in scale must 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). Landscape ecologists (Allen and Hoekstra 1992, Allen and Starr 1982, Turner and Gardner 1991) are concerned with scale and hierarchies because the objects and processes may vary with scale. Setting the scale for an investigation or sampling of physical landscape is an important step and must be explicit.

Researchers who use scale to investigative landscape ecological analyses apply hierarchy theory to order 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 human-made obstacles), 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, it requires us to constantly scale up and scale down.

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. For example, to sample whales and plankton, the size of the overall net is the extent and the size of the net's mesh is the grain. For 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. 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 and study.

This analogy holds with human observation of the landscape because our moment-to-moment views are 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 be explicit when we describe the relationships between parts at a lower level.

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

LINKING LANDSCAPE ECOLOGY, SCALE, AND VISUAL STUDIES

Landscape ecologists have clearly defined scale and explicitly used it in structuring their studies. Because visual assessments are often used alongside other environmental or ecological studies, it is useful to compare how scale is used. Landscape ecologists 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. 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 have a slower return time, 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).

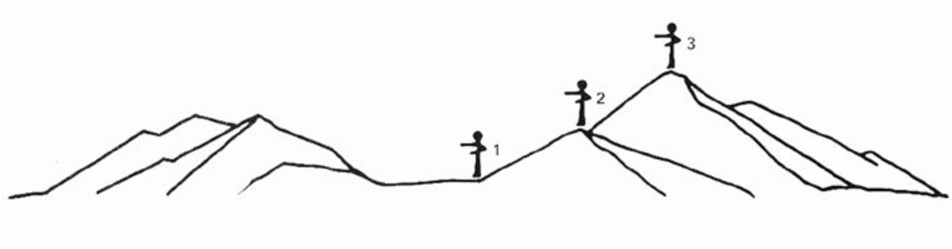

Figure 2.—Observer positions affect a viewer's understanding of scale. Elevated position (3) allows the observer to view a larger area of landscape thus moving the observer to a higher hierarchical level than observers 1 or 2. Image from Litton 1968, used with permission.

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. Assuming an elevated view (what Litton [1968] calls "observer superior position") (Fig. 2) 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, 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 [or her] knowledge and interest in the operation of the syste ... 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 as 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. 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., Litton and Tetlow 1978, Zube 1970) 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 (2006) 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 (Silbernagel 1997). Wu and Li (2006, p. 9) define relative scale as "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 by Bell (1993) 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.

REVIEW OF LANDSCAPE ASSESSMENT STUDIES

What might be considered a visual landscape study? Some refer to them as landscape assessments (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), visual preferences (Dramstad et al. 2006, Kaplan and Kaplan 1989), aesthetic preferences (Gobster and Chenoweth 1989), landscape perceptions (Palmer 2003), or scenic beauty estimates (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, Hammitt et al. 1994, Sutton 1997), and they may imply an interest in quality (Palmer 2003).

Twenty-one visual landscape studies (Tables 1a, 1b, and 1c) were examined for how they addressed scale linkage and corresponded with Wu and Li's (2006) conceptual structures. Many others were reviewed but not included because of space limitations. Some of those selected are more conceptual than applied; only detailed, published studies that featured scale, hierarchy, or space were used. While the review covers work from an earlier period (1968–2006), it remains relevant to current theory, practice, and technology.

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 tied to kinds of scale. As applied experiments, 15 of the studies used or tested hypotheses or models and 19 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 11 implied grain or extent. European researchers (Coeterier and Dijkstra 1976, De la 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 European Union policies aimed at preserving rural landscape structure and amenities.

TOWARD A BETTER INTEGRATION OF SCALE WITH VISUAL LANDSCAPE ASSESSMENTS

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

Research Need #1: Using Relative versus Absolute Scale

Earlier in this paper, while defining scale in ecology and landscape assessments, it became apparent that 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.

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 but did believe they could be modified: foreground 0.40 to 0.80 km (0 to ¼ or ½ miles), middleground 0.80 to 4.83–8.0 km (½ to 3–5 miles), background 4.83-8.0 km to infinity (3-5 miles to infinity).

Table 1a.—Dimensions of scale compared with 21 visual assessments

Citation	Dimensions of scale		
	Space	Time	Hierarchical org.
Coeterier (1994)	√	√	Small-trans-large
Coeterier and Dijkstra (1976)	√	Implied	Small-trans-large
DeVeer and Burrough (1978)	√	Implied	Nested
Dramstad et al. (2006)	√	√	Nested
De la Fuente de Val et al. (2005)	√	√	Nested
Germino et al. (2001)	√	√	3 Dist. Zones
Gimblett et al. (1985)	√	√	B - M - F
Hammitt (1988)	√	Implied	B - M - F
Hammitt et al. (1994)	√	Implied	B - M - F
Higuchi (1983)	√	Implied	B - M - F
Hull and Buhyoff (1983)	√	√	Close-dist.
Iverson (1985)	√	√	Nested
Kaplan, Kaplan et al. (1979-89)	√	Implied	Close - Far
Litton (1968)	√	Implied	B - M - F
Litton and Tetlow (1978)	√	Implied	Nested
Litton et al. (1974)	√	√	Nested
Palmer (2004)	√	√	Nested
Palmer and Lankhorst (1998)	√	√	Nested
Ruddell et al. (1988)	√	√	Near - Far
Shafer et al. (1969)	√	√	B - M - F
Zube et al. (1975)	√	√	Implied

Table 1b.—Kinds of scale compared to 21 visual assessment

Citation	Kinds of scale				
	Intrinsic	Obs.	Exp.	Model	Policy
Coeterier (1994)	√	√	√	√	
Coeterier and Dijkstra (1976)	√	√	√	Implied	√
De la Fuente de Val et al. (2005)	√	√	√	√	√
DeVeer and Burrough (1978)	√	√	√	√	√
Dramstad et al. (2006)	√	√	√	√	√
Germino et al. (2001)	√	√	√	√	√
Gimblett et al. (1985)	√	√	√		
Hammitt (1988)	√	√	√	√	√
Hammitt et al. (1994)	√	√	√	√	√
Higuchi (1983)	√	√		√	√
Hull and Buhyoff (1983)	√		√	√	
Iverson (1985)	√				√
Kaplans et al. (1972-89)	√	√	√		√
Litton (1968)	√	√	√	√	√
Litton and Tetlow (1978)	√	√			
Litton et al. (1974)	√	√	√		√
Palmer (2004)	√	√		√	√
Palmer and Lankhorst (1998)	√	√	√	√	√
Ruddell et al. (1988)	√	√	√	√	√
Shafer et al. (1969)	√	√	√	√	√
Zube et al. (1975)	√	√		√	√

Table 1c.—Components of scale for 21 visual assessments

Citation	Components of scale				
	Grain	Extent	Cover.	Sample spacing	Map scaling
Coeterier (1994)	Implied	Implied			
Coeterier and Dijkstra (1976)	√	√	√	√	
DeVeer and Burrough (1978)	Implied				
Dramstad et al. (2006)	√	√	√	√	√
De la Fuente de Val et al. (2005)	√	√	√	√	√
Germino et al. (2001)	Implied	Implied	√	√	
Gimblett et al. (1985)					
Hammitt (1988)	Implied	Implied	√	√	
Hammitt et al. (1994)	Implied	Implied	√	√	
Higuchi (1983)					
Hull and Buhyoff (1983)	Implied	Implied			
Iverson (1985)					
Kaplan, Kaplan et al. (1979-89)					
Litton (1968)	Implied	Implied			
Litton and Tetlow (1978)					
Litton et al. (1974)					
Palmer (2004)	√	√	√	√	√
Palmer and Lankhorst (1998)	√	Implied	Implied	√	
Ruddell et al. (1988)			√	√	
Shafer et al. (1969)			Implied		
Zube et al. (1975)	Implied	√	√	√	

Felleman (1982) notes that the USDA Forest Service says that these distance zones are in the West and care should not be applied without thinking. He 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) used 140–360 m (0.08–0.23 miles) and 3,300–6,600 m (2.04–4.1 miles) as the break point between short distance and mid-distance and mid-distance and long distance, respectively, depending on textural cues from deciduous or evergreen vegetation. Texture is scale dependent.

Impacts on relative scaling (object, space, or object/space to their context) (Fig. 1) occur as we move not only laterally in the landscape, but also vertically. When we become elevated above and detached from the surroundings below, two things happen. First, 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 (Fig. 2).

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

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

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 most visual landscape assessment methods reviewed (Table 1a, 1b, 1c) 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

Figure 3.—Grain, indicated by a small area in foreground and limited extent, results in small grain and small scale. Photo by Richard K. Sutton, used with permission.

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 (Fig. 3). Researchers should answer: Just what is the size range of such a space, if any, that a viewer perceives and how does a study relate 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 square meters as a lot (and grain) size, as Palmer (2004) does, fails to account for other visible landscape boundaries or compartments (De Veer and Burrough 1978, Palmer and Lankhorst 1998). This 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.

Extent might be conceptualized as the visible spaces and their boundaries 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

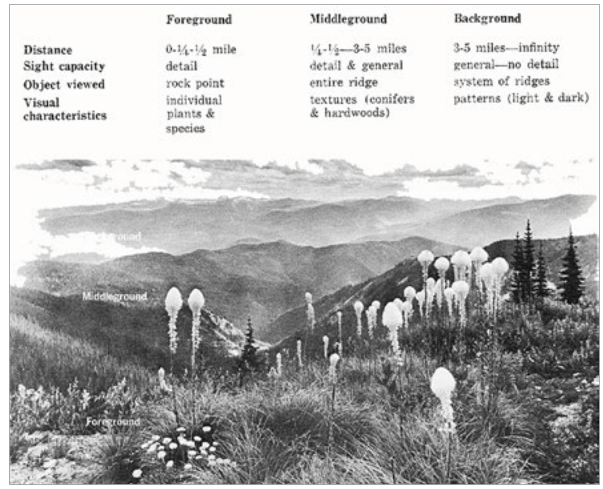

Figure 4.—Distance zones seem reasonable for the western forests, but maybe need rethinking in other contexts. Image from USDA Forest Service 1973.

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.

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 (Fig. 4). They collect and examine data without stating a net and mesh size. Often, they do not acknowledge that to understand scale in visual landscape studies, there must be some level of extent (context) 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 concludes that distance of view is a variable; it is not singular and may represent composite effects. Coeterier's (1994) work begins to explain some of the cognitive processing needed to understand spatial configuration's impact on preference for landscape scenes. Coeterier's work surmises that scale integrates distance and spatial size, two aspects of configuration of scale.

Palmer and Lankhorst (1998) struggled with modeling landscape space. When they assume 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

Figure 5.—Visual assessments must focus on spatial qualities while simultaneously understanding the masses with which spaces interact. Masses create boundaries to spaces but are often not completely opaque or continuous. Photo by Richard K. Sutton, used with permission.

Figure 6.—On this rural stage, does the foreground ditch create a smaller space? As a part of a trompe-l'oeile rural landscape, the viewer decides whether visual grain and extent reach the ditch, the trees, or the horizon. It illustrates the Dramstad et al. (2006) concept of space-grain. Photo by Richard K. Sutton, used with permission.

a percolation model (Turner et al. 2001) based on visibility in which objects within the landscape modify spaciousness. 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 farther away from the observer (i.e., locus of photographed view) in a 250-m × 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 modified and improved predictive model using what they call a neighbor effect, though Palmer and Lankhorst (1998) offer no explanation tied to any theory about why their modified model was better. The root of the problem is the substitution of spatial distance for scale.

Ruddell et al. (1989) also misunderstand the potential importance of spatial extent. If we conceptualize their work as having both a grain and extent component (which they did not), their study scenes all could be described as small-grained and limited in extent. They found that the 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 such conclusions based on the constrained examples of enclosure.

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, is likely not strongly visible and would thus be irrelevant to visual studies proffering direct visual stimuli as photographs of landscape scenes.

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

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

Humans perceive spatial wholes defined by edges of massive patches (Fig. 5) but may not perceive 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 for 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 operationalize a concept called "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 is 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" (Fig. 6).

Landscape architects are quite familiar with the space versus 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 their "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). 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, then finding our way around in the world 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.

Research Need #5: Resolving the Chorological Nature of Visual Landscape Assessments With the Topological Nature of Psychophysical 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 et al. (2001), De la Fuente de Val et al. (2005), Dramstad et al. (2006), and Palmer (2004) all attempt to apply landscape ecological metrics garnered directly from plan views 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 (Kaplan 1979, Kaplan and Kaplan 1989, Ruddell et al. 1989).

Visual studies are chorological (Zonneveld 1990), horizontal, subjective, and multi-scaled perspectives (Gibson 1986). Conversely, landscape metrics are topologic, vertical (Zonneveld 1990), objective, single-scaled, and two dimensional. Germino et al. (2001) show there is poor correspondence between landscape metrics from eye level and planimetric views. Therefore, if you attempt to directly correlate landscape preference with such 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. (2006) appear to be using.

CONCLUSIONS

In the last 50 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. If citations in Table 1a, 1b, and 1c were ordered chronologically it would show more recent visual studies cover more of Wu and Li's (2006) scale ideas. Future studies and theory must continue to become more cognizant of scale factors because the hierarchical structure of the landscape interacts with our hierarchical system of human sensory perception to create information, much of it dealing with environmental and landscape quality.

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