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ABSTRACT—Landscapes such as the Great Plains have been described as lacking human scale. This study developed a quantitative model of human scale and compared it with viewers' perceptions of visual structure. Visual structure was selected from the physical features of Otoe County, NE, forming boundaries, found as ground textures, vegetative screens, and topographic breaks and was depicted in photographs of landscape scenes. The model used and tested nine classes of scale based on grain and extent of the photos rated by viewers against those from the model. Viewers identified boundaries representing grain and extent that were synthesized into a viewer-perceived scale class. Good agreement with the proposed model occurred at four smaller scales but deteriorated as scale increased. Larger-scale scenes appear to offer more opportunities for the viewer to select closer or farther visual boundaries, thus changing their interpretation of scale.

Key Words: grain, extent, visual structure, landscape structure, visual assessment

INTRODUCTION

Scale connects humans to their environment. Absolute scale (Fig. 1) relates "the size of any object to a definitely designated standard" and relative scale (Fig. 2) refers to "the size [comparison] . . . between landscape components and their surroundings" (Grinde and Kopf 1986:329). Both types of scale interest an array of researchers: landscape ecologists (Meentemeyer and Box 1987; Wiens 1989, 1992; Turner et al. 1991; Allen et al. 1993), archeologists (Lock and Molyneaux 2006), geographers (Harvey 1968; Montello 1993, 2001), psychologists (Coeterier 1996; Schyns and Oliva 1994; Henderson and Hollingsworth 1999), and landscape architects (Fabos et al. 1975; Zube et al. 1975; Toth 1988; Stiles 1994; Swaffield 2005; Swaffield and Primdahl 2006).

The perceived quality of the landscape has been studied for nearly 40 years (Daniel 2001), and interest in perception quality has included some interest in scale effects. Landscape quality studies support environmental assessments mandated by the U.S. National Environmental Policy Act (NEPA 1969). In 2000 the European Landscape Convention also bolstered assessment of rural landscapes and aesthetic quality (Déjeant-Pons 2007). Some investigators mention scale in connection with landscape structure and its impact on quality of life (Zube et al. 1982; Gobster 1993; Coeterier 1994; Eaton 1997; Nassauer 1997; Sutton 1997; Bhakuni 2000; Tveit et al. 2006; Gobster et al. 2007).

Human perception and experience of landscape are important because we, as the dominant species on most of the earth, rely on our perceptions and experiences in making judgments about the existing landscape structure, function, and future changes. These judgments affect decisions regarding use and management of landscapes (Fedorwick 1993; Nassauer 1995; Sutton 1997; Gobster et al. 2007). For example, Thorne and Huang (1991) proposed modifying landscape structure in a rural New York watershed only to the extent that changes did not degrade the wildlife habitat and block scenic views.

Humans are biological and ecological creatures as well as cognitive, social, and intellectual. We respond to the structure and scale of landscapes, and thus are affected by the structure and scale of landscapes. Scale is a feature of the landscape, a component of visual organization, and an interactive process, all of which engage human beings and relay information about our ambient environment.

Researchers have developed no explicit models of human scale, although Montello (1993) has verbally described a model. This study proposes a model aimed at measuring and understanding attributes of the human

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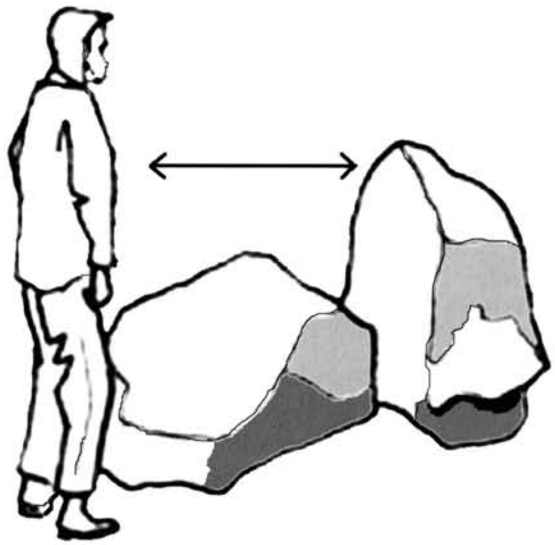

Figure 1. Absolute scale compares the rock to the human body as a standard (after USFS 1973).

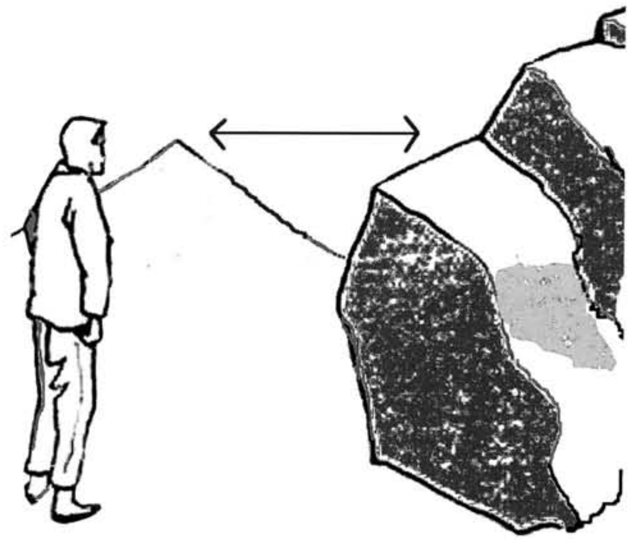

Figure 2. Relative scale compares a landscape feature to its landscape surroundings (after USFS 1973).

scale as affected by the structure of a portion of the Great Plains agricultural landscape.

Scale

Forman and Godron (1986:15) state that scale is "the level of spatial resolution perceived or considered," while Allen and Hoekstra (1992:4) declare that "scale independent entities do not change their qualities when perceived at different scales." While these ideas seem contradictory, human scaling of landscapes appears to use both. Scale relates the size of objects, but because of the optics of the human eye, the apparent size of objects diminishes with distance, and it is easy to interchange clues about size (Fig. 3) with clues about distance (Iverson 1985; Coeterier 1994). Therefore human scale also applies to perception of relative distance. Montello (1993) verbally described a hierarchy of four human scales: (1) *figural scale*, smaller than a human and containing objects manipulated by them; (2) *vista scale*, as viewed from one point; (3) *environmental scale*, which requires movement and multiple viewpoints to understand it; and (4) *geographic scale*, which can only be assessed indirectly via maps or remotely sensed media. Ahl and Allen (1996) have explained spatial scale as hierarchical and rather like a fishnet. Everything not captured by the net is merely background. That is, the smallest thing captured is a function of the size of the mesh, and the largest thing, of the size of the net. This mesh size is the grain, whereas the size of the net is the extent. Observers of a landscape in Montello's vista scale cast their view rather like a net, but in the process of perception likely make a decision about what constitutes the smallest space in which they reside. The visible landscape beyond (to as far as one can see) would then become the viewer's extent.

The process is similar to fishing with a net, except for two potentially conflicting differences: (1) not every observer may use the same size grain, and (2) the very structure of boundaries in the landscape works to suggest a grain and an extent. Landform, vegetative walls, or breaks in surface texture can trigger a boundary designation, and if one focuses upon the grain, then the extent becomes background (Fig. 4). Two basic features that affect scale are landscape structure and what humans interpret from this space as visual structure.

Landscape Structure

Forman and Godron (1986:595) define landscape structure as "the distribution of energy, materials and species in relation to the sizes, shapes, numbers, kinds and configurations of landscape elements." Landscape structure, then, becomes the arrangement, organization, and physical juxtaposition of fixed biological, abiotic, and cultural entities. For example, most dominant in the rural landscape are vegetation, landform, and land cover. Scale becomes a way to describe the relative size and distances inherent in landscape structure.

Landscape structure as a fixed pattern becomes similar to Gibson's (1986) "invariant structure." Invariant structure operates as a limit or boundary. Examples

Figure 3. Scale relates the size of objects. These hay bales diminish with distance and imply scale.

Figure 5. Horizons, topographic breaks, and vegetation represent invariant structure.

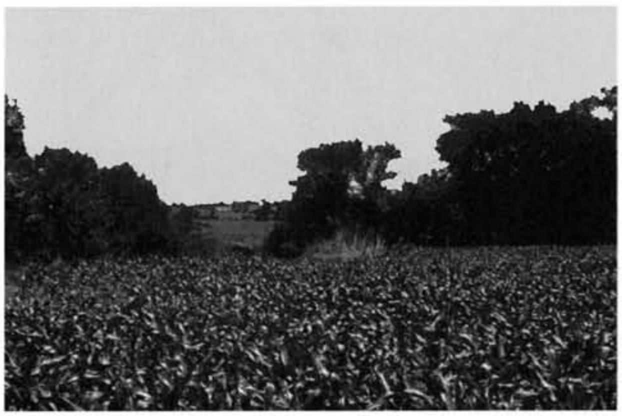

Figure 4. Boundaries parse the rural landscape.

of invariant structure are horizons, vertical topographic breaks, and vegetation barriers (Fig. 5). Such structure contains, halts, or slows the flow of species, energy, nutrients (Forman and Godron 1986), and information (Cadenasso et al. 2003; Wiens 2005). Visible information for humans is a critical aspect of the informational theory of landscape preference (Kaplan and Kaplan 1989).

For the landscape ecologist, physical processes such as erosion, and ecological processes such as species succession, respond to structure over space and time. Yet if we take the idea of landscape structure further to examine how humans act on and react to landscapes, then structure is a basis for studies of <u>both</u> visual and ecological processes (McCarthy 1979; Lyle 1985; Gibson 1986; Barrett and Bohlen 1991; Thorne and Huang 1991). Thus, when humans visually perceive, consider, and act on the structure of a landscape, it is transformed into visual structure. Gobster et al. (2007:960) call this "perceptible structure" and they include other senses besides sight.

Visual Structure

Visual structure is an anthropocentric construct representing a viewer's interpretation of arrangement, importance, and meaning of landscape structure. Visual structure is tied to a place and arises from landscape structure, yet it obviously does not occur without an observer. So, visual structure could be examined as aggregations of basic human perceptions and responses.

Schauman and Pfender (1982:107) and Schauman (1988a, 1988b) describe visual structure as "the range of landscape spatial conditions: from those that offer unlimited but undefined views to those that offer no vista or where all views are blocked." Implicit in their definition are humans who see visual structure from a viewpoint (Montello 1993). Gibson (1986) describes this activity as gaining "perspective structure." Visual structure, just as Gibson's (1986:75) perspective structure, "contains information about the potential observer, not about the environment as the invariants do." The viewpoint or the motion of a roving observer controls incoming information about the environment. Using visual structure places the observer in the system.

The viewer responds to the scale of a scene. For example, a major component of human perception is the mind's ability to imagine and cognize. In those, scale has been recognized as a component (Kosslyn 1994). But perception and cognition, like visual structure, must be based on or triggered by something physical. According to Gibson (1986:284), the "invariants [of physical structure] display a world with nobody in it and the perspective displays where the observer is in that world. . . . To the extent that the invariants are detected, all observers will perceive the same world." To the extent that landscape structure is selected, interpreted, and scaled by an observer, a visual structure appears.

GRAIN AND EXTENT

By identifying structural boundaries, we can use the concepts of grain and extent to examine human scale.

Boundaries

In both the landscape structure and visual structure of a particular place, scale can be identified as a combination of grain and extent (also sometimes called resolution and scope) (Schneider 1994; Kosslyn 1994). Regarding visual structure, grain is the smallest area of interest to the observer (i.e., the mesh size of the net); extent defines all else that can be seen beyond, thus offering a context for grain (i.e., the size of the net). The observer, however, decides what to focus on and what to call grain and extent.

Boundaries mark an edge or contrast between contiguous land areas (Schauman 1988b). Cadenasso et al. (2003) propose a theory of boundary functioning categorizing impacts on movements across open space into: (1) type of flow, (2) patch contrast, and (3) boundary structure. Boundaries represent structural constraints on visual information, separating surfaces and defining what is perceivable of the landscape spaces. Thus, these spaces become visual entities or wholes determined by the homogeneity of surfaces (often the ground plane) (Brown 1994) (Fig. 6). One unique aspect of landscape as a visual phenomenon arises in the variability in the composition and location of its boundaries. Boundaries that are longest, tallest, and most dense have the greatest power to constrain our visual information, enclose a space, and most strongly fix its perceived grain (Schauman 1988b; Hammitt 1988). Tveit et al. (2006) describe these as a "grain space." The relative order of the assessed strength of a boundary is linked, first, to how tightly any given homogeneous space or grain holds together visually to form a whole, and second, to the relative importance of the boundaries delimiting it (Fig. 7). Topographic breaks, vegetative barriers, and ground pattern represent basic classes of landscape boundaries found in rural landscapes.

The viewer determines a boundary's importance because boundaries vary in their capacity to hold attention and filter information. One becomes aware of the larger landscape beyond a primary space stretching to other visible but less dominant boundaries in the distance. Distant boundaries would then most likely form the context, or extent. Distant boundaries also suggest visual relationships between a primary space of interest and other larger ones that could be selected from those that encompass it.

Figure 6. Fields planted to the same crop and treated with the same conservation techniques display homogeneity of surface.

Figure 7. The grassed waterway slices through this field. Does it possess enough visual strength to overcome the field as a "space grain"?

To illustrate what grain and extent mean in relation to visual structure, imagine a person at some point in a landscape (see Figs. 8 and 9). Figure 8 is reproduced from the Elmwood, NE, quadrangle (USGS 1966) and depicts a planimetric view of a landscape's topographic structure. Projected on this map is a portion of the limits to a stationary observer's vision cone looking northwest from the designated viewpoint. Figure 9 shows what might be interpreted about the landscape's boundaries moving sequentially out from his or her location. (The boundaries for each corresponding horizontal limit of view in Fig. 9 are marked by letters and are shown and noted similarly in Fig. 8).

First, it is likely that the viewer might unconsciously and quickly expand his or her focus to a visual boundary—one that offered enough contrast, density, and

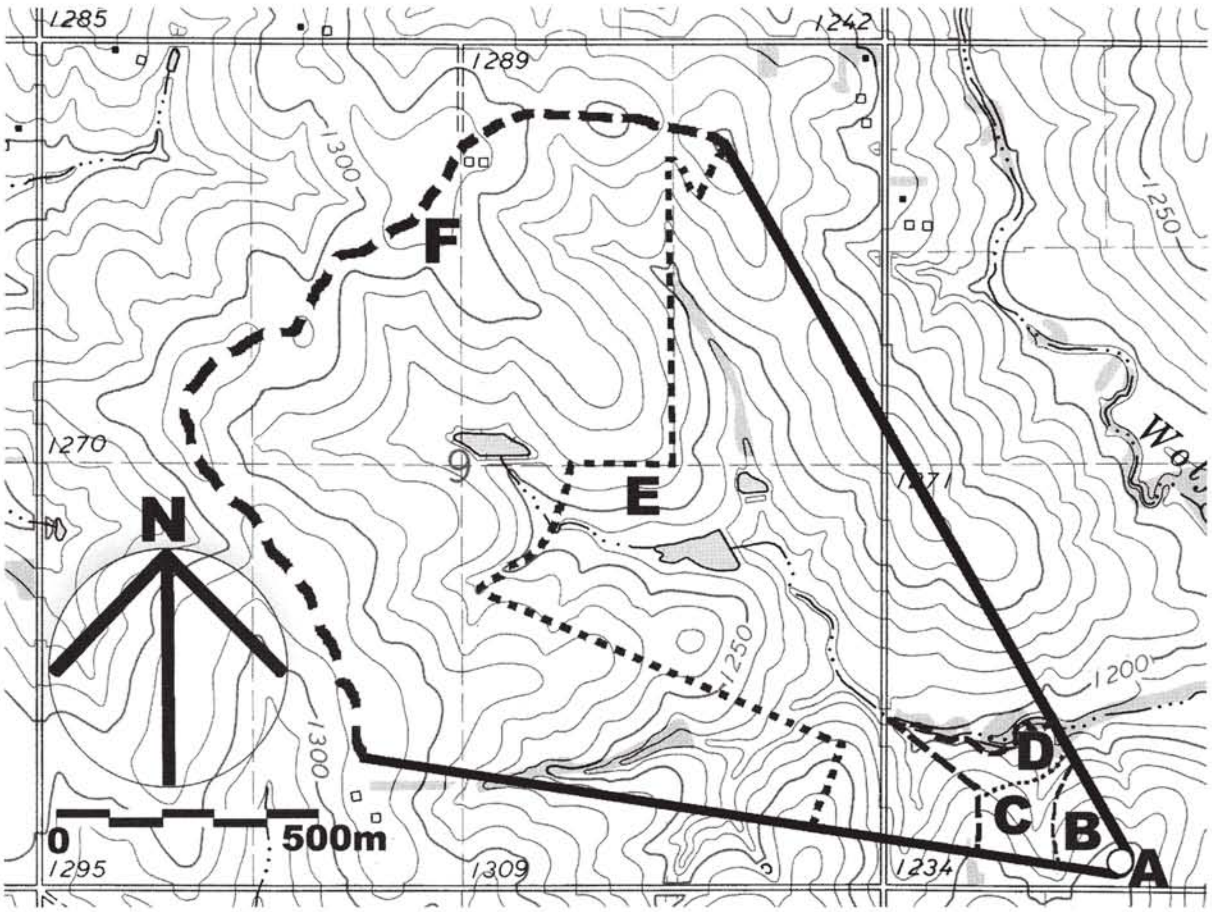

Figure 8. Planimetric view of landscape structure and a cone of vision are shown for a rural scene (USGS 1966). Boundaries are labeled as Boundary A through Boundary F and correspond to the landscape scenes in Figure 9.

enclosure to stop the eye and stabilize the focused view, say, to one such noted as boundary B. That is, the viewer would "scale up" to fit the grain suggested by the landscape structure. Continuing outward to boundary C, we see boundary B nested within it. So arranged hierarchically, the cornfield's stubble edge (B) is more easily seen and understood, because a true boundary's structure shows the differences between areas. The arc shown in each scene represents an imaginary border (A) of an arbitrary circular plot surrounding the viewpoint.

As we continue to deconstruct what is seen from the observer's viewpoint and move out through boundaries D, E, and F, we can see the roles that landscape structure, formed from breaks in the topography and barriers of vegetation, play in revealing and enclosing the visual landscape. The viewer may look outward through a series of nested landscape spaces quickly collapsing the view inward and expanding it again outward several times. At the completion of this process, the view will have become fixed in the viewer's mind, and one of the boundaries will dominate. It could be the horizon (boundary F), the riparian vegetation (boundary D), or the edge of the corn stubble (boundary B). The viewer will have settled upon a primary boundary; thus other perceived boundaries beyond form its context. The primary boundary defines the viewer's grain; boundaries more distant than the dominant one are a measure of the viewer's extent. Thus, for purposes of understanding the visual landscape's scale, we must consider both grain and extent.

Distance of View

Measures of grain and extent make it possible to quantify scale. Researchers have often employed distance of view (DOV) as a variable to describe a scene's scale (Hull and Buhyoff 1983; Gimblett et al. 1985; Gobster 1987; Ruddell et al. 1989). In these studies, DOV defines the distance a viewer could see. There is no accounting for a viewer affixing on a range of boundaries. Modification of the DOV to where the viewer identifies boundaries would

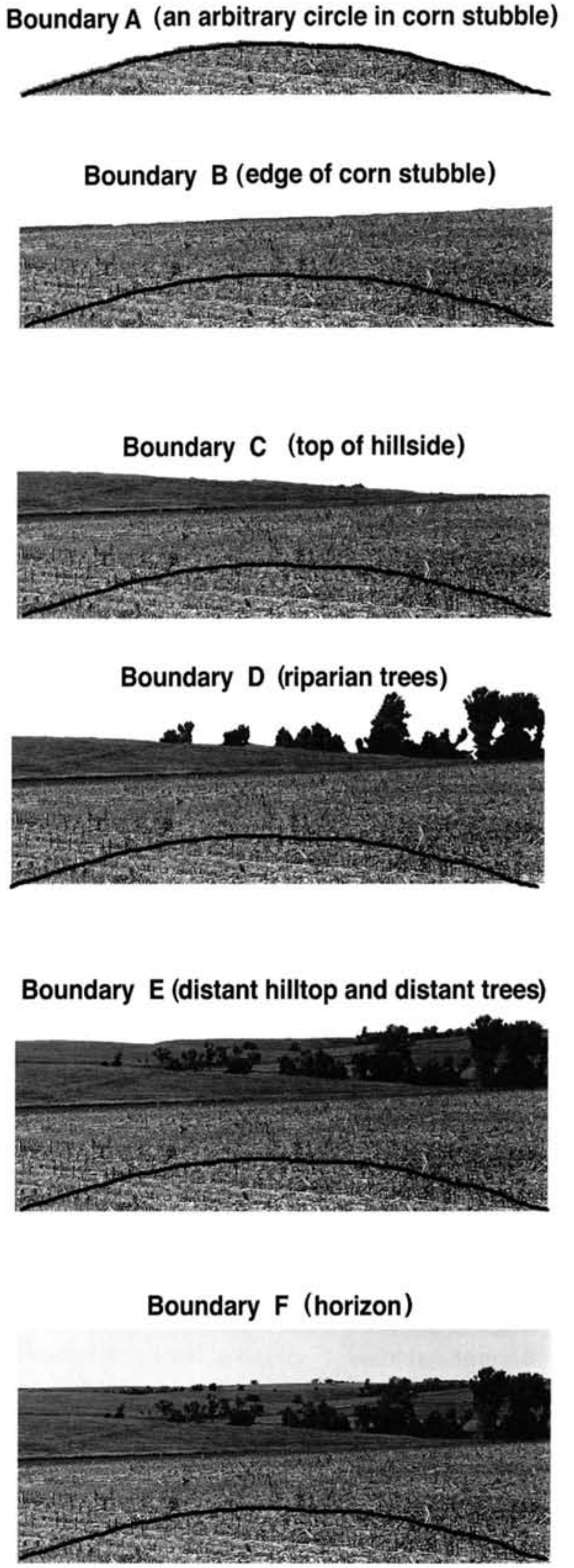

Figure 9. Deconstruction and delimitation of a view based on nested boundaries moving out from a viewpoint. Boundary locations, A through F, can be seen in Figure 8.

Figure 10. The horizon, distant tree lines, and ridges not only parse the landscape and visually structure this scene but also provide context that gives the view a sense of extent.

be a better indicator of scale, especially relative scale. It would convey more information about the observer's interpretation, and once marked on a photo, it could readily be measured in the field or from maps or aerial photographs. However, neither DOV, nor distance of view to a primary boundary (DOV-prime), alone determines scale. We also need a measure of extent, without which no reliable determination of a scene's context is possible. Boundaries identified by the viewer beyond DOV-prime can be used to determine the degree of nesting of grain within a given context (Fig. 10). This nested relationship between DOV-prime and number of boundaries beyond becomes relative, contextual, and hierarchical.

A MODEL RELATING LANDSCAPE AND VISUAL STRUCTURE WITH SCALE

Physical landscape structure can be defined as:

$$\textit{Landscape structure} = f(\textit{Boundaries}), \qquad (1)$$

where in rural landscapes,

$$\textit{Boundaries} = f\textit{Horizon} + (\textit{Topographic breaks} + \textit{Vegetative barriers} + \textit{Textural surfaces}). \qquad (2)$$

Vegetative boundaries occur as changes in land cover, enclosing walls, or overhead canopies. Large masses are readily identified whether near or far. Topographic breaks vary in size but are easily recognized even at a distance, for example, the horizon. Textural surfaces of the ground plane weakly define edges.

Although these boundaries are fixed and measurable physical elements, they are still open to interpretation

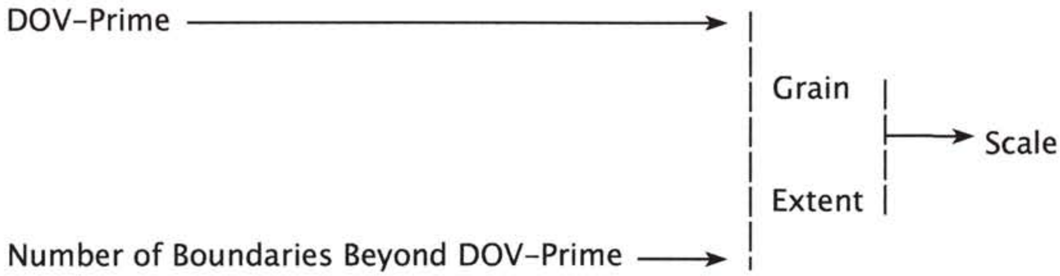

Figure 11. Hierarchical interaction of landscape structure components and modeled as scale.

(see Fig. 9). When viewers select a boundary, they select a scale where

$$Scale = f(Grain + Extent). \quad (3)$$

Grain and extent relate and interpret landscape structural boundaries. Scale can be defined by its grain and extent cued by boundaries that form its context.

Grain and extent can be delimited in sample photographic scenes of the landscape by two visual structure variables: (1) distance of view to the critical, viewer-identified primary boundary (DOV-prime) and (2) the number of boundaries identified beyond the DOV-prime in the scene by the viewer (Fig. 11).

Thus, we have the relation

$$Grain = f\ (DOV\text{-}prime). \quad (4)$$

Extent sets the context for grain and can be measured by the number of viewer-identified boundaries beyond the viewer-identified primary boundary (i.e., the more boundaries beyond the primary boundary, the greater the perceived extent):

$$Extent = f\ (Number\ of\ viewer\text{-}identified\ boundaries\ beyond\ DOV\text{-}prime). \quad (5)$$

Again, just as for grain, other factors are involved, such as the prominence of the horizon and orientation of the boundaries to the viewer. Where the existing boundaries cross perpendicular to the view, a greater extent is possible because the viewer sees more potential boundaries. Where boundaries tend to be parallel to the direction of view, the boundaries do not function as effectively as edges but function as visual corridors. Visual corridors tend to expand one's distance of view and thus increase the perceived scale of a landscape, just as a drainage corridor links and more closely connects nutrient flows in a landscape. Likewise, a prominent horizon means less enclosure increasing the likelihood of viewing at larger scale.

MATERIALS AND METHODS

Using the model in Figure 11, the author compared selected grains and extents present in photographs of rural scenes to determine how well the selected scales agreed with those determined by the viewers.

The materials used as stimulus sets were color slides and black-and-white photographs of rural landscape scenes. Landscape boundaries depicted in the scenes were measured in the field and from aerial photographs. The scenes were selected to represent the nine scale classes in a 3-by-3 matrix consisting of three levels of grain and three levels of extent (Table 1). They were photographed

TABLE 1
NINE ASSIGNED SCALE CLASSES FOR VARIOUS MODEL GRAIN AND EXTENT LEVELS

Grain[1]	Extent[2,3]	Scale class
$X_{DOV\text{-}prime} < 30$ m	$X_b \leq 1$	1
$30\text{ m} \geq X_{DOV\text{-}prime} \leq 400$ m	$X_b \leq 1$	2
$X_{DOV\text{-}prime} > 400$ m	$X_b \leq 1$	3
$X_{DOV\text{-}prime} < 30$ m	$1 \geq X_b \leq 2$	4
$30\text{ m} \geq X_{DOV\text{-}prime} \leq 400$ m	$1 \geq X_b \leq 2$	5
$X_{DOV\text{-}prime} > 400$ m	$1 \geq X_b \leq 2$	6
$X_{DOV\text{-}prime} < 30$ m	$X_b > 2$	7
$30\text{ m} \geq X_{DOV\text{-}prime} \leq 400$ m	$X_b > 2$	8
$X_{DOV\text{-}prime} > 400$ m	$X_b > 2$	9

[1]$X_{DOV\text{-}prime}$ is the distance to the boundary identified as primary.
[2]Less than 1 occurs where no boundaries occur beyond the primary one (DOV-prime).
[3]X_b is the total of viewer-identified boundaries beyond the one identified as primary.

Figure 12. Landscape scenes representing scale classes collected in Otoe County, Nebraska.

in the same rural Otoe County, NE, watershed during two weeks in June (Fig. 12). Representative samples of scenes from the scale classes are shown in Figure 13. To control potential researcher bias, a panel of experts reviewed a set of 100 landscape scenes to corroborate designated scale classes represented by grain and extent and their interaction scale.

Expert Panel

The expert panel consisted of two landscape architects and two geographers familiar with visual assessments and rural landscapes. They were given background readings on grain and extent that were discussed before viewing the sample scenes. Panelists were not informed about the grain and extent levels or of the scale classes used in taking specific photos. Each panel member was asked to sort the randomized stack of the 100 scenes into three separate piles representing large, medium, and small grain. The 100 scenes were then reshuffled, and panelists were asked a second time to place them into three piles representing large, medium, or small extent. Each scene's identification number and sort level were recorded. The panel suggested eliminating 34 scenes that did not fit the proposed scale classes, and it reclassified seven. Elimination occurred for several reasons: (1) the scene portrayed a corridor effect; (2) scenes were ambiguous across a range of boundary types (Fig. 14); (3) densities of boundaries were not consistently interpreted; and (4) the scenes had been misclassified.

Respondent Sampling

Respondents for the next procedure were university students and residents of rural areas and small towns near the area photographed. The University of Nebraska–Lincoln Institutional Review Board approved questions and procedures (IRB 93-9-22). The students were members of planning, architecture, geography, horticulture, and natural resources classes, and the residents were members of civic and school groups and garden club. Often groups exhibit characteristics that might influence their responses as a whole. So, groups were compared to check for unusual members by demographic variables collected from all respondents, including group identifier, age, gender, and a self-rating about knowledge, interest, and experience of the eastern Nebraska rural landscape. Purcell and Lamb (1984) found such data could be used to account for unusual variability in scene responses. The demographic variables were normally distributed across all respondents and across all groups.

Respondents first received instructions. Then black-and-white reproductions of the scenes were given to the respondents for marking during simultaneous projection of a color slide of the same scene. Next, they viewed one "warm-up" scene to clarify questions about the procedure. That clarification was followed by projection of a 27-scene slide set created by drawing and displaying at random three scenes from each of the nine scale classes. Three-hundred forty-eight respondents from 24 groups were asked to identify, mark, and rank the importance

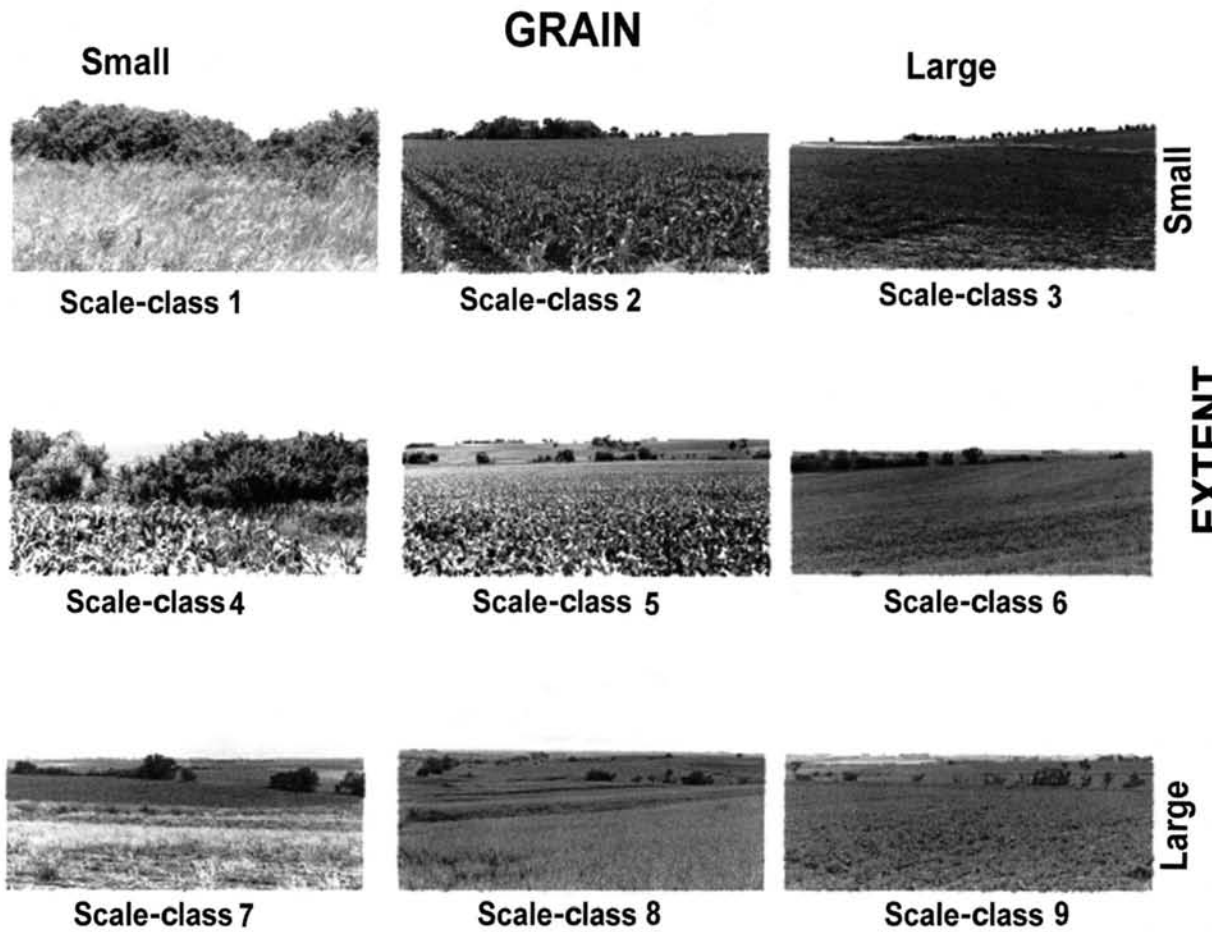

Figure 13. Examples of some landscape scenes used to depict various scale classes.

of boundaries found in each scene on black-and-white reproductions printed four to a page. First, respondents marked the boundaries of each succeeding space as one's view moved into the landscape depicted in the scene. After drawing the boundaries, respondents ranked them 1, 2, 3, 4, or 5, based on what they felt was the importance that each boundary exhibited in defining the boundary of a landscape scene's most important space or area, with 1 being most important. Over 9,000 responses were tabulated (Table 2).

RESULTS AND DISCUSSION

The respondents' scale classification for each scene was synthesized by comparing their perceived DOV-prime (grain size) and number of boundaries they marked beyond the DOV-prime (extent). These were aggregated as a variable called perceived scale class (P-scale) and then cross-tabulated and compared with the scale class set by the researcher (i.e., the model). Respondent-perceived scale classes were compared to those designated by the model using an appropriate categorical statistical program, Procedure CATMOD (SAS Institute 1990), with contrasts to test for statistically significant relationships. If the model of scale class derived from grain and extent perfectly matched those perceived by the respondents, the corresponding P-scale correspondence would be 100%.

Figure 15 delineates all scale-class versus P-scale designations and shows several trends. The P-scale distributions with the exception of 7, 8, and 9 do not appear to be normal curves. Larger classes such as 5, 8, and 9 did not have good correspondence between the P-scale class and the researcher-designated scale class. However, in most others a plurality of respondents' P-scale class agreed with the researcher-designated scale class. There was no significant difference between scale class 4 and P-scale 4.

Figure 14. A "corridor" effect frames distant landscape features, cuts across boundaries, and reduces the visual scale of a scene.

TABLE 2
NUMBERS OF RESPONSES PER SCALE CLASS

Scale class	Count
1	1,174
2	1,160
3	803
4	1,166
5	1,006
6	713
7	1,170
8	1,056
9	1,148
Total	9,396

For scale class 1 scenes (Fig. 16), more than 40% of respondents agreed with the model (Fig. 15A). The next closest level, at 32%, represents responses shifted up one extent level to scale 4. P-scale 1 versus P-scale 4 had a chi-square of 1,044 and $p < 0.0001$. Though scale class 1 scenes were selected to have a structure of small grain and extent, the viewers appear to have seen a closer primary boundary and thus increased the extent. Interestingly, no respondents saw the scenes as containing large grains found in scales 3, 6, and 9, and only a few found the grain larger, which would move their responses into P-scales 2, 5, or 7.

For scale class 2 scenes (Fig. 17), 60% of the respondents agreed with the model scale class (Fig. 15B). P-scale 2 versus P-scale 5 had a chi-square of 107 and $p < 0.0001$. Like the preceding class, a similar shift up in extent level occurred to P-scale 5 with about 30% of respondents.

For scale class 3 scenes (Fig. 18), 50% of respondents agreed with the model (Fig. 15C). The next closest level, at 25%, was shifted down one extent level to P-scale 2. P-scale 3 versus P-scale 2 had a chi-square of 59.5 and $p < 0.0001$. Though scale class 3 scenes were selected to have a structure of large grain and small extent, some viewers appeared to have seen a closer primary boundary but did not perceive increased extent by noting boundaries beyond the one designated most important. A similar though dampened trend was found in the first two scale classes where about 12% of respondents shift up one extent level. Few respondents saw the scenes as containing the small extents found for scale classes 1, 4, or 7.

For scale class 4 scenes (Fig. 19), 38% of respondents agreed with the model (Fig. 15D). This was followed closely by the P-scale 7 level, at 36%, in an apparent repeat of the pattern of shifting up one extent level in scale classes 1 and 2. P-scale 4 versus P-scale 7 had a chi-square of 0.27 and $p < 0.6121$, and therefore were not significantly different. Though scale class 1 scenes were selected to have a structure of small grain and extent, the viewers appeared to have seen a closer primary boundary and thus increased the extent. However, no respondents saw the scenes as containing large grains found in scale class 9, and few found them for scale classes 2, 3, 5, or 6. Perception of grain size is apparently very stable at this scale.

For scale class 5 scenes (Fig. 20), only 17% of the respondents agreed with model (Fig. 15E), and like the preceding one, scale class 5, the respondents had a similar shift up in distribution of responses in extent level to P-scale 8. However, 35% of the respondents saw larger grain size in the scene and selected P-scale 6. P-scale 5 versus P-scale 6 had a chi-square of 59.4 and $p < 0.0001$, but in the opposite direction. Some, 17% of respondents, saw smaller extent and larger grain, thus moving their responses to scale class 3. These two trends may be the result of selecting a larger, more distant DOV-prime that subsumes a boundary and reduces extent to P-scale 3. Likewise, 10% of respondents saw more extents and thus selected P-scale 8, and 15% selected P-scale 9 (15%). Few respondents saw other P-scale classes, and none saw small grain and extents of P-scale 1.

For scale class 6 scenes (Fig. 21), only 27% of respondents agreed with the model (Fig. 15F). The next closest levels were at 24% for P-scale 3 and 19% for P-scale 9. P-scale 6 versus P-scale 3 had a chi-square of 1.44

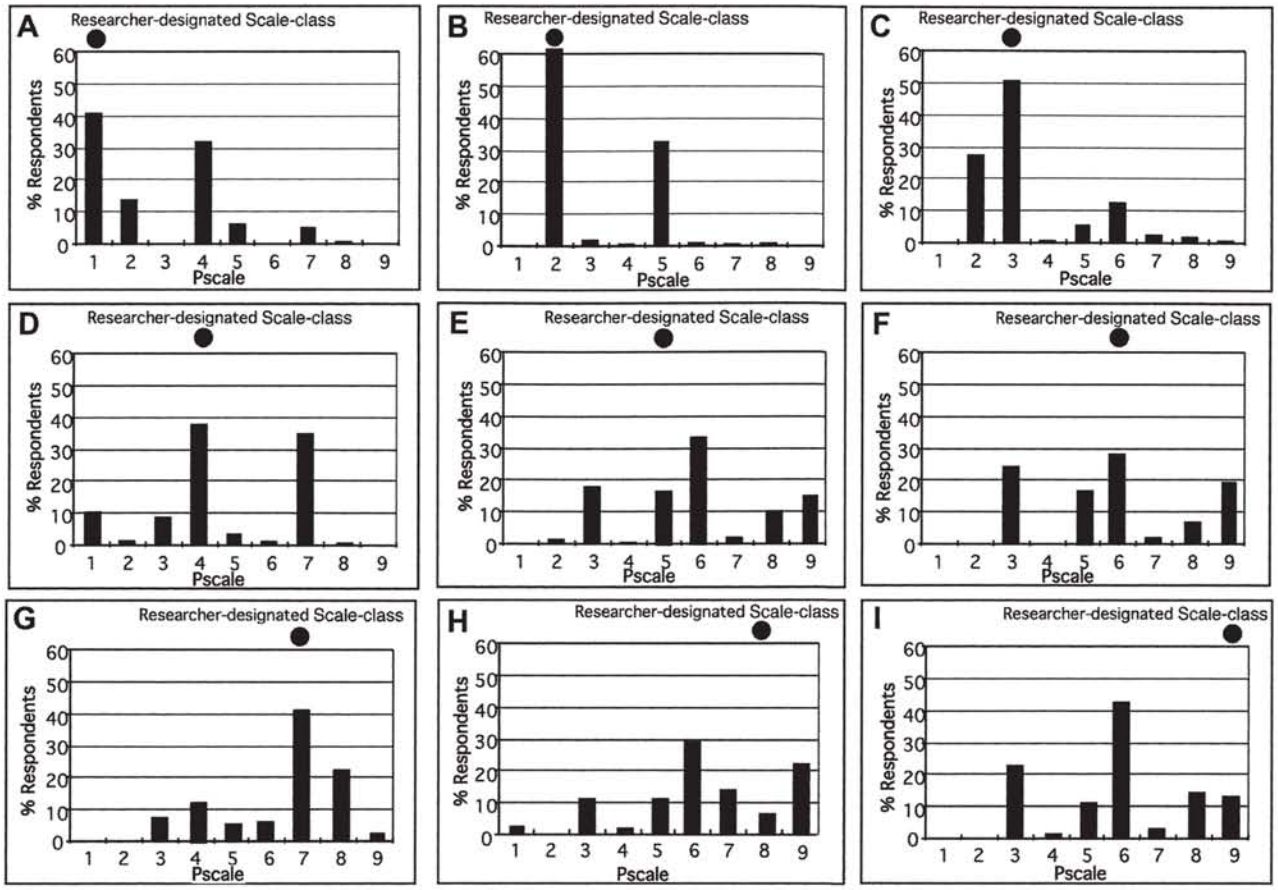

Figure 15A–I. Percentage of respondents' perceived scale (P-scale) classes versus researcher-designated scale class used in the human-scale model.

and $p < 0.23$. Thus, there is not a significant difference between responses of P-scale 6 and P-scale 3. Though scale class 6 scenes were selected to have a structure of large grain and moderate extent, some viewers shifted down one extent level. This would have happened if the viewer designated a DOV-prime farther into the scene. Larger grains potentially offer more choices for defining boundaries. Few respondents saw the scenes as containing small extents found for scale classes 1, 4, or 7. None saw moderate grain with small extent present for scale class 2. A trend similar to that found in the first two scale classes showed about 19% of respondents shifting up in extent level to P-scale 9.

For scale class 7 scenes (Fig. 22), over 40% of the respondents agreed with the model (Fig. 15G). Twenty-two percent of respondents shifted up in extent and saw P-scale 8. No viewers saw small extent or grain sizes. A few saw scale classes 3, 4, 5, 6, or 9. P-scale 7 versus P-scale 8 had a chi-square of 64.9 and $p < 0.0001$.

For scale class 8 scenes (Fig. 23), only 6% of the respondents agreed with the model's (Fig. 15H) designated moderate grain and large extent. P-scale 8 versus P-scale 6 had a chi-square of 191 and $p < 0.0001$, but in the wrong direction. Few viewers saw small extent or grain sizes in scale classes 1, 2, or 4. However, over 10% of the viewers saw P-scales 3, 5, 6, 7, or 9. As with scale class 5, there appears to be more choice of boundaries to select as the primary one, and this factor decreased grain size or increased extent level.

For scale class 9 scenes (Fig. 24), many respondents either dropped a grain level to scale class 8 or dropped an extent level to scale class 6, different from the model (Fig. 15I). P-scale 9 versus P-scale 6 had a chi-square of 650.7 and $p < 0.0001$, but in the wrong direction. For this scene, 23% saw the large grain but only a limited extent, the horizon. No respondents saw these scenes as small grained or limited in extent. P-scales 1 and 2 had no responses and P-scales 4, 5, and 7 less than 4% each.

Figure 16. Example scene of scale class 1

Figure 17 Example scene of scale class 2.

Figure 18. Example scene of scale class 3.

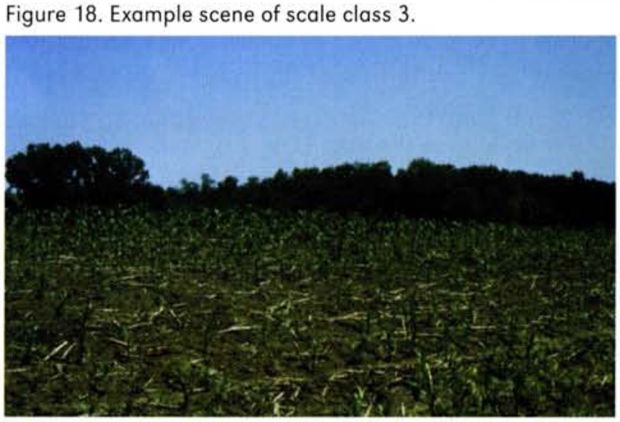

Figure 19. Example scene of scale class 4.

Figure 20. Example scene of scale class 5.

Figure 21 Example scene of scale class 6.

Figure 22. Example scene of scale class 7

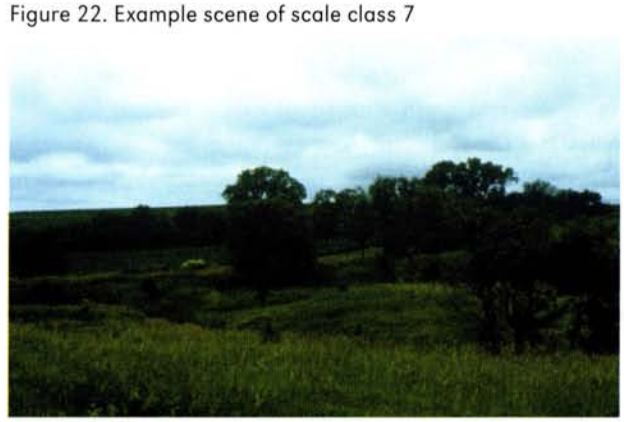

Figure 23. Example scene of scale class 8.

Figure 24. Example scene of scale class 9.

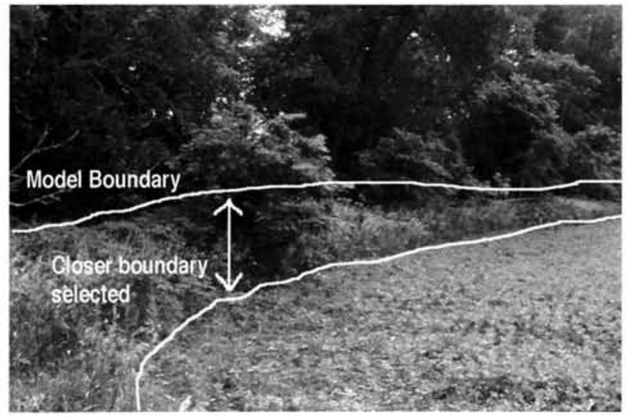

Figure 25. The foreground effect occurs when a closer boundary is selected as most important.

CONCLUSIONS

Relationships between the model and perceived scale in Figures 15A–I suggest that scalar characteristics, grain, and extent can be described and tied to a human scale. Significantly more respondents agreed on close, defined spaces shown in scenes from scale classes 1, 2, 3, and 7. However, Figures 15E, 15H, and 15I also indicate that we humans may have a limit to our visual scaling ability. This limit may dampen our perception of and connection to distant boundaries in space. The agreement between P-scale classes and scale classes 1, 2, 3, and 7 suggests the restrictions from enclosure and from the view beyond were successful in constraining responses. However, as extent or extent and grain increase, the opportunity for different interpretations also increases and predictability wanes. At the middle ranges of grain and extent found in scale classes 5, 6, 8, and 9, many respondents simply did not perceive large, distinct differences.

In management of landscape resources and their visual consequences, Litton (1968) has noted the importance of what he called "middle ground views." The middle ground links close and distant impressions of a landscape. This study suggests that as viewers' attention moves from fore- to middle to background views (a process that is tantamount to scaling), their ability to recognize changes in the landscape diminishes. The visual structure and associated human-scale responses to middle-ground landscape as detected in the model may also fall into a class of middle-number systems. Allen and Hoekstra (1992) note that middle-number systems often defy prediction because they contain too many variables to model and too few to average.

Generally, it appears that smaller-scale changes in landscapes do make a difference in the similarity of some

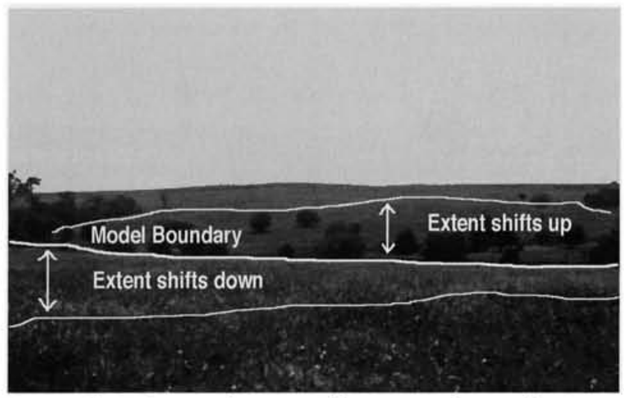

Figure 26. Mid-ground extent effects come from selecting a closer boundary.

human responses. Humans may tend to restructure the pattern of the landscape partially to satisfy those responses and thus not include a scale of structure appropriate for other organisms. Therefore, if changes in landscape do not account for our penchant for a human scale, then such schemes may fail to gain acceptance.

To summarize what was found:

- Good agreement with the model occurred with P-scale in scale classes 1, 2, 3, and 4. Disagreement with the model can be called a "foreground effect," where extent shifts up due to seeing a closer boundary because the foreground is too variable. Ground textural differences likely come into play (Fig. 25).
- Fair agreement with the model occurred with P-scale in scale class 6. Disagreement with the model can be called a "mid-ground extent effect," where extent shifts up due to selecting a closer boundary or shifts down due to selecting a more distant boundary (Fig. 26).
- Good agreement with the model occurred with P-scale in scale class 7. Disagreements with the model could

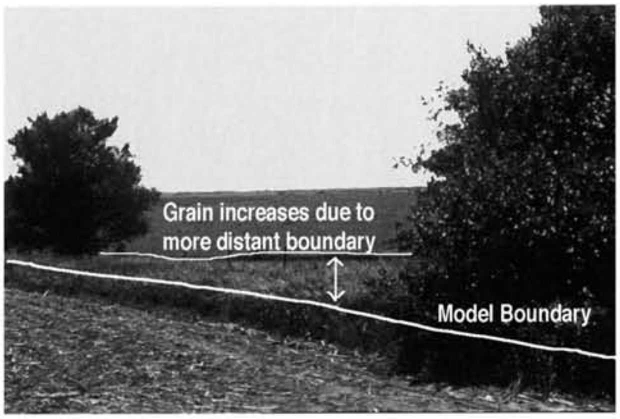

Figure 27. Mid-ground grain effects occur when grain shifts up.

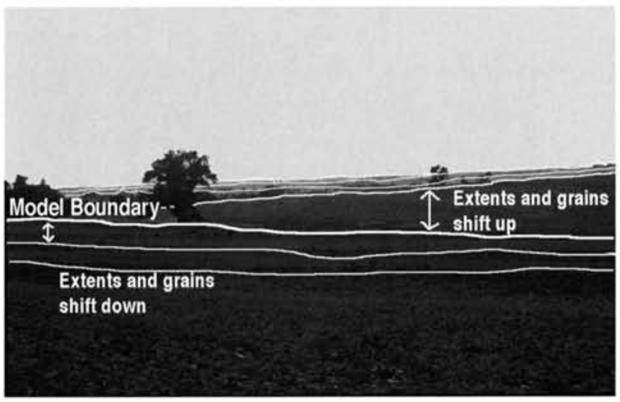

Figure 28. The background effect occurs from a complex interaction of grain and extent.

be called a "mid-ground grain effect," where grain shifts up due to selecting a farther boundary since more boundaries are available, possibly due to ground textural differences (Fig. 27).

- Poor agreement with the model occurred with P-scale in scale classes 5, 8, and 9. It is likely due to what could be called "background effects," where complex interaction of both mid-ground extent and mid-ground grain effects probably occurred. Here the variety of scene grains and extents makes prediction harder (Fig. 28).

This study suggests that plans for major manipulations in rural landscapes, such as clearing or planting windbreaks and hedgerows, consolidating fields, building new roads, siting rural electrical transmission lines, and creating riparian buffers, among others, are subject to the filter of human response to scale. This filter is implicit in visual preference studies that are a part of documentation in major environmental impacts. It is quite possible that a portion of visual preference assigned to the quality of landscape results from our predilection for human scale.

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