Chapter 2. The Landscape Context of Forest and Grassland in the United States

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Introduction

As development introduces competing land uses into forest and grassland landscapes, the public expresses concern for landscape patterns through headline issues such as urban sprawl and fragmentation. Resource managers need a deeper understanding of the causes and consequences of landscape patterns to know if, where, and how to take any needed actions. The spatial arrangement of the environment affects all ecological processes within that environment, and the task for resource managers is to arrange a forest or grassland in an appropriate way to provide the desired balance of biodiversity, water quality, and other amenities. National assessments of landscape patterns can help to inform those decisions by documenting the status and trends of the landscape context of natural resources.

Resource management has always considered the administrative and biophysical context within which natural resources occur. For example, forest parcels are managed according to the ecoregions in which they reside, owner objectives, road-free designations, or current human activity nearby. This chapter focuses on the landcover context of natural resources, which can indicate the type and degree of human activities. The objective is to answer two general questions about the landcover context of forest and grassland at a national scale. First, how much forest (or grassland) is contained in landscapes dominated by natural, agricultural, or urban landcover types? Second, of the forest (or grassland) contained in natural-dominated landscapes, how much resides within a potential zone of transition to more developed landscapes? High-resolution national maps provide answers to those general questions and can help local resource managers identify opportunities for protecting natural landscapes and managing future changes in transitional landscape.

Methods

Briefly, a landcover map of the conterminous United States was used to classify every 0.09-ha parcel of land according to the landcover context of its surrounding neighborhood, for several neighborhood sizes. Landcover context was classified analogously to vegetation classification, except now the labels refer to landcover types instead of species, and the classification refers to landcover in a neighborhood surrounding a land parcel instead of species contained within the parcel. The parcel-level statistics for all land, for forest only, and for grassland only were aggregated to regional summaries using the reporting units employed by the Forest Service for Resource Planning Act (RPA) assessments.

The classification model is similar to the familiar soil triangle, a tripolar chart that classifies soil texture based on the proportions of sand, silt, and clay in a soil sample (fig. 2.1A). The soil texture tripolar chart is partitioned into subspaces with labels such as sandy clay and silt loam; a soil sample that falls within a subspace is given the corresponding soil texture name. To use a tripolar chart for classifying landcover context, the proportions of three generalized landcover types (agriculture, developed, natural) replace sand, silt, and clay along the three axes (fig. 2.1B). The new partitioning of the tripolar chart indicates the critical values of 10, 60, and 100 percent along each axis. The class labels are coded as follows: a lowercase letter (n, d, a) appears in a label if the corresponding landcover type (natural, developed, agriculture, respectively) comprises at least 10 percent, but < 60 percent of the neighborhood (see below); an uppercase letter (N, D, A) appears if that landcover type comprises at least 60 percent but < 100 percent of the neighborhood. A letter does not appear if that landcover type comprises < 10 percent of the neighborhood. The labels NN, DD, and AA indicate neighborhoods that contain exactly 100 percent of the corresponding landcover type.

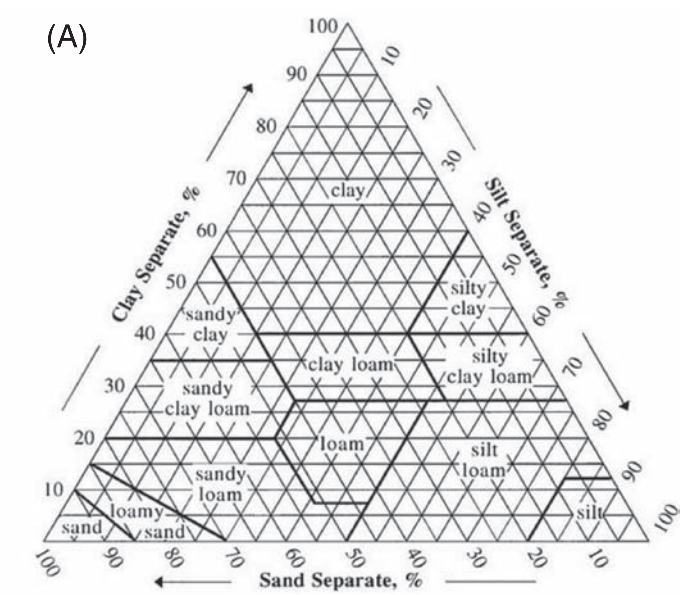

Figure 2.1A—The soil texture classification model identifies 12 soil textures according to the proportions of sand, silt, and clay in a soil sample. (Source: U.S. Department of Agriculture; see also http://en.wikipedia.org/wiki/Image:SoilTextureTriangle.jpg)

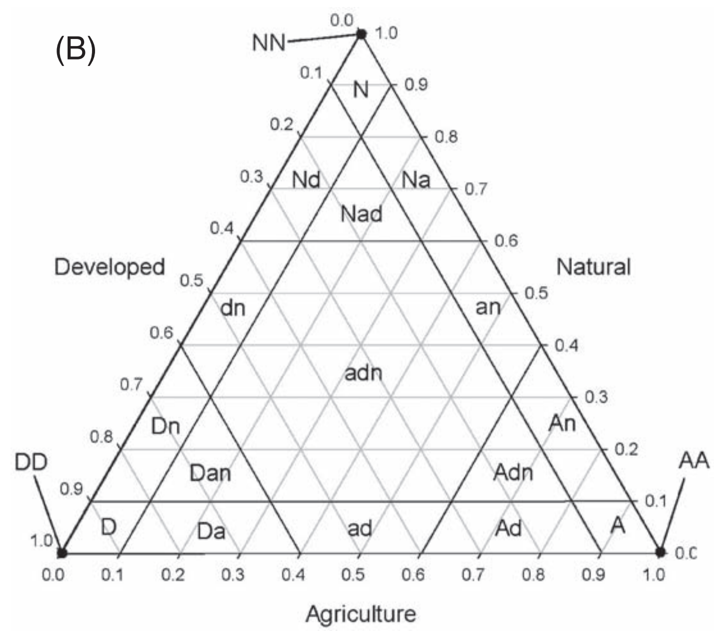

Figure 2.1B—The landcover context classification model identifies 19 landcover contexts according to the proportions of natural, developed, and agriculture landcover in a neighborhood. (See text for additional explanation.)

The model is implemented using the 2001 high-resolution, national landcover map [National Land Cover Database (NLCD)] (Homer and others 2007) of the conterminous United States. Each parcel (hereafter pixel) on the NLCD represents 0.09 ha on the ground and has one of 16 possible landcover type labels (table 2.1). Whereas the landcover label describes the **contents** of a pixel, the **context** of that pixel is described by the landcover in the surrounding neighborhood. In other words, the proportions of agriculture, developed, and natural landcover needed for the tripolar labeling of context are calculated from the landcover pixels in the surrounding neighborhood. Since the context of each pixel is based on its unique neighborhood, the new map of landcover context has a spatial resolution equivalent to the pixel size of the original landcover map. Furthermore, the original landcover map can be intersected with the map of landcover context to summarize context according to original landcover types, e.g., the context of forest pixels only.

Table 2.1—Aggregation of the NLCD landcover legend for tripolar classification and identification of forest and grassland landcover types

NLCD landcover class	Aggregation For tripolar classifications	Identification of forest and grassland landcover
Water	Natural	—
Perennial ice/snow	Natural	—
Developed, open space	Developed[a]	—
Developed, low intensity	Developed	—
Developed, medium intensity	Developed	—
Developed, high intensity	Developed	—
Barren land (rock/sand/clay)	Natural	—
Deciduous forest	Natural	Forest
Evergreen forest	Natural	Forest
Mixed forest	Natural	Forest
Shrub/scrub	Natural	—
Grassland/herbaceous	Natural	Grassland
Pasture/hay	Agriculture	—
Cultivated crops	Agriculture	—
Woody wetlands	Natural	Forest
Emergent herbaceous wetlands	Natural	—

— = neither forest nor grassland; NLCD = National Land Cover Database.
[a] The developed class also includes all pixels containing a road segment (see text).

The NLCD landcover map was modified as follows before implementing the tripolar classification. First, to better account for ecological impacts of roads, a detailed roadmap (Environmental Systems Research Institute 2005) was overlaid on the landcover map, and any pixel that contained a road segment of any size or type was changed to developed. The landcover legend was then aggregated into three generalized classes called agriculture, developed, and natural (table 2.1) for a tripolar classification model. The landcover legend was also aggregated separately to identify forest and grassland pixels (table 2.1) for summarizing context according to those two particular landcover types.

The size of a neighborhood is important because the context of any given pixel can change if more or less of the surrounding area is included in the neighborhood. In the case of a small farm embedded in a mostly forested landscape, agriculture dominates a small neighborhood in and around the farm, but is only a minor component of a larger neighborhood that is dominated by forest. As a practical matter, several neighborhood sizes were used in this analysis because there is no *a priori* reason to choose any one size. The six neighborhood sizes are 4.41 ha (7- by 7-pixel neighborhood, ~10.9 acres); 15.2 ha (13 by 13, ~37.6 acres); 65.6 ha (27 by 27, ~162 acres); 590 ha (81 by 81, ~1,460 acres); 5 310 ha (243 by 243, ~13,100 acres); and 47 800 ha (729 by 729, ~118,000 acres). Thus, the landcover context of each landcover pixel was evaluated for each of the six neighborhood sizes to produce six maps of landcover context for the conterminous United States at a spatial resolution of 0.09 ha per pixel.

To address the first question posed in the introduction to this chapter, the 19 landcover context classes (fig. 2.1B) were aggregated into four background categories called agricultural, natural, developed, or mixed (fig. 2.2A). This identifies neighborhoods dominated by, i.e., containing at least 60 percent, of one of the

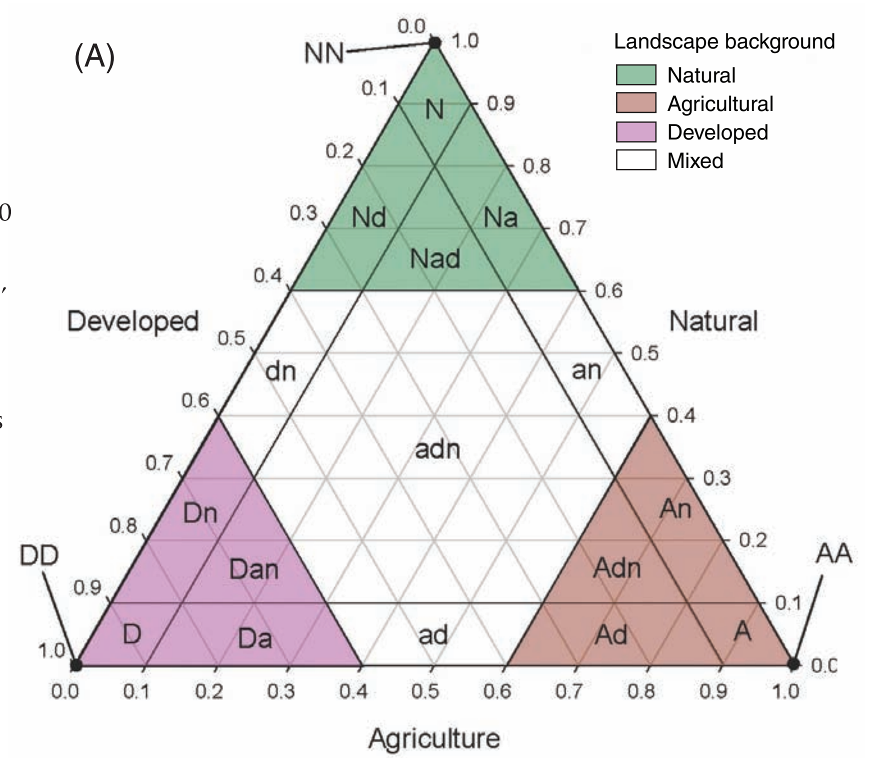

Figure 2.2A—Aggregation of 19 landcover context classes into four background classes.

three aggregated landcover types and a mixed background class for which no single landcover type dominates. To address the second question posed in the introduction, the 19 landcover context classes were aggregated in a different way (fig. 2.2B) to more specifically describe the context of forest (or grassland) that appears in a seminatural background (compare to figure 2.2A). This highlights the contexts labeled Nd (natural developed), Na (natural agricultural), and Nad (natural-agricultural-developed), which are of particular interest as potential transition zones between natural and anthropogenic landscapes, places where future landcover change is likely to be manifest as a change in the landscape background. Maps of either forest only or grassland only were overlaid on a map of landcover context to extract the context values for forest or grassland only.

Each map of the conterminous United States contains approximately 8.6 by 10^9, i.e., 8.6 billion, pixels representing a total area of approximately 7.4 million km^2, including approximately 2.3 and 1.2 million km^2 of forest and grassland, respectively. Note that those area estimates from NLCD will not match official area statistics for forest and grassland since the definitions of forest and grassland are not necessarily the same for NLCD as for official statistics. To avoid potential confusion when using area statistics, the results of the context analysis were expressed as percentages of NLCD area (total area, forest area only, or grassland area only) by RPA assessment region.

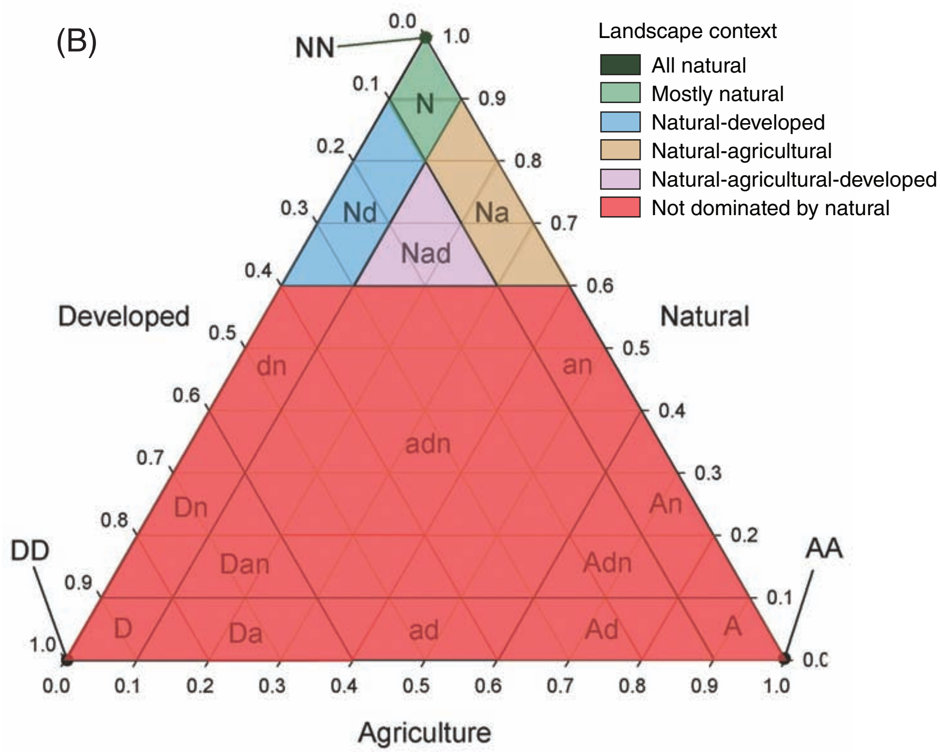

Figure 2.2B—Aggregation of 19 landcover context classes into six resource-specific classes. (See text for additional explanation.)

Results and Discussion

Figure 2.3 illustrates the results for background context (using the model shown in figure 2.2A) for neighborhood sizes of 4, 66, and 5 300 ha in the States of Colorado, Kansas, and Missouri. A comparison of results for a smaller neighborhood size (top) and a larger size (bottom) confirms the expectations that the maps are more detailed for smaller neighborhood sizes and that the context of a given location can change with neighborhood size. It is also evident (fig. 2.3) that the agricultural, developed, and natural background contexts are more likely to be observed in smaller neighborhoods, whereas the proportion of the mixed context increases with neighborhood size. The simplest explanation is that local landcover tends to be the same in a neighborhood because of local factors like soil type and road infrastructure, whereas regional landcover appears more mixed simply because it includes a variety of local situations.

Another important trend that is evident in figure 2.3 is that the signal from a locally important feature, e.g., agriculture in southwest Colorado, that is detectable in smaller neighborhoods (top) is not detectable in larger neighborhoods (bottom). That reflects the fact that different neighborhood sizes sample the landscape at different spatial frequencies; smaller neighborhoods are more sensitive to local (fine-scale) patterns, and larger neighborhoods are more sensitive to regional (coarse-scale) patterns. Furthermore, that is part of the rationale for employing several neighborhood sizes when creating maps of landcover context. A resource manager with a local orientation and ability to influence local landcover is presumably more interested in fine-scale context, e.g., the top inset map in figure 2.3, whereas a regional manager with ability to influence regional land use policy is more interested in coarse-scale context. Finally, for a particular location, the range of neighborhood sizes over which a particular background context is obtained defines the range of spatial scales over which

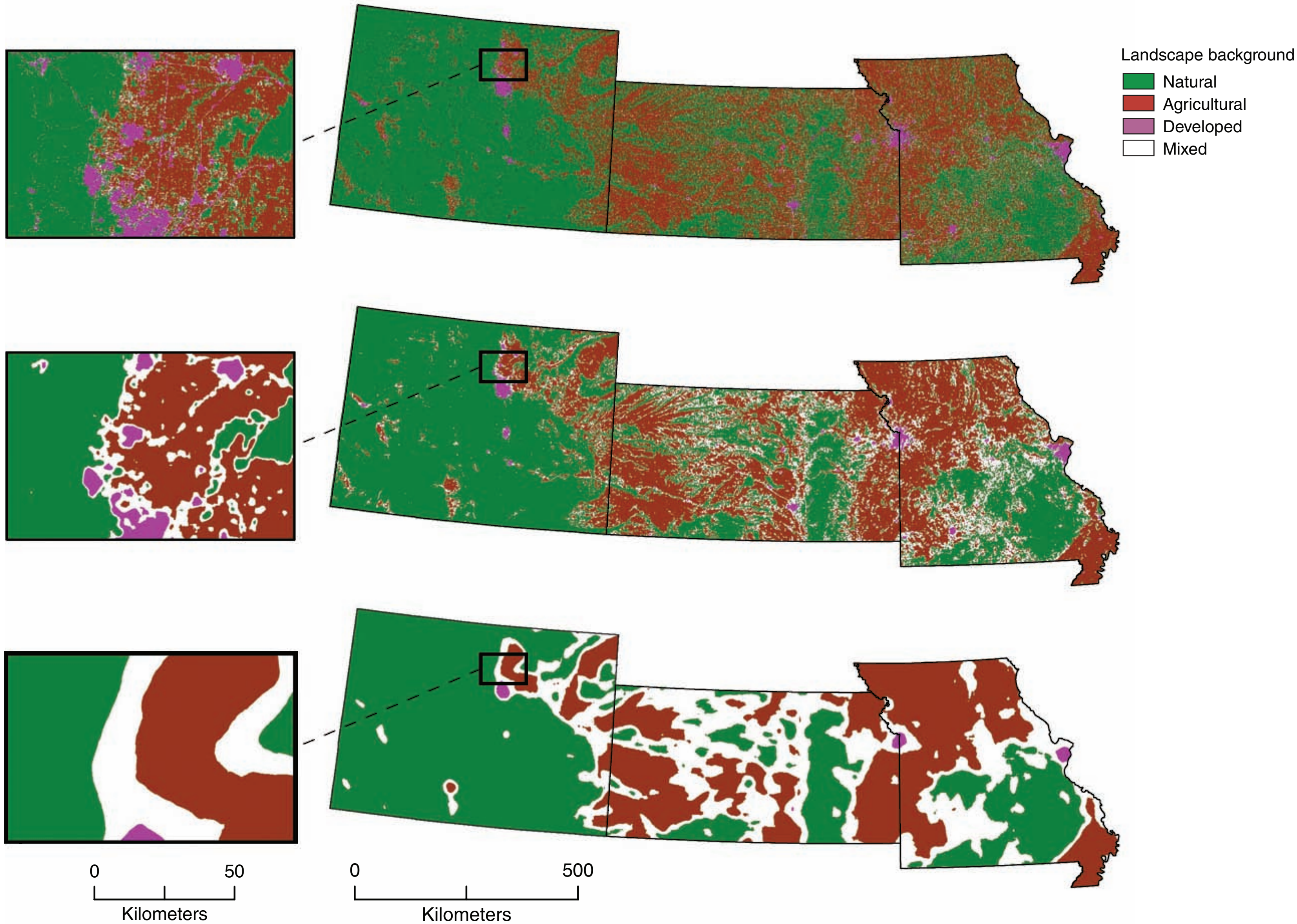

Figure 2.3—Illustration of landcover background (legend as in figure 2.2A) for all locations in the States of Colorado, Kansas, and Missouri, for neighborhood sizes of 4 ha (top), 66 ha (middle), and 5 300 ha (bottom), with inset of region immediately north of the city of Denver, CO.

particular types of landcover can be said to dominate the landscape. For example, while cities of different sizes occur throughout the three-State area, only the largest cities (Denver, Wichita, Kansas City, St. Louis) are sufficiently large to dominate the landscape at scales approximating hundreds of square kilometers (compare figure 2.3, top and bottom).

Figure 2.4 illustrates the landcover context of the forest in the three-State region. Note that the white areas in this figure are nonforest locations; the colors of the forest locations refer to the model shown in figure 2.2B. The trends in relation to increasing or decreasing neighborhood size are generally the same, with similar explanations, as were illustrated for the background context (fig. 2.3). The higher thematic detail of this version of the model is evident in the top inset map of figure 2.4, where development associated with road infrastructure is visible as a network of the natural-developed context, i.e., context class Nd. This signal is not visible for larger neighborhood sizes because roads, while pervasive and locally dense, never occupy a large percentage of total area over larger regions.

One of the more striking comparisons in figure 2.4 is the difference in forest context between the States of Colorado and Missouri over a range of neighborhood sizes. In Colorado, nearly all forest occurs in neighborhoods that are 100 percent natural, i.e., context class NN, whereas in Missouri the same is observed only on the Ozark Mountains. With increasing neighborhood size, the forest in Colorado tends to remain in mostly natural contexts (class N) while the forest in Missouri tends to occur in neighborhoods that are not dominated by natural landcover. For the largest neighborhood size, the natural-agricultural context (class Na) in Colorado appears as inclusions in regions otherwise dominated by natural landcover types, but in Missouri that same context (class Na) appears as rings or edges surrounding a core region dominated by natural landcover types.

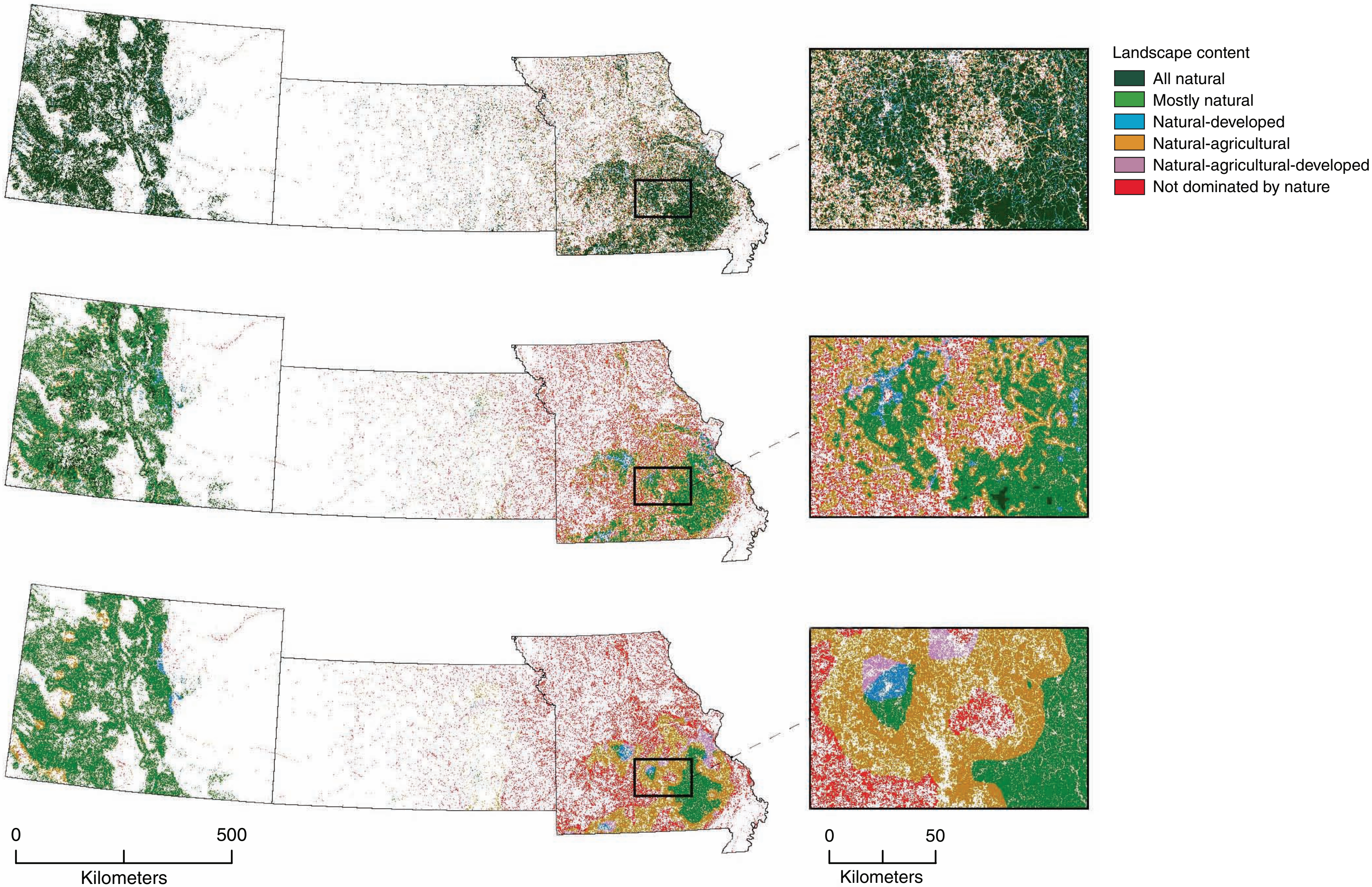

Figure 2.4—Illustration of landcover context (legend as in figure 2.2B) for forest in the States of Colorado, Kansas, and Missouri, for neighborhood sizes of 4 ha (top), 66 ha (middle), and 5 300 ha (bottom), with inset of region of the Salem Plateau in the Ozark Mountains, MO.

The examples for grassland landcover context in the three-State region (fig. 2.5) generally exhibit trends in relation to neighborhood size that are similar to the forest examples (fig. 2.4). Note that the white areas in this figure are nongrassland locations, which permits comparison of the distributions of forest and grassland across the three-State region, i.e., the presence or absence of colored pixels on the two maps. The purpose of using the model shown in figure 2.2B was to focus on the occurrence of forest and grassland in transition zones. The examples show clearly the differences between local (top) and regional (bottom) perspectives of transition zones. Local transition zones by definition are mapped in more detail, and the pixels in those zones are more likely to have a different context than their immediate neighbors, in comparison to regional transition zones.

Ultimately, the pixel-level maps of context will provide the most flexibility for both regional and local resource managers to examine contexts at different scales and in different places. Local details necessarily are ignored for the purpose of this report, for which the results are summarized within each of the four RPA reporting regions (North, Pacific Coast, Rocky Mountain, and South) and are displayed as pie charts for each region. Figure 2.6 shows the proportion of total area within each region that is within each of the four background contexts (compare to figures 2.2A and 2.3). Figure 2.7 shows the proportion of total forest area within each region that is within each of the six contexts shown in figure 2.2B (compare to figure 2.4), and figure 2.8 shows the proportion of total grassland area for the same model (fig. 2.2B, compare to figure 2.5). Note that expressing results as proportions of area (total, forest, or grassland) does not take into account difference in absolute area (total, forest, or grassland) among the reporting regions.

Considering first the regional shares of background context (fig. 2.6), several important observations can be made. In all regions

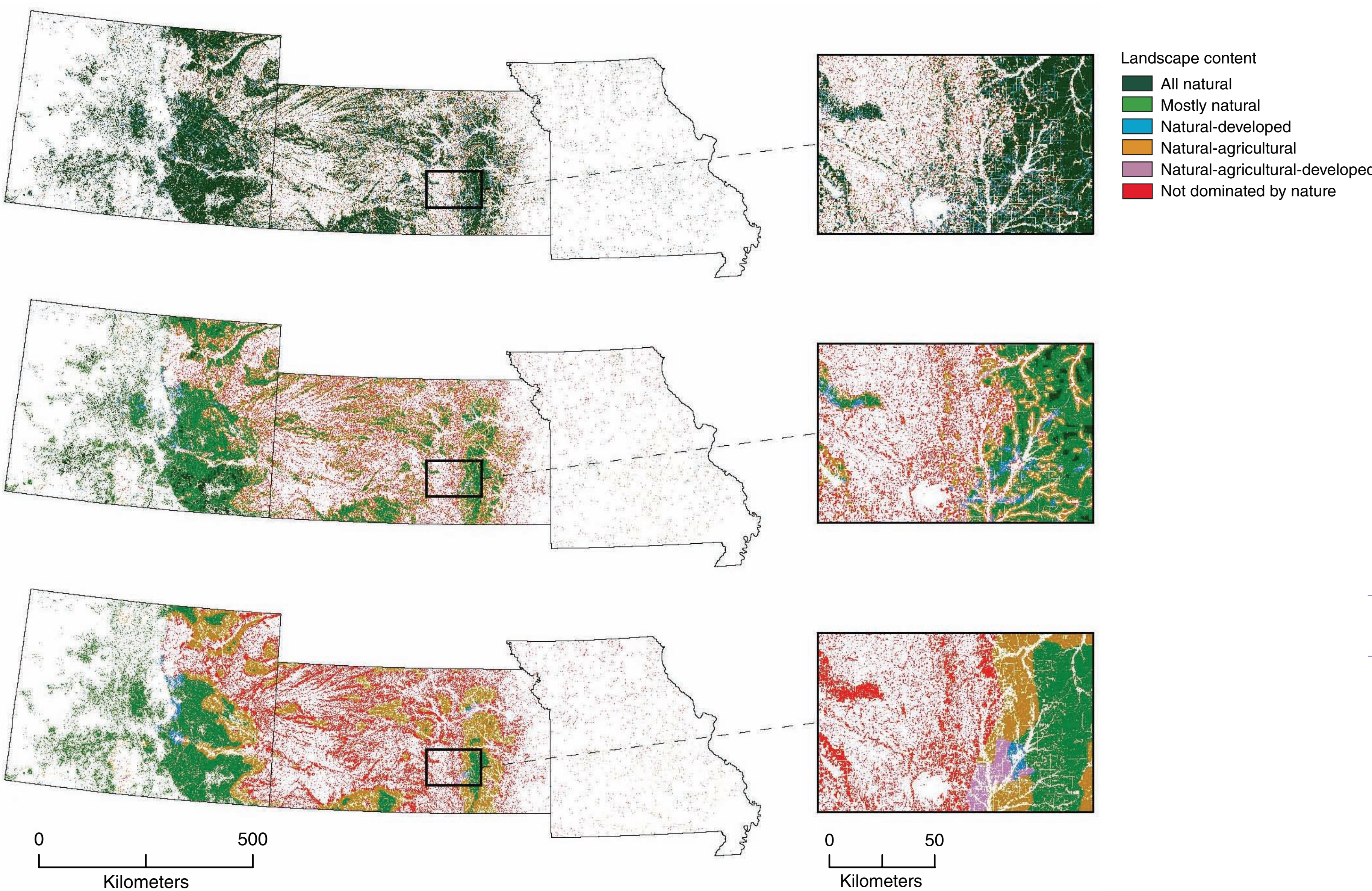

Figure 2.5—Illustration of landcover context (legend as in figure 2.2B) for grassland in the States of Colorado, Kansas, and Missouri, for neighborhood sizes of 4 ha (top), 66 ha (middle), and 5 300 ha (bottom), with inset of region surrounding the city of Wichita, KS.

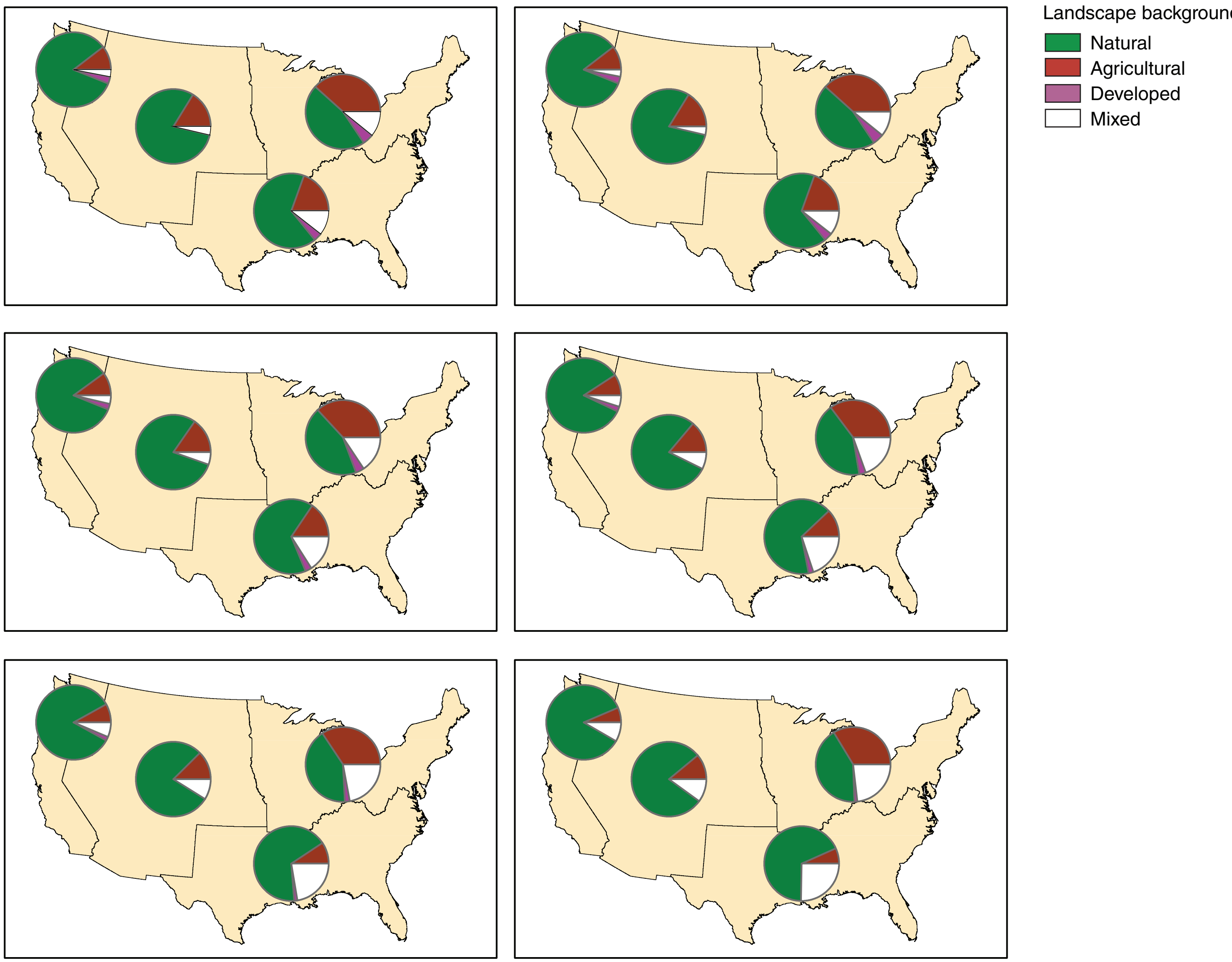

Figure 2.6—The proportions of all land in each of four Resource Planning Act reporting regions (North, Pacific Coast, Rocky Mountain, South) that are within each of four landscape background classes (legend uses the same colors as shown in figure 2.2A) for neighborhood sizes of 4 ha (top left), 15 ha (top right), 66 ha (middle left), 590 ha (middle right), 5 310 ha (bottom left), and 47 800 ha (bottom right).

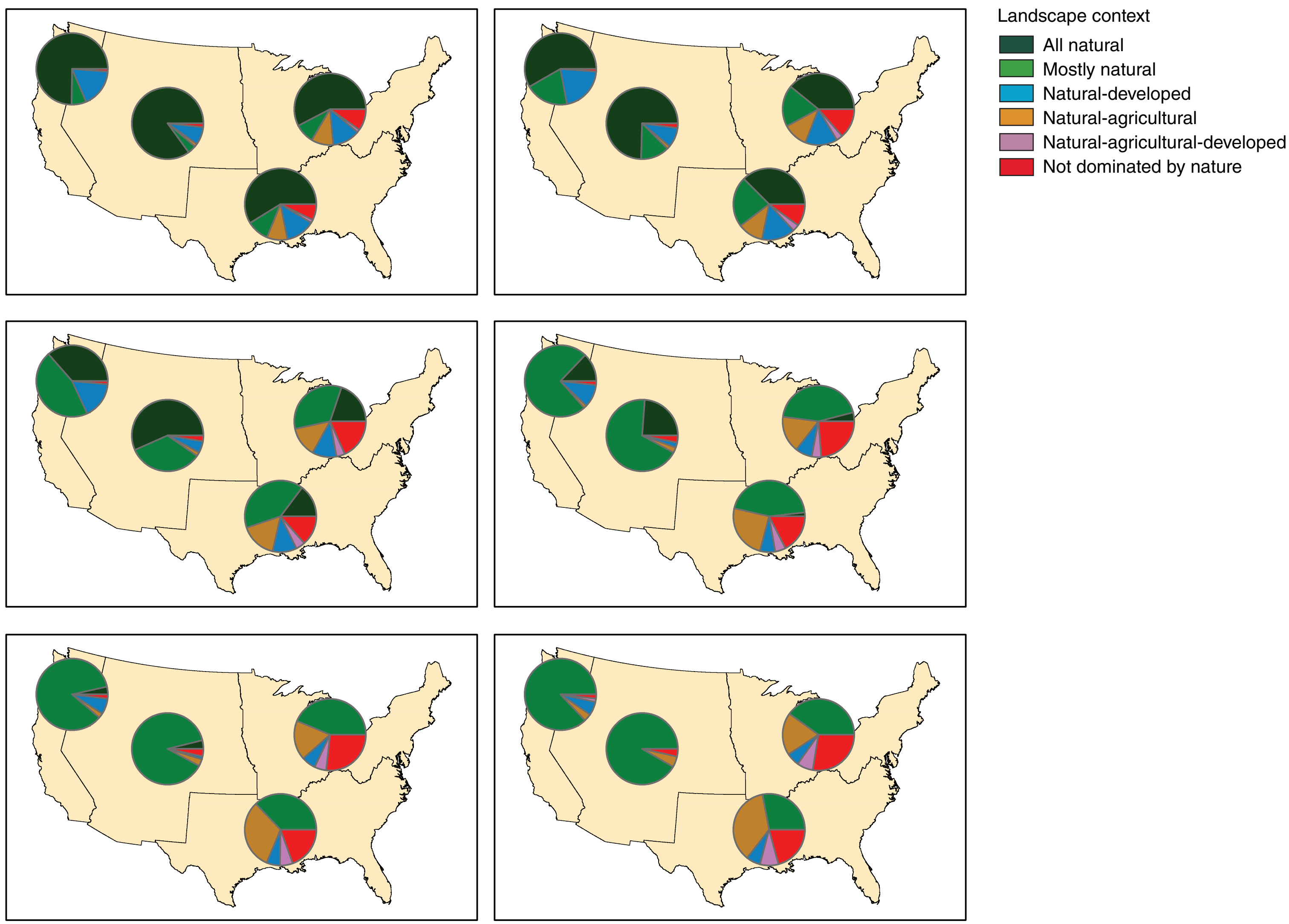

Figure 2.7—The proportions of all forest land in each of four Resource Planning Act reporting regions (North, Pacific Coast, Rocky Mountain, South) that are within each of six landscape context classes (legend uses the same colors as shown in figure 2.2B) for neighborhood sizes of 4 ha (top left), 15 ha (top right), 66 ha (middle left), 590 ha (middle right), 5 310 ha (bottom left), and 47 800 ha (bottom right).

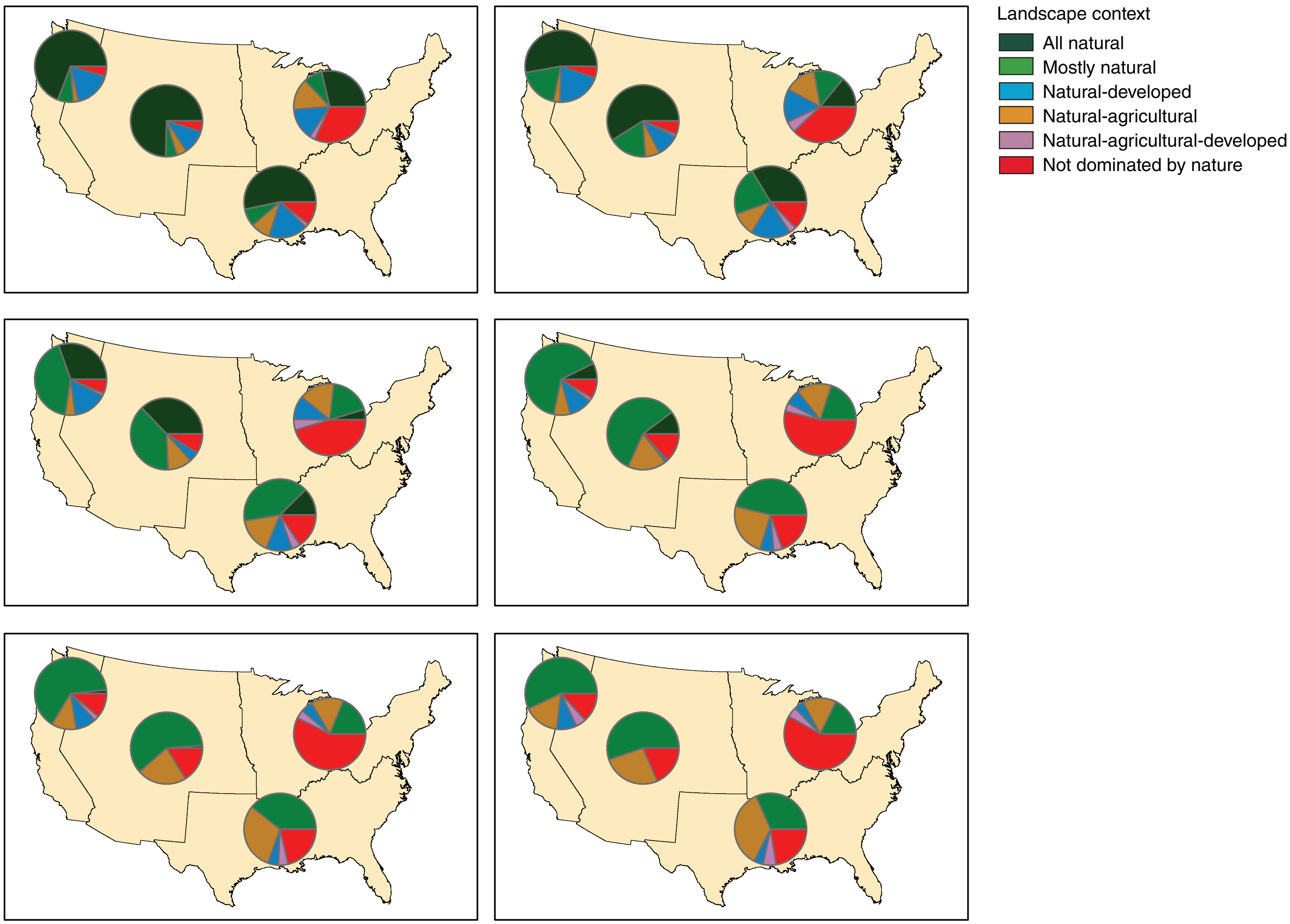

Figure 2.8—The proportions of all grassland in each of four Resource Planning Act reporting regions (North, Pacific Coast, Rocky Mountain, South) that are within each of six landscape context classes (legend uses the same colors as shown in figure 2.2B) for neighborhood sizes of 4 ha (top left), 15 ha (top right), 66 ha (middle left), 590 ha (middle right), 5 310 ha (bottom left), and 47 800 ha (bottom right).

except the North, the majority of all land occurs in a natural background context, and the regional share of agricultural background generally decreases with neighborhood size. The implication is that in those three regions, no matter how intensive agriculture might be on a local basis, it still appears as an anomaly when set against the regional backdrop of natural landscapes. In contrast, in the North region the share of the agricultural background is large compared to other regions and is less affected by neighborhood size. The latter observation, which also applies to the Rocky Mountain region, can be attributed to the presence of extensive agricultural regions such as the corn belt in the North region and the wheat belt in the Rocky Mountain region. In those cases, the natural background has been converted to an agricultural background over large areas. Finally, it is interesting that the regional share of the developed background is never large, i.e., typically < 5 percent, for any of the situations shown. That observation agrees with the proportions of developed landcover itself (not shown here), which is approximately 7 percent for the Nation (including roads) and concentrated in the more populated South and North regions.

The regional shares of forest (fig. 2.7) in different landcover contexts highlight additional aspects of landscape patterns. For example, while the regional shares of natural background (fig. 2.6) are typically 50 to 60 percent, the regional shares of forest in natural background are typically 70 to 90 percent. The implication is that forest tends to occur in natural backgrounds if it occurs at all. Of significant interest is the observation that over half of all forest, in all regions, occurs in a landscape context that is 100 percent natural on a local basis. That means simply that a large proportion of forest occurs within locally intact tracts. However, that proportion decreases rapidly with neighborhood size in all regions, implying that most of those intact tracts are not very large in total extent. A relatively small proportion (typically < 20 percent) of the forest in both the Pacific Coast and Rocky Mountain regions occurs in landscape contexts other than all natural or mostly natural. In contrast, that proportion in the North and South regions is at least 30 percent in the smallest neighborhoods and increases to 60 to 70 percent in the largest neighborhoods. The implication is that eastern forests overall are more exposed than western forests to both short- and long-range impacts from intensive human land uses such as agriculture and development.

The regional shares of grassland (fig. 2.8) in different landcover contexts are generally similar to those of forest (fig. 2.7) with two important exceptions: (a) a smaller share of grassland occurs in 100 percent natural landscapes in comparison to forest, and (b) a higher share of grassland occurs in landscapes that contain more than 10 percent agricultural or developed landcover. It should be noted that the grassland statistics for the North and South do not reflect the fact that there is relatively little grassland overall in those regions in comparison to the other two regions (results not shown here).

Conclusion

This brief summary of a multiscale, national assessment of landcover context indicates that at least half of the area of the conterminous United States can be characterized as a natural background for scales ranging from several hectares to several hundred hectares. Agricultural and developed landcover backgrounds are important locally, but at regional scale they typically occupy no more than 30 percent of total area, principally in the North and South regions and in the eastern portion of the Rocky Mountain region. Considering the questions posed in the introduction to this chapter, we conclude that at local scales, both forest and grassland tend to occur in landscape contexts dominated by forest, grassland, and other natural landcover types. For forest, the same remains true as scale increases from local to regional in the two western regions but not in the two eastern regions where much higher proportions of forest appear in landscapes that contain a significant (more than 10 percent) component of agriculture and developed landcover types. Relatively small proportions of western forest were identified as occurring in transition zones and these zones were more apparent at local scale than at regional scale. The proportions of eastern forest in transition zones were larger and more apparent at regional scale than at local scale. Trends for grassland were generally similar except that a higher proportion of grassland is found in transition zones in all regions, at both local and regional scales. In addition, the proportion of grassland found in landscapes not dominated by natural landcover types is much higher than that proportion for forests, again for all regions and at both local and regional scales.

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