A critique of patch-based landscape indicators for detection of temporal change in fragmentation

James WICKHAM and Kurt RIITTERS

Summary

Landscape indicators, primarily derived from land-cover maps, are used widely to assess environmental condition. Most landscape indicators are based on the patch-matrix conceptual model, which is an adaptation of island biogeography theory to the terrestrial environment. Though widely used, evaluation of landscape indicators to detect temporal changes in fragmentation is less common. We have noticed three problems with using patch-based landscape indicators for detection of temporal changes in fragmentation: 1) patch-based indicators can produce inconsistent and counterintuitive results; 2) patch-based indicators fix the observation scale, by delineating patches, which inhibits multi-scale analysis, and; 3) patch-based indicators are not as applicable when the feature of interest (e.g., habitat) is the matrix (i.e., abundant) rather than the patch. To avoid these problems, we have relied on amount (i.e., proportion (*p*)) to analyze and interpret temporal changes in fragmentation at multiple scales. Further evaluation and testing of patch-based landscape indicators are needed to determine their utility for detection and interpretation of temporal changes in fragmentation.

Abstract

Since O'Neill et al. (1988), analysis of landscape indicators based on measurements from land-cover maps has been a core area of research in landscape ecology. Landscape indicator research has focused on development of new measurements, statistical properties, and indictor behavior across a gradient of context (e.g., urban, rural). Habitat fragmentation has been a strong motivating force for landscape indicator development, and island biogeography theory (McArthur and Wilson 1967) has been the main conceptual model underpinning their development (see Laurance 2008). Average patch size, inter-patch distance, and related measurements are commonly used landscape indicators because of the strong link to island biogeography theory.

Reviews and syntheses of landscape indicators are now appearing in the literature (e.g., Turner 2005) because the research has been ongoing for a few decades. Such reviews typically omit discussion of the use of patch-based landscape indicators for detection of temporal change in fragmentation because there are relatively few empirical studies on the topic. Our research has revealed at least three problems with the use of patch-based landscape indicators for detection of temporal changes in fragmentation. First, patch-based landscape indicators do not always provide clear and unambiguous temporal change results. Riitters et al. (2004) showed that average inter-patch distance could decrease with the introduction of roads onto the landscape. These empirical results support intuition. Consider a three-patch landscape where the smallest patch is also the most distant. Removal of the smallest patch would decrease in inter-patch distance and increase average patch size, suggesting less fragmentation, even though there was attrition (sensu Bogaert et al. 2004) of the resource. Second, reliance on patch-based landscape indicators fixes the observation scale by focusing on objects (patches) that make multi-scale analyses more difficult (Hay et al. 2003, Wickham et al. 2007a). Use of patch-based landscape indicators may miss temporal changes in the spatial scale of a resource that arises from resource loss even though spatial scale is usually an important aspect of resource condition and function (Wickham et al. 2007a, Wickham et al. 2008). Third, the patch-matrix conceptual model is less applicable when the feature of interest is not the patch, but rather the matrix. Thus, patch-based indicators are less suitable for those locations where the feature of interest dominates the landscape (Riitters et al. 2002, Wickham et al. 2008). Still, fragmentation is

relevant in locations where the feature of interest dominates the landscape (Lindenmayer et al. 2008), because loss can introduce perforations (Riitters et al. 2000, 2002, Boegart 2004) that produce edge effects (Harper et al. 2005, Laurance 2008) and change the portion of the remaining resource that is interior (e.g., Wickham et al. 2007b).

We have relied on amount (i.e., proportion (*p*)) as our primary landscape indicator in order to avoid the potential problems that arise from using patch-based landscape indicators in a temporal context. Reliance on *p* made intuitive sense because it is regarded as a fundamental landscape indicator (Li and Reynolds 1994, Gardner and Urban 2007), changes in *p* are unambiguously interpretable in the temporal domain (Wickham et al. 2008), and use of *p* easily accommodates multi-scale analyses (Riitters et al. 2002). We have used *p* to show changes in forest resource spatial pattern (e.g., fragmentation) over time for the continental United States (US). Our results have shown that: 1) while continental US forests are dominant where they occur, more the half of US forests are influenced by edge effects of some type (Riitters 2002); 2) loss of interior forest due to mountaintop mining in the Appalachian region of the eastern US was about 2 to 5 times greater than the amount of forest loss attributable to the practice (Wickham et al. 2007b), 3) local-scale forest losses have had broader impacts on the spatial scale at which forests dominate US landscapes (Wickham et al. 2007a, Wickham et al. 2008), and; 4) temporal dynamics of forest change along the US Gulf coast were more strongly determined the shifting mosaic of landscape context than forest dynamics within the landscape (Riitters et al. 2009). Our research does not constitute a formal evaluation of the utility of patch-based landscape indicators for detecting temporal changes in fragmentation, suggesting more research is needed.

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