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Review Article

Environmental heterogeneity as a bridge between ecosystem service and visual quality objectives in management, planning and design

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HIGHLIGHTS

- Dimensions of environmental heterogeneity are compared with indicators of visual complexity.
- Substantial overlap between ecological and aesthetic heterogeneity indicates the potential for cross-disciplinary bridge.
- Visual and ecological complexity may be jointly used to promote resilient and multi-functional landscapes.
- Future work should develop objective, replicable indicators of complexity applicable to both disciplines.

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ABSTRACT

Environmental heterogeneity has recently received increased attention due to its effect on biological diversity, ecosystem services and ecological resilience to disturbance and hazards. However, its relationships with landscape complexity as an indicator of visual aesthetic quality have not been yet extensively discussed. The purpose of this paper is to review different dimensions of environmental heterogeneity and to explore their potential for bridging visual quality with provision of other ecosystem services and resilience in landscape design, management and planning. This synthesis reveals the substantial overlap between spatial and temporal indicators of heterogeneity from ecological literature and the indicators of visual complexity, diversity and variety from the studies of subjective preferences and objective scenic beauty criteria. The potential of heterogeneity is also reviewed in the context of the relationship between visual quality and ecological resilience to perturbations, an increasingly important objective in the face of the global environmental change. The limitations of heterogeneity as a design and management goal are also discussed, including links between heterogeneity and disturbance, undesirable outcomes of excessive landscape complexity and present lack of criteria for its optimal levels. The synthesis concludes by identifying the key strategies and research needs to facilitate the application of this concept towards multi-functional landscapes supporting versatile ecosystem services together with scenic priorities.

Contents

1. Introduction 91
2. Background and key definitions 92
   2.1. Environmental heterogeneity and its relationship to ecosystem services 92
   2.2. Visual landscape quality and aesthetic proxies of heterogeneity 93
   2.3. Components of environmental heterogeneity in relation to ES and visual quality 93
3. Dimensions of environmental heterogeneity and their use in visual quality evaluation 93
   3.1. Spatial heterogeneity 93
      3.1.1. Land cover composition 93
      3.1.2. Vegetation heterogeneity and biodiversity 96
      3.1.3. Physical environmental heterogeneity 96

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3.1.4. Edges and ecotones 97
3.1.5. Vertical and 3-D heterogeneity 97
3.2. Temporal heterogeneity 98
3.2.1. Short-term heterogeneity 98
3.2.2. Long-term heterogeneity 98
4. Heterogeneity, visual quality and resilience 99
5. Limits to heterogeneity 100
6. Synthesis and future research needs 100
Acknowledgment 101
Appendix A ..... ??
References 103

1. Introduction

One of the most challenging tasks in present-day environmental planning is reconciling the long-term objectives concerning ecosystem services (ES), conservation and protection against hazards with more immediate needs to improve and maintain visual landscape quality affecting human perception and valuation of places (Allan et al., 2015; Daniel, 2001; de Groot, Alkemade, Braat, Hein, & Willemen, 2010; Gobster, Nassauer, Daniel, & Fry, 2007; Kremen, 2005; Parrott and Meyer, 2012). This task requires an in-depth understanding of how ecological functions underlying critical ES affect landscape composition, structure and dynamics contributing to visual quality. In particular, environmental heterogeneity, broadly denoting non-uniformities in physical and ecological landscape characteristics, has been shown to influence biodiversity (Cardinale et al., 2006; Mace, Norris, & Fitter, 2012; Stein, Gerstner, & Kreft, 2014; Tscharntke et al., 2012), resilience of natural and human ecosystems to stressors (Hodbod, Barreteau, Allen, & Magda, 2016; Levine et al., 2016; Oliver et al., 2015), agricultural productivity (Kremen & Miles, 2012; Ostman, Ekbom, & Bengtsson, 2001) and landscape complexity related to visual aesthetic quality and preferences (de la Fuente de Val, Atauri, & de Lucio, 2006; Hasund, Kataria, & Lagerkvist, 2011; Junge, Schuepbach, Walter, Schmid, & Lindemann-Matthies, 2015; Kaplan & Kaplan, 1989; Lindemann-Matthies, Briegel, Schupbach, & Junge, 2010). However, despite the abundant research on the links between visual quality and complexity, their ecological underpinnings have not yet been extensively discussed, and the potential of environmental heterogeneity to sustain both landscape aesthetic benefits and ecological functionality remains under-studied.

The interest in multi-functional and visually appealing landscapes has persisted since the earlier legislative frameworks (e.g., Multiple Use-Sustained Yield Act of 1960 and the National Environmental Policy Act of 1969), becoming even more evident in recent pursuits for robust, ecologically informative landscape quality indicators (Cassatella, 2011; Fry, Tveit, Ode, & Velarde, 2009; Llausas and Nogue, 2012; Ode & Miller, 2011; Sowińska-Świerkosz & Chmielewski, 2016; Tveit, Ode, & Fry, 2006). However, ecological mechanisms and functions controlling landscape determinants of visual quality have not been frequently discussed in such a context. Furthermore, in the earlier literature, the terms "picturesque" and "functional" were sometimes considered as distinct and not always compatible landscape properties (Hull and Buhyoff, 1986; Nassauer, 1986; Ulrich, 1986), while some analysts also noted the tension between ecological and cultural underpinnings of aesthetic preference (de la Fuente de Val et al., 2006; Gobster et al., 2007; Mozingo, 1997; Tveit et al., 2006). These issues have stimulated an important ecological aesthetic discourse on to what extent the landscapes can be both functional and visually pleasing (Carlson, 2001; Gobster et al., 2007; Nassauer & Opdam, 2008), and which spatial and temporal attributes are particularly useful in connecting these objectives (de Groot et al., 2010; Fry et al., 2009; Lindemann-Matthies et al., 2010; Tveit et al., 2006). However, the potential of ecological heterogeneity in this capacity has not yet been explicitly discussed.

Importantly, such a potential is strongly suggested by both ecological and landscape aesthetic literature (Allan et al., 2015; de la Fuente de Val et al., 2006; Nassauer, 1997). Several comprehensive recent reviews report the significance of environmental heterogeneity for biological diversity and resilience (Oliver et al., 2015; Spasojevic et al., 2016; Stein et al., 2014) with major implications for critical ES, such as agricultural food production, water and air quality, ecosystem regulation (pollination, pest control, soil quality), landscape connectivity, and more (Cardinale et al., 2012; Kremen & Miles, 2012; Tscharntke et al., 2012). Similarly, both subjective indicators of visual preference and objective scenic quality criteria have been frequently associated with landscape complexity and variety – concepts related to but not directly representing environmental heterogeneity (Herzog & Barnes, 1999; Kaplan & Kaplan, 1989; Tveit et al., 2006; Ulrich, 1986), discussed in Section 2 in more detail. However, the evidence of favorable effects of complexity on visual quality has not been uniform, showing positive, negative as well as more complex and context-dependent relationships (Coeterier, 1996; Kaplan & Kaplan, 1989; Sevenant & Antrop, 2010; Stamps, 2004). For instance, in the meta-analysis by Stamps (2004) the correlation between complexity and preference ranged from −0.11 to 0.97, precluding a singular interpretation of their association. In various studies summarized by Kaplan and Kaplan (1989), the rank of complexity among other visual criteria varied, but often was moderately important. In contrast, two studies of perception in the Dutch (Coeterier, 1996) and Belgian (Sevenant & Antrop, 2010) landscapes did not find complexity to be significant. This uncertainty parallels the gaps in ecological understanding of specific effects of heterogeneity on different ES (e.g., Balvanera et al., 2014; Cardinale et al., 2012) and underscores the need for cross-disciplinary investigations of the links between visual complexity, environmental heterogeneity and their synergistic benefits for landscape management and ES goals.

Some efforts have also been made to link visual landscape quality with ecological heterogeneity and diversity, such as the Biophilia concept referring to human affection and affinity for nature and its elements (Grinde & Patil, 2009; Van Den Born, Lenders, De Groot, & Huijsman, 2001). However, few studies have addressed specific mechanisms by which environmental and ecological heterogeneity translate into aesthetic quality (Ding, Tang, Dai, & Wei, 2014; Junge et al., 2015; Lindemann-Matthies et al., 2010; Sowińska-Świerkosz, 2016), which could be then used to develop a stronger bridge between functional and aesthetic priorities in landscape planning (Fig. 1). The need to better understand this potential is especially important in the face of planning challenges posed by the degradation of natural resources, climate change and food security issues (Allan et al., 2015; de Groot et al., 2010; Hodbod et al., 2016; Ungaro, Haefner, Zasada, & Piorr, 2016) and worldwide homogenization of both urban and rural human-dominated