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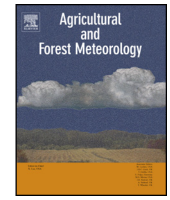

Review

Gradients of microclimate, carbon and nitrogen in transition zones of fragmented landscapes – a review

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ABSTRACT

Fragmentation of landscapes creates a transition zone in between natural habitats or different kinds of land use. In forested and agricultural landscapes with transition zones, microclimate and matter cycling are markedly altered. This probably accelerates and is intensified by global warming. However, there is no consensus on defining transition zones and quantifying relevant variables for microclimate and matter cycling across disciplines. This article is an attempt to a) revise definitions and offer a framework for quantitative ecologists, b) review the literature on microclimate and matter cycling in transition zones and c) summarise this information using meta-analysis to better understand bio-geochemical and bio-geophysical processes and their spatial extent in transition zones. We expect altered conditions in soils of transition zones to be 10–20 m with a maximum of 50 m, and 25–50 m for above-ground space with a maximum of 125 m.

Contents

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1. Introduction

Most landscapes are composed of different kinds of ecosystems, which are nested but also often physically separated into fragments (Ries et al., 2004). Fragmented forested and agricultural landscapes are characterised by the occurrence of discontinuities or variations in prevalent or native land cover and habitat properties (Strayer et al., 2003).

In quantitative terms, they differ from other landscapes by having a lower average size of the fragment, a lower interior-to-edge ratio (see Section 2.3 for definitions) and an increase in isolation and distance to each other for patches of similar properties (Mitchell et al., 2014; Saunders et al., 1991).

Fragmented landscapes are not static *per se* but are rather in a continuous natural process of fragmentation. Drivers of fragmentation act on various spatio-temporal scales: geogenic (e.g. differing parent rock), topographical (relief), geomorphological (e.g. kettle holes), pedogenic (e.g. climate), hydrological (e.g. groundwater or rivers), and phytological (e.g. seed dispersal or succession) (Cadenasso et al., 2003a; Wu and David, 2002). Moreover, landscapes are fragmented by sudden events, such as wind throw, erosion (water or wind), volcanic eruptions, earthquakes, pests and diseases, fires or floods (e.g. Braithwaite and Mallik, 2012; Laurance and Curran, 2008).

The total area of forest has been decreasing for millennia (probably for more than 6000 years) due to deforestation and the intrusion of agricultural land (FAO, 2012; Williams, 2006); currently, the area of contiguous intact forest is decreasing twice as quickly as the total area of forest (Riitters et al., 2015). Fragments of native vegetation are often surrounded by managed land (Saunders et al., 1991). This anthropogenically driven fragmentation of landscapes largely changes the land's properties and functioning by mixing zones of different habitat quality and ecological features. The main man-made drivers are agriculture and forestry (e.g. horizontal expansion, logging), urbanisation (Liu et al., 2016), rural development (e.g. road construction) and energy production (e.g. dams). In addition to natural sudden events, man-made disasters such as fires or pollution (e.g. chemical spill, nitrogen deposition, acid rain) also cause fragmentation.

Fragmentation leads to biome patches with zones of transition in between them. These transition zones are characterised by active and passive exchange of matter, energy and information – their properties differ from native forest, plain pasture and agricultural land (Gosz, 1992; Wiens et al., 1985). In fact, 74% of the total forest area in England (Riutta et al., 2014), 74% of semi-deciduous savanna forest in north-east Ivory Coast (Hennenberg, 2005; Hennenberg et al., 2008), almost 50% of all Brazilian Atlantic rainforests (Ribeiro et al., 2009), 44% of continental United States forest (Riitters et al., 2002) and 40% of the total forest area in Bavaria (Germany) (Spangenberg and Kölling, 2004) have been defined as being located within a transition zone of 90–100 m from the forest edge. Globally, Haddad et al. (2015) calculated that 20% of forested land was located in a 100 m transition zone within forests.

Fragmentation affects the local climate. For example, the air within and above cropland is warmer and drier than the moister and cooler air in adjacent forests (Ewers and Banks-Leite, 2013; Laurance et al., 2011). The different microclimate which evolves within the fragments fosters the establishment of differently adapted plant communities, which in turn also influence the microclimate (Chen et al., 1992; Laurance et al., 2011; van Rooyen et al., 2011; Saunders et al., 1999). Some taxa clearly respond positively or negatively to changes in microclimate caused by fragmentation (Godefroid et al., 2006; Heithecker and Halpern, 2007; Magnago et al., 2015). Research on edges conducted in recent decades mainly described them as hot spots for biodiversity and evolutionary processes (Kark and van Rensburg, 2006; Lidicker, 1999 see Ries et al., 2004), which will not be addressed in this review.

Within transition zones, microclimate alters matter cycling (Laurance et al., 2007, 2011; Nascimento and Laurance, 2004). In forested transition zones, above-ground carbon storage capacity has been found to be as little as half that of the forest interior (Paula et al., 2011). Pütz et al. (2014) calculated a total of 200 Tg carbon gas emissions per year due to forest degradation (fragmentation) in tropical forests; this is one-fifth of all emissions caused by deforestation. Moreover, in addition to the carbon gas emissions caused by deforestation, simulations by Laurance et al. (1998) suggest that another 22–149 Tg C loss per year is caused by fragmentation of tropical forests worldwide. Due to altered decomposition rates and primary production (Chen et al., 1992) within these transition zones, Ewers and Banks-Leite (2013) hypothesise that, as global climate change take place, transition zones will increasingly gain in importance.

The relevance of transition zones is thus substantially increasing. However, up to this point, there is no consensus among scientists with respect to definitions and investigation strategies. A synthesis of the existing knowledge on matter dynamics and the connection to microclimate in transition zones is currently lacking. This review provides a first attempt to fill this gap.

The aim of this review is to a) address the various definitions of 'edge effects', b) review the literature on microclimate and matter cycling in transition zones and c) summarise this information using meta-analysis to better understand bio-geochemical and bio-geophysical processes in transition zones (Fig. 1).

The meta-analysis consisted of a literature search for the expressions 'edge effect', 'forest', 'microclimate', 'ecotone', 'transition zone', 'pasture', 'agriculture', 'carbon', 'nitrogen', 'matter and nutrient dynamics' and 'cycling'. To define the spatial extent of the influence of transition zones, the maximum distance had to be stated as measured from the zero line (see Fig. 2 or Table 1) perpendicularly in one direction. If a range was given, both values were used. Although the magnitude of variables has not been taken into account, studies that reported no significance were omitted.

2. Definitions – gradients in fragmented landscapes

2.1. Structural traits in fragmented landscapes

Ecosystems are usually understood as complex systems: they are nonlinear, emergent, self-organised and self-regulated, interrelated, open and agent-based; they also have attractors (Gosz, 1992; Müller and Kroll, 2011; Wu and Loucks, 1995). In order to understand them better, humans tend to structure things when investigating units of a system. In ecology, patches are often used as such a concept for structuring a system (see Wu and Loucks, 1995 for a review). The characteristic feature of patches is a delineation from their environment in which patches can be seen as physical systems. As such, a system boundary must be identified, which is a question of definition and scale. Delineation is usually considered