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Tall herb sites as a guide for planning, maintenance and engineering of riparian continuous forest cover

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ABSTRACT

Continuous cover riparian forests host significant plant and animal species richness, a range of habitats, and natural processes of importance for both terrestrial and aquatic ecosystems. Riparian forest is thus a green infrastructure for biodiversity conservation. However, a long history of landscape alteration now calls for maintenance and restoration by ecological engineering. This study evaluates management guidelines advocating constant vs. variable width of riparian forest protected zones in managed landscapes. In naturally dynamic forests, stands with gap-phase dynamic along streams often provide a network of habitats with a high degree of continuity in tree canopy cover and dead wood for biodiversity conservation and delivery of ecosystem services including water purification. Based on the observation that tall herb sites indicate a potential for temporally continuous forest cover, we tested three null hypotheses. Tall herb sites (1) are equally common in the riparian zone and in the surrounding forest landscape; (2) have the same width on both sides of a stream; and (3) their widths are independent of the width of the adjacent stream. We described the ground vegetation in transects along and perpendicular to streams, and in the surrounding landscape, in six 3rd stream order catchment located in Sweden, Lithuania and the Komi Republic of Russia. The results showed that tall herb sites were 21–27 times more common along streams compared to in the rest of the landscape, the width of tall herb sites varied considerably along streams, and it was independent of the width of the adjacent stream. This study suggests that rather than fixed-width guidelines for riparian set-asides, to support cost-efficient maintenance of riparian forest, local site conditions should be used as guide for planning, maintenance and engineering of riparian ecotones. Because tall herb forest sites were historically cleared for agricultural purposes, the potential natural amount of riparian forest is severely underestimated.

1. Introduction

Despite comprehensive policy, research as well as common endorsement and effort by land owners and managers, it is obvious that the EU still falls short of achieving its biodiversity conservation targets (European Commission, 2015). European forest policy processes defining sustainable forest management accommodate biodiversity conservation concerns (European Commission, 2013a); and there is a general pledge to secure the supply of a diversity of ecosystem services (European Commission, 2014). However, assessment in both forestry and agricultural systems indicates that greater efforts are still needed to conserve and enhance biodiversity as base for delivery of ecosystem services (European Commission, 2015). Similarly, from a catchment perspective, good status of many waters in Europe also still remains to be achieved (European Commission, 2012). To secure ecosystem benefits that are limited in supply, strategically planned networks of representative natural and semi-natural can be designed and managed to deliver a wide range of ecosystem services; the term green infrastructure captures this (European Commission, 2013b).

Biodiversity conservation in landscapes managed for forestry and agriculture is crucial because (1) only protected areas will not protect biodiversity; (2) securing benefits from ecosystems ultimately relies on vital services provided by biodiversity; and (3) biodiversity enhances ecosystems' capacity to recover from external pressures or management mistakes (e.g., Fischer et al., 2006). To improve policy implementation, it is crucial that evidence-based knowledge is developed about the functionality of ecosystems as green infrastructure (European Commission, 2013b) that supplies ecosystem services (e.g., Burkhard et al., 2012).

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A concrete issue is the role of considerations to biodiversity in land management, such as how to design aquatic-terrestrial ecotones in forest and agricultural landscapes. Riparian ecotones are particularly important for the maintenance of biodiversity and delivery of ecosystem services (e.g., Naiman et al., 1993; Kuusemets et al., 2001; Grygoruk and Acreman, 2015). Riparian forests are an essential contributor to the precipitation and evapotranspiration cycles, by drawing in moist air from elsewhere, and improving water availability at various scales (Makarieva et al., 2014; Makarieva and Gorshkov, 2013; Ellison et al., 2011; Sheil and Murdiyarso, 2009). The interface between the terrestrial and the aquatic environment contributes to the maintenance of compositional, structural and functional elements of biodiversity (Noss, 1990) in both terrestrial and aquatic forest ecosystems (Wiens, 2002; Williams et al., 2003; Sweeney and Czapka, 2004). Naturally dynamic riparian forest ecotones provide suitable conditions for a wide range of vascular plants (Nilsson, 1983), substrate for lichens requiring a moist local climate (Sjöberg and Ericson, 1992), species dependent on naturally dynamic forest (Stighäll et al., 2011), and often a more diverse tree species composition in the adjacent terrestrial system. Riparian forest ecotones also supply streams with woody debris (Bergquist, 1999), leaf litter (Cummins et al., 1989) and regulate nutrient uptakes into the aquatic food chain (Lowrance et al., 1984; Gregory et al., 1991; Osborne and Kovacic, 1993; Mander et al., 1995; Tabacchi et al., 1998). Finally, in the aquatic system riparian forests buffer against flow peaks during snow melt and autumn rains, erosion, leakage of organic matter and nutrients (Lowrance et al., 1984; Gregory et al., 1991; Schlosser, 1991; Osborne and Kovacic, 1993; Mander et al., 1995; Tabacchi et al., 1998; Bergquist, 1999; Kuusemets et al., 2001).

Managing riparian forest ecotones for continuous provision of this multitude of ecosystem services is a complex task (Bergquist, 1999; Nyberg and Eriksson, 2001; Wiens, 2002). Restoring riparian vegetation as part of green infrastructures of agriculture-dominated landscapes is even more demanding. Moreover, ecological objectives in management and planning must compete with economic interests. By default, the majority or land owners and managers are interested in economic gains. Due to long landscape histories, the riparian ecotone is a natural vegetation type that has changed very much following historic clearing of forest for agriculture and development of intensive forest management through modification of streams to improve draining and for wood transportation (e.g., Carlgren, 1886; Lundberg, 1914; Bergquist, 1999). The recently reported low current loss of riparian forest in Europe (Clericia et al., 2014) underestimates this problem by just focusing on contemporary changes, and not the historic loss of forests and woodlands, which is commonly much higher on more productive ecosystems where continuous cover forests is the natural potential vegetation (e.g., Angelstam and Andersson, 2001). Therefore, there is a paucity of data from naturally dynamic reference areas, which would allow an objective determination of an appropriate structure and form of the aquatic-terrestrial ecotone (but see Lazdinis and Angelstam, 2005; Angelstam et al., 2011b). This makes it difficult to find guidance for conservation, management, restoration and re-creation of compositional, structural and functional elements of biodiversity (e.g., Angelstam and Andersson, 2001).

The ways of managing forests in riparian ecotones has been a topic for scientific research and political debate for a long time in many countries (e.g., Malanson, 1993; Greminger, 2003; Murphy et al., 2008; Kuglerová et al., 2014a; Laudon et al., 2016). Commonly, the guidelines have focused on preserving fixed-width corridors (see Macdonald et al., 2004; Lazdinis and Angelstam, 2005; Kuglerová et al., 2014a). However, some recent studies have demonstrated that the use of variable-width buffer zones with different management interventions would allow more cost-efficient trade-offs between biodiversity conservation and wood production benefits of managed forests (Murphy et al., 2008; Laudon et al., 2016; Kuglerová et al., 2014a).

To support planning, management and ecological engineering evidence-based knowledge is required from a wide range of contexts. In naturally dynamic forests, continuous cover forest stands with gap-phase dynamic on productive tall herb sites are often found along streams (Yaroshenko et al., 2001; Jasinski and Angelstam, 2002). Tall herb vegetation (see species list in Hägglund and Lundmark, 1984) is thus a good indicator when selecting sites for conservation of riparian forest by management, restoration and re-creation (Nilsson, 1983; Curry and Slater, 1986; Nilsson et al., 1988, 1989; Learner et al., 1990; Gregory et al., 1991; Satterlund and Adams, 1992; Malanson, 1993; Karazija and Vaičiūnas, 1994; Spackman and Hughes, 1995; Fries et al., 1997; Angelstam, 1998). Knowledge about how to handle riparian forest and vegetation is also relevant in a diversity of other benefits (e.g., Kuusemets et al., 2001; Richardson et al., 2007).

In this study we use ground vegetation plant communities to identify and analyze the occurrence and width of sites which are suitable to be maintained by conservation, management, restoration and re-creation as riparian continuous cover forests for biodiversity conservation and subsequent ecosystem services. In order to mirror some of the range of biophysical factors, management regulations and practices on the European continent, we conducted this study in three landscapes with different biophysical conditions and socio-economic contexts representing Sweden, Lithuania and the Komi Republic in Russia. Due to different ideological and socio-economic conditions these three countries have experienced different forest management regimes. In Lithuania and Komi Republic – both former Soviet Union territories – already before the breakup of the Soviet state after 1991, forest management guidelines had prescribed conservation of riparian forests for many decades (see Lazdinis and Angelstam, 2005), and they still remain to a large extent. By contrast, in Sweden riparian ecotone management has become an issue mainly only during the last two decades (Rosén et al., 1996; Bergquist, 1999; Nyberg and Eriksson, 2001; Kuglerová et al., 2014a).

Based on the evidence that tall herb sites indicate a potential for conservation, management, restoration and re-creation of continuous cover forests highly valuable for biodiversity conservation (e.g., Kuuluvainen, 1994; Angelstam, 1998; Jasinski and Angelstam, 2002), we test three null hypotheses. Herb sites: (1) are equally common in the riparian zone and in the surrounding forests; (2) have the same width on both sides of the stream at the same location and do not vary along a stream; and (3) their width is directly related to the stream width.

2. Methods

2.1. Study areas

A total of six sets of transects were replicated in two catchments each in south-central Sweden, southern Lithuania and the Komi Republic of Russia. The selected study areas represent similar types of forest landscapes with mixed pine (*Pinus sylvestris*) and spruce (*Picea abies*) stands with small proportions of birches (*Betula* spp.) and aspen (*Populus tremula*). The biophysical conditions at the stand level scale in the six sets of transects in catchments of the three countries all provide opportunity for the same range of ground vegetation types linked to edaphic, hydrological and climatic conditions. This is clearly indicated by the close similarity of ground vegetation classification systems in Sweden (Arnborg, 1990), Lithuania (Karazija, 1988) and Russia (Sukachev, 1928; Sukachev and Dylis, 1964).