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Short communication

Zoned selective coppice – A management system for graded forest edges

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ABSTRACT

Graded forest edges with low shrubs at the periphery and increasingly higher shrubs and trees towards the interior are often considered ideal in urban and infrastructure environments. They provide high biodiversity, filter and shelter functions, aesthetic appeal and recreation values, while keeping potentially hazardous trees away from railways, houses, roads and power-lines. This short communication presents zoned selective coppice (ZSC) as a novel management system for developing and sustaining species-rich forest edges with graded profile. ZSC is based on threshold height decreasing stepwise from the inner through the middle to the outer edge zone, resulting in height and density gradients over the edge cross-section. Preliminary results from simulation and implementation of ZSC in a controlled trial in 14 unmanaged edge sections 20 years after planting showed that the trend towards abrupt edge profiles was reversed and the strong spatial regularity of the original planting reduced. Most edge sections approached complete spatial randomness after only one coppicing operation and woody species diversity increased, without reducing species richness. While these results are based on one management operation, the controlled trial enables future long-term monitoring of how edge profile and species diversity are affected by repeated ZSC operations.

Introduction

In fragmented urban and infrastructure landscapes, the edges of forest patches and woody shelterbelts provide aesthetically appealing vertical structures (Boris, 2012) and important habitats for biodiversity (Buckley et al., 1997). Typically such 'forest' patches are small and confined to narrow, elongated forms, resulting in a very high edge-interior ratio (Corona et al., 2012). However, it is not forest edges per se, but their composition and structure, that are of the greatest importance. For example, edges with an abrupt profile lack the 'ecotonal structures' of more graded edge profiles with low shrubs at the periphery and increasingly higher shrubs and trees towards the interior (Buckley et al., 1997; Wuyts et al., 2009).

In urban and infrastructure settings (the latter also referred to as 'right-of-ways'), development of species-rich forest edges with a graded profile is often the ideal (Hodge, 1995), since these better support biodiversity, filter and shelter functions, as well as aesthetic appeal and recreation value (Buckley et al., 1997; Fry and Sarlöv-Herlin, 1997; Wuyts et al., 2009). In parallel, they keep tall and potentially hazardous trees away from e.g. railways (Rühle, 1995), houses (Rydberg and Falck, 2000) and power-lines (Ballard et al., 2007).

However, graded edge profiles (also called 'sloping' (Fry and Sarlöv-Herlin, 1997), 'outdrawn' (Gustavsson, 2004), 'step-shaped' (Rydberg and Falck, 2000) or 'three-step' (Sarlöv-Herlin and Fry, 2000)) are rare. In Sweden, Esseen et al. (2004) estimated that only 20% of forest edges are shrub-dominated and only 2% have a graded profile. Gustavsson (2004) and Wuyts et al. (2009) attribute this to lack of specific edge management. Today, graded edge profiles are often restricted to long-term continuity habitats, where they result from:

- Natural succession of forest into old fields, also called 'advancing edge phenomena' (e.g. Dierschke, 1974; Ranney et al., 1981; Gustavsson, 1986).
- Cultural landscapes with a moderate disturbance regime, where e.g. low-intensity grazing often supports the development of edge zones with a graded profile (e.g. Gustavsson, 1986; Fry and Sarlöv-Herlin, 1997).

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- Locations with outdrawn intrinsic environmental gradients, such as moisture gradients and soil depth gradients (van der Maarel, 1990; Lloyd et al., 2000).

In urban and infrastructure contexts, environmental gradients are often neutralised or modified. Moreover, the intense land use in such areas imposes major restrictions for management regimes relying on grazing and the possibility for forest edges to advance through natural succession. Therefore, other management systems which demonstrate environmental stewardship, maintain biodiversity and satisfy the expectations of stakeholders and the general public need to be adopted.

While forest fragmentation and related edge effects have been intensively studied during recent years (e.g. Riutta et al., 2014), studies on controlled forest edge management trials are surprisingly few and date back to the 1980s and 1990s (e.g. Ferris-Kaan, 1989; Buckley et al., 1997). This short communication conceptualises zoned selective coppice (ZSC), a novel management system for developing and sustaining graded forest edge profiles, and presents preliminary results from simulation and implementation of ZSC in a controlled trial. The objective was to make a general assessment of the effects of ZSC on the profile and woody species diversity of planted forest edges of varying width and species composition.

Conceptualising the zoned selective coppice management system

Historically, selective coppice systems have been widely used in Europe for continuous supply of raw materials for various products (Emanuelsson, 2009). In mountain regions of Northern Italy, selective coppicing of beech (*Fagus sylvatica* L.) is still practised (Coppini and Hermanin, 2007). In Sweden, Rydberg (2000) tested selective coppice in urban areas as a low-impact management system for maintaining low stands with continuous tree/shrub cover and associated environmental, recreational and aesthetic benefits. Compared with traditional selective coppice systems, which are guided by target diameter (Harmer, 2004), Rydberg (2000) modified the system so that only specimens exceeding a threshold height were coppiced.

The ZSC management system for forest edges is also guided by threshold height decreasing in steps from the inner through the middle to the outer edge zone. The drop in height means that initially more individuals are coppiced in the middle and especially the outer edge zone. Therefore a density gradient also develops. Through repeated cycles of ZSC, fast-growing pioneer tree species are continuously cut and lower species favoured, where the height and density gradient theoretically stimulates distribution of woody species over the cross-section of the edge in relation to their final height and shade tolerance. Low, light-demanding shrub species are favoured in the outer zone and shade-tolerant, tall shrubs and small tree species in the inner zone, while the middle zone represents a transition between the outer and inner zones (Larson and Oliver, 1996; Rydberg, 2000). Such species distribution patterns are reported to be essential for sustaining graded profiles over time (Wiström and Nielsen, 2014).

Allied with the height and density gradients enforced by the ZSC management system, light, leaf litter and disturbance gradients are also created through the edge cross-section. Buckley et al. (1997) found that management treatments which created such gradients invariably increased field layer species richness (often doubling the number of species). As this in turn increases the availability of invertebrate food sources, higher species richness of various insects and birds also develops (Buckley et al., 1997). Therefore the ZSC management system complies with the broad objective of forest management for biodiversity conservation (Buckley et al., 1997).

Simulation and management trial with zoned selective coppice in Alnarp landscape laboratory

Alnarps Västerskog (AVS) is part of the landscape laboratory at the Swedish University of Agricultural Sciences (SLU) in Alnarp (55.39° N; 13.04° E) and comprises a 9-ha rectangular forest plantation established on loamy glacial till overlaid by fine sand deposits, with a long record of agricultural production prior to afforestation in 1994. At establishment, experimental edge sections (average length 45 m) were planted with 1- to 2-year-old bare-rooted plants at 1.5 m × 1.5 m spacing along the stand peripheries and framed by meadows (Fig. 1). Stands and edges were fenced off to reduce browsing (mainly by wild rabbits) and mechanically weeded during the first three growing seasons, but otherwise left unmanaged.

The experimental edge sections in AVS include both *shrub edges* planted exclusively with deciduous shrub species and *mosaic edges* planted with a mosaic of deciduous trees and shrubs (Wiström and Nielsen, 2014). These two edge typologies were replicated with: (i) narrow (three planting rows) and wide (six planting rows) edge sections (cross-sectional width 5 and 10 m, respectively); (ii) intimate species mixtures and single species groups of light-demanding, lower-growing shrubs in the two outermost planting rows; and (iii) an orientation facing a 'warm' exposed aspect (west and south) and 'cool' unexposed aspects (east and north).

A total of 14 edge sections in AVS, representing the two edge typologies and different combinations of design parameters (i)–(iii) were selected for this study (Fig. 1). Their planting design is summarised in Table 1a and their species composition in Table 1e.

Field measurements

Field inventories were conducted in autumn 2010 and autumn 2013. In each inventory, all planted and spontaneously established woody seedlings of a size where the crown touched the crown of neighbouring planted specimens were measured using a tape-measure, height pole and digital clinometer (Haglöf Vertex IV).

In 2010, the spatial location of the specimens was recorded in terms of planting row and within-row position and height and crown diameter were measured (the latter in north-south and east-west orientations). However, the dense and thorny vegetation structure implied that measurement of crown diameter was hazardous for the field staff and also extremely time-consuming. Therefore in 2013 crown diameter measurement was replaced by measurement of the circumference at the root neck (just above the root collar). For specimens with a single stem at 1.3 m also DBH was measured while this measurement was not deemed suitable for the shrubs and trees branching out at <1.3 m height. Furthermore, the spatial position of the species was checked and a record was made as to whether the specimen was alive or dead. For live specimens, height was measured again.

Acknowledging that the adjustment of the field methodology from measurement of crown diameter in 2010 to measurement of circumference at the root neck in 2013 implies an inherent inaccuracy for comparison, this modification was verified by Pearson correlation coefficient (r_{Pearson}) calculations. The results showed that the base area calculated from circumference at the root neck was significantly correlated to both DBH from 2013 ($r_{\text{Pearson}} = 0.742$, $n = 678$, $p < 0.001$) and crown area calculated from the 2010 measurements ($r_{\text{Pearson}} = 0.656$, $n = 1165$, $p < 0.001$), and thus provided a reliable indicator of the vertical aspect of the species.