Ecological Engineering 95 (2016) 665–670

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

# Initial species composition predicts the progress in the spontaneous succession on post-mining sites

Ondřej Mudrák[a,*], Jiří Doležal[a], Jan Frouz[b,c]

[a] Department of Functional Ecology, Institute of Botany, The Czech Academy of Sciences, Dukelská 135, CZ 37982 Třeboň, Czech Republic
[b] Institute for Environmental Studies, Faculty of Science, Charles University in Prague, Benátská 2, CZ 128 01 Prague 2, Czech Republic
[c] Environment Center, Charles University in Prague, José Martího 407/2, 162 00 Prague 6, Czech Republic

ARTICLE INFO

*Article history:*
Received 2 March 2016
Received in revised form 23 June 2016
Accepted 4 July 2016
Available online 25 July 2016

*Keywords:*
Spontaneous succession
Ecological restoration
*Calamagrostis epigejos*
Post-mining sites
Woody species

ABSTRACT

Although research has demonstrated that spontaneous succession of vegetation can be useful for the restoration of post-mining sites, spontaneous succession has only rarely been taken advantage of because of its low predictability. Spontaneous succession is difficult to predict because it depends, especially in the first stages, on many stochastic processes. Our goal was to determine whether the succession can be predicted based on the study of the chronosequence (space for time substitution) and whether the predictability of spontaneous succession can be improved by inventorying the plant community at disturbed sites during the initial stages of succession. After investigating successional changes by annual resampling of 50 permanent plots during 8 years (2007–2014) at chronosequence of five post-mining sites (created in 1965, 1987, 1990, 1995, and 2003) and located in the Sokolov coal mining district (northwestern Czech Republic), we found that species composition of younger chronosequence sites changes predictably towards the older sites. Simple parameters of initial species composition (cover of woody species, cover of the dominant grass *Calamagrostis epigejos*, total plant cover, and number of species) explained 24% of the variability in species composition in the last year of observation. The best predictor was cover of woody species. In the first years of succession, the post-mining sites are usually colonized by herbaceous vegetation but often also by pioneer trees. Over the next 20 years, succession may proceed to a forest stage or may be arrested in a non-forest stage, and this can be predicted based on woody species establishment early in succession. We demonstrate that inventorying vegetation before selecting restoration activities might improve the ability to predict the outcome of spontaneous succession and might therefore simplify its use in restoration.

© 2016 Elsevier B.V. All rights reserved.

## 1. Introduction

Succession has long been an important topic in ecology. Ecologists are fascinated by how spontaneous processes may lead to the recovery of disturbed ecosystems (Pulsford et al., 2016) including industrial, post-mining sites (Prach and Walker, 2011; Prach et al., 2013). Several studies have demonstrated that spontaneous processes do lead to ecosystem recovery, especially when the substrate or climatic conditions do not limit plant growth (Wiegleb and Felinks, 2001; Rebele and Lehmann, 2002; Prach and Hobbs, 2008; Alday et al., 2011; Alday et al., 2012; Baasch et al., 2012; Prach et al., 2014). Although the succession often do not provide fast restoration of important ecosystem properties such as productivity as effectively as active reclamation approaches, Frouz et al. (2015) showed that older unreclaimed succession sites may provide woody biomass production equal or higher than reclaimed sites. Moreover, sites overgrown by succession are essential for maintaining biodiversity and can restore other non-productive functions of the ecosystem (e.g. protection agains erosion) rather quickly (Prach 2003; Mudrák et al., 2010; Tropek et al., 2010). Despite this evidence, spontaneous succession has only rarely been used as a tool in ecosystem recovery. To a large extent, this is due to its low predictability. Succession, especially in the first stages, depends on colonization and many other stochastic processes. These processes might be predictable on a broad scale (Foster and Tilman, 2000; Baasch et al., 2012), but this scale is usually larger than is needed in the planning of restoration measures. One way to overcome this problem might be to inventory which species are present in disturbed sites before beginning restoration because the initial species composition might greatly influence

* Corresponding author.
*E-mail address:* ondrej.mudrak@centrum.cz (O. Mudrák).

http://dx.doi.org/10.1016/j.ecoleng.2016.07.002
0925-8574/© 2016 Elsevier B.V. All rights reserved.

later changes in succession (Fukami and Morin, 2003). At the same time, restoration often does not start immediately after the disturbance (Štýs, 1981; Mudrák et al., 2010), which means that there might be sufficient time for first colonizers to become established. Knowing which species are established early in succession might substantially increase the ability to predict the course of succession (Wiegleb and Felinks, 2001; Tischew and Kirmer, 2007).

Several predictive models have been used to describe succession. These models assume either that the early, stress-tolerant colonizers improve the environmental conditions for later, less-stress tolerant but more competitive colonizers (the relay floristics model), or that all important colonizers appear early in succession and then spread during succession (the initial floristic composition model) (Egler, 1954; Connell and Slatyer, 1977). These models include various parameters that affect the prediction of succession. Site stressfulness, which is the inverse of site productivity, might indicate the rate of succession, but often only a few strong competitors dominate and block further succession in productive sites (Rebele, 1992; Jírová et al., 2012). With respect to both succession and overall ecosystem functioning, researchers have stressed the importance of diversity, which is often represented by the number of species in the community. Diverse communities are expected to be more resistant to changes but have a greater probability than less diverse communities of containing important species that change the environmental conditions (Fukami and Morin, 2003).

Although knowledge of these parameters may provide valuable information about the future progress in the succession, the predictability of succession is disputed by some researchers, who have stressed its stochasticity. The main criticism concerns mainly the chronosequence (so called space for time substitution) approach on which many of the studies of the succession are based (Johnson and Miyanishi, 2008). In this static view of the succession, sites of different age are examined within one time point and it is assumed that the succession of younger sites direct the older sites (Connell and Slatyer, 1977; Wiegleb and Felinks, 2001; Frouz et al., 2008; Prach et al., 2014). However, random events, especially at the beginning of the succession, might change the course of the succession and such assumption should not be necessarily met (Pulsford et al., 2016). The colonization can be to the large extent stochastic event (Karrenberg et al., 2002; Hintze et al., 2013). Due to priority effects the early established colonizers have competitive advantage over latter ones, might dominate over long time period and change the environment (Fukami and Morin, 2003). Another possibility to study the succession is dynamic view of the succession based on repeated sampling of the same site. It provides us with unbiased information about the successional changes, but it desires long time period (Wiegleb and Felinks, 2001). Only few studies combine both of these approaches (Foster and Tilman, 2000).

In the Sokolov coal mining district in the northwestern Czech Republic, the area disturbed by mining activities is approximately 90 km$^2$. The mining sites in this area were either excavated or overlaid by spoil heaps from coal overburden. Most of this area has been reclaimed by the planting of trees or by the development of pasture. The excavated mines are flooded. A large area, however, has been left for spontaneous development. This has led to the establishment of forest stands dominated by trees such as goat willow (*Salix caprea*), birch (*Betula pendula*), and aspen (*Populus tremula*), which are common in the surrounding landscape and have seeds easily dispersible by wind. The trees are accompanied by a species-rich understory dominated by common grassland and woodland species. This late successional vegetation occurs on sites more than 40 years old (time since heaping). The woody species at these sites established mainly in the early successional stages, but the succession is also strongly related to soil development, which is driven by the activity of soil fauna. Earthworms in particular improve the substrate quality and enable the colonization by late successional species (Frouz et al., 2008; Mudrák et al., 2012). Although succession often results in the rapid formation of forest stands at some sites, succession at many sites is arrested at earlier stages. This slowing of succession has mainly occurred on the sites dominated by the grass *Calamagrostis epigejos*, which is native but highly expansive in central Europe. *C. epigejos* suppresses other plant species and is the cause of considerable problems in agriculture, forestry, and nature conservation (Rebele and Lehmann, 2001; Somodi et al., 2008; Mudrák et al., 2010).

In the current study, we combined static view of the succession based on chronosequence and dynamic view of the succession based on long term repeated measures of the same plots. Over an 8-year period, we observed the changes in the spontaneously developing vegetation in permanent plots at five sites differing in age. We tested the assumption of the chronosequence that succession on younger sites is directing towards the older sites and whether the age of the successional site is good predictor in species composition. We also investigated how the variability in the course of the succession is affected by the initial floristic composition and we attempted to identify vegetation parameters that have high predictive power and that can be readily estimated or measured by experts in a variety of disciplines. We determined how the following parameters, when measured in the first year of observation, were related to the vegetation community measured in the last year of observation: cover of woody species (as a potential indicator for forest development), cover of the dominant grass *Calamagrostis epigejos* (as a potential cause of arrested succession), total plant cover (as a surrogate of productivity), and number of plant species.

## 2. Methods

The study was carried out on spoil heaps in the Sokolov coal mining district, which is located in the northwestern Czech Republic, Central Europe. The area has an altitude of 500–600 m a.s.l., a mean annual precipitation of 650 mm, and a mean annual temperature of 6.8 C. The heaps were created during mining by the deposition of the substrate from the coal overburden. The substrate is tertiary clay of the so-called cypris formation. This material is alkaline (pH 8–9) and consists mostly of caolinite, montmorilonite, and illite. These minerals may be impregnated with calcite, siderite, and fossil organic matter (Kříbek et al., 1998; Rojík, 2004). For further information see e.g. Frouz et al. (2008), Frouz et al. (2011), Mudrák et al. (2012), Bartuška et al. (2015), Mudrák et al. (2016).

We selected five sites that differed in age, i.e., that differed in time since substrate deposition. Site I was deposited in 2003, site II in 1995, site III in 1990, site IV in 1987, and site V in 1965 (see Appendix 1 for illustrative photos). The time of deposition was provided by the Sokolovská uhelná a.s. coal mining company. The heaped substrate at these sites had not been manipulated after deposition, and the vegetation had developed spontaneously. Two older sites spontaneously overgrown by trees and because the forest was the target of the reclamation, these sites were not further managed. Trees had enough time to establish due to originally planned technical break prior the reclamation, which is needed for physical changes of the substrate (Štýs 1981), and due to later lack of capacity of restoration companies to reclaim whole area in short time period. Three youngest sites were selected as research area and not further managed for this reason. All sites are now preserved as research area for spontaneous successional processes. At each sites, we designated 10 permanent, 5-m × 5-m plots. Within these plots, we annually estimated the cover of individual vascular plant species at the time of maximal productivity, i.e., in late July or early August, for 8 consecutive years (2007–2014). In the first year of observation, sites I, II, III, IV, and V were 4, 12, 17, 20, and 45

Download English Version:

https://daneshyari.com/en/article/4388496

Download Persian Version:

https://daneshyari.com/article/4388496

Daneshyari.com