LONG-TERM MONITORING OF SANDY DRY GRASSLAND IN A POST-MINING LANDSCAPE

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Abstract: We applied the Markov approach to a dataset that resulted from monitoring the succession in a post-mining landscape in East Germany. The data have been compiled over more than a decade. We calculated probabilities of processes that determine succession (e.g. colonization, replacement). More than 30 years after start of succession, the study area is still largly covered by acidic dry grassland communities. Particularly at sites characterized by a high substrate acidity, the speed of succession is low and communities with high conservation priority persist over decades. The preservation of suitable sites for such rare communities should be an important goal in restoration schemes for mining areas.

Keywords: Corynephorus grasslands, spontaneous succession, environmental policy

Introduction

The ecological restoration of highly disturbed ecosystems, such as surface-mined land, presents great opportunities to explore the basic processes that promote and maintain target communities. Knowledge of the mechanisms, rates and pathways of primary succession is crucial for understanding the response of the vegetation to disturbance and to design strategies for ecosystem management (e.g. Harris & van Diggelen 2006).
The Markov model is one of the mathematical models that can be used to indicate pathways of succession and to generate hypotheses on mechanism. Markov models are based upon probabilities of replacement of one defined ecological state by another. The probability of every subprocess within the overall successional process can be determined (e.g. Usher 1992). We applied the Markov approach to a dataset that resulted from long-term monitoring the succession of a sandy dry grassland in a post-mining landscape (e.g. Tischew & Mahn 1998, Baasch et al., resub.). Until 1974 the investigated area was first used for brown coal surface mining and then for dumping overburden layers that consisted of mixed Quaternary and Tertiary material. Usually, post-mining soils that contain high amounts of Tertiary material and thus showing strong acidification and poor nutrient availability were reclaimed by traditional recultivation methods (e.g. liming, fertilization; Tischew & Kirmer 2007). Probably for economical reasons, our study area remained unreclaimed and thus, presents the opportunity to examine its ecological potential without any restoration measures.

Materials and methods

The study site is part of the post-mining area Goitzsche, located in the Central-German lignite area (51°34'06" N, 12°18'23" E, 79 m a.s.l.). To observe the development of vegetation a 10 m-grid was set up on the total area of 4.8 hectare. Each of the 480 plots measured 100 m². For each grid cell, the area of twelve a priori defined vegetation types was estimated on a percent scale. Vegetation observations were made every three years starting 1995 until 2007. The soil pH(KCl) of the grid cells ranged from 2.2 to 7.8 with a mean of 4.4 in 1995 and from 2.6 to 7.9 with a mean of 4.3 in 2007.

A Markov chain represents a system of elements undergoing transitions from one state to another over time (described in detail e.g. in Usher 1992). Since we did not observe transitions within each grid cell directly, we first had to estimate transition probabilities by constructing contingency tables based on the observed values for each state in each grid cell and certain predefined model assumptions (Baasch et al., sub.).
The probability p of every subprocess within the overall successional process is represented by the state transition probability matrix P. We calculated P for the whole study period (1995 – 2007) with respect to two contrasting environments: (1) for all grid cells that exhibited soils with high amounts of Tertiary material, pH value < 4.0, (2) for grid cells with soils of moderate amount of Tertiary material, pH value ≥ 4.0.
The elements of P describe the processes that determine succession: colonization, disturbance, persistence, and replacement. These can be quantified for a certain state/vegetation type or for the entire system (e.g. Hill et al. 2004).

Results and discussion

Frequent vegetation types were pioneer stages with *Corynephorus canescens* on bare soil, consolidated areas covered either by cryptogams and *C. canescens* or by cryptogams only, sandy dry grassland characterized by *Helichrysum arenarium*, ruderal stages characterized by short-lived legumes (*Trifolium campestre* and *T. arvense*) or *Artemisia campestris*. Thus, the grid represents a mosaic of transitory patches made-up of species typical for dry acidic grassland. During the last decades, dry acidic grasslands dominated by *Corynephorus canescens* became increasingly rare in Central Europe and thus are of high conservation priority (see Jentsch & Breyschlag 2003). Particulary non-ruderal stages are rare in the surrounding cultural landscape, which is characterized by an ongoing eutrophication. Therefore, we refer to these vegetation types as valuable target stages in ecological restoration (see Table 1). More than 20 years after start of succession, the percentage of area covered by target stages was particularly high and showed an ongoing increase at sites exhibiting low pH values < 4.0. At sites with higher pH values the percentage of target stages was lower and tended to decrease, whereas ruderal stages of sandy dry grassland became increasingly more frequent.

Table 1. Percentage of vegetation types (grouped) in 1995 and 2007 with respect to soil acidity.

		pH < 4.0 (n= 265)		pH ≥ 4.0 (n= 215)	
Vegetation type	code	1995	2007	1995	2007
Beginning stage - bare soil	BS	18.4	8.2	5.8	1.7
Target stages (pioneer stages with Corynephorus canescens and/or cryptogams, sandy dry grassland characterized by Helichrysum arenarium)	TS	57.3	66.3	43.1	29.2
Further stages (mostly ruderal stages with short-lived legumes or *Artemisia campestris*)	RUS	6.8	8.5	35.2	39.0
Calamagrostis epigejos-stage	CES	17.0	7.3	15.6	23.9
Final stage - areas dominated by shrubs and trees	FS	0.5	9.7	0.4	6.2

Another frequent vegetation type is one dominated by the strong competive, clonal grass *Calamagrostis epigejos*, which is widely seen as problem species for conservation of dry grasslands (e.g. Rebele & Lehmann 2001, Somodi et al. 2008). The percentage of the *Calamagrostis*-stage in the grid remained almost the same compared to 1995, but decreased considerably at sites with low pH and increased at more favorable sites.

Table 2. Probabilites of successional processes calculated from time-invariant transition matrices P with respect to soil acidity. Probabilities refer to changes in a period of three years.

	Colonization	Disturbance	Persistence	Replacement
pH < 4.0	0.24	0.01	0.72	0.28
pH ≥ 4.0	0.34	0.00	0.63	0.37

Table 2 shows the probabilities of processes that determine succession. Main trajectories are presented in Figure 2. The probability that an empty square meter (BS) is colonized by any vegetation type is lower at sites with pH < 4. These sites were almost solely colonized by target stages (mainly pioneer stages with co-dominance of Corynephorus canescens and cryptogams), which then persist to a high degree. Transitions both from bare soil and from target stages to the more ruderal sandy grassland or to the *Calamagrostis*-stage are rare ($p < 0.05$). Moreover, patches characterized by ruderal species as well as *Calamagrostis epigejos* are not as stable as those covered by target stages and also convert into these valuable stages with a high probability of around 0.3. In a more favorable environment, i.e. at higher pH, bare soil is also colonized by ruderal stages and *Calamagrostis epigejos* with considerable probabilities. Overall, transitions are higher and persistence is lower. Target stages tend to turn into ruderal sandy grassland stages, even though the reverse trajectory is also possible. *Calamagrostis epigejos*-stages develop from ruderal stages, and vice versa.
Shrubs and trees, in particular *Pinus sylvestris* and *Betula pendula*, did not play any role in first 20 years of the succession and have begun only in the last decade to establish themselves to some degree and since then, show rapidly expanding patches. Thus, although transition probabilities to the final state dominated by shrubs and trees are all still < 0.05, we can predict that, without any counteractive measures, *Pinus sylvestris* will become dominant in next two decades (Baasch et al., sub.).

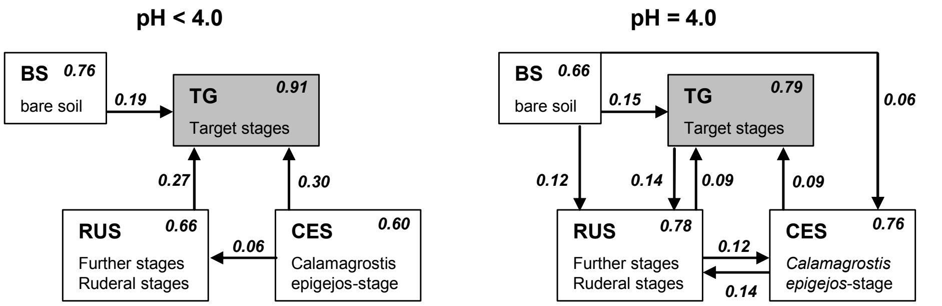

Figure 2. Schematic outline of main trajectories with respect to soil pH. Probabilities for persistence are shown inside of rectangles. Transition probabilities are positioned at the middle of arrows that indicate transitions. Transition probabilities < 0.05 are not shown.

Conclusions

More than 30 years after start of the succession, the study area is still largely covered by acidic dry grassland communities, indicating that sandy, acidic and nutrient-deficient successional sites in former mining areas offer long-term habitats for competitively inferior species and plant communities. In particular sites that are usually ameliorated because of extreme soil conditions, are relatively resistant against an effective invasion of ruderal and competitive species such as *Calamagrostis epigejos*. The speed of succession is low and communities with high conservation priority persist over decades. Since *Corynephorus* grasslands are currently more endangered in Germany than bogs or calcareous grasslands (Ssymanek et al. 1998, Jentzsch & Breyschlag 2003), the preservation of suitable sites for such rare communities should be an important goal in restoration schemes for mining areas. The development of suitable sites should not be unnecessarily accelerated by the application of traditional recultivation methods.

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References

Baasch, A., Tischew, S. & Bruelheide, H. Insights into succession processes by temporally repeated habitat models. Results from a long-term study in a post-mining landscape. Journal of Vegetation Science (resubmitted after revision).

Baasch, A., Tischew, S. & Bruelheide, H. Twelve years of primary succession on sandy substrates in a post-mining landscape: A Markov Chain Analysis. (submitted).

Harris, J.A., van Diggelen, R. (2006). Ecological restoration as a project for global society. In: van Andel, J. & Aronson, J. (Ed): Restoration Ecology. Blackwell Publishing, Oxford, pp. 3-15.

Hill, M.F., Witman, J.D. & Caswell, H. (2004). Markov chain analysis of succession in a rocky subtidal community. The American Naturalist 164, E46-E61.

Jentsch, A. & Beyschlag, W. (2003). Vegetation ecology of dry acidic grasslands in the lowland area of central europe. Flora 198, 3-25.

Rebele, F. & Lehmann, C. (2001). Biological flora of Central Europe: *Calamagrostis epigejos* (L.) Roth. Flora 196, 325-344.

Somodi, I., Virágh, K. & Podani, J. (2008). The effect of the expansion of the clonal grass *Calamagrostis epigejos* on the species turnover of a semi-arid grassland. Applied Vegetation Science 11, 187-192.

Ssymank, A., Hauke, U., Rückriem, S. & Schröder, E. (1998). Das europäische Schutzgebietssystem NATURA 2000. Schr.-R. f. Landschaftspfl. u. Natursch. 53, 1-558.

Tischew, S. & Kirmer, A. (2007). Implementation of basic studies in the ecological restoration of surface-mined land. Restoration Ecology 15, 321-325.

Tischew, S. & Mahn, E.-G. (1998). Ursachen räumlicher und zeitlicher Differenzierungsprozesse von Silbergrasfluren und Sandtrockenrasen auf Flächen des mitteldeutschen Braunkohlentagebaus – Grundlagen für Renaturierungskonzepte. Verh. Ges. Ökol. 28, 307-317.

Usher, M.B. (1992). Statistical models of succession. In: Glenn-Lewin, D.C., Peet, R.K. & Veblen, T.T. (Ed.): Plant succession: theory and prediction. Chapman & Hall, London, pp. 215-248.