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Succession and management of calcareous dry grasslands in the Northern Franconian Jura, Germany

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Abstract

The massive decline of calcareous grasslands in the Franconian Jura is caused mainly by land use abandonment and afforestation. In the district Lichtenfels, the northernmost part of the Franconian Alb, management measures were put in action since the middle of the 1980s to conserve or restore those threatened ecosystems. Important actions were removal of trees (mainly *Pinus sylvestris*) and shrubs as well as reintroduction of sheep grazing. This study analyses the success of restoration measures taken at two Natura 2000 sites. Based on vegetation relevés from 70 sites with different land use histories, we investigate the influence of the successional status of the woodlands prior to clear-cutting and the time period of subsequent grazing on the actual vegetation. The results suggest that both factors influence species composition. On formerly dense pine woodland sites, it takes at least five years of grazing until the number of target species increases. On formerly more sparsely wooded sites, target species establish faster after reintroduction of grazing. Our results show that keeping sites open by tree and shrub removal followed by seasonal grazing are important measures to maintain and restore plant communities of calcareous grasslands in the Franconian Jura.

Zusammenfassung: Sukzession und Management von Kalkmagerrasen der Nördlichen Fränkischen Alb, Deutschland

In der Fränkischen Alb ist der großflächige Rückgang von Kalkmagerrasen vorwiegend auf Nutzungsaufgabe und Aufforstung zurückzuführen. Im Landkreis Lichtenfels, dem nördlichsten Teil dieser Region, werden seit Mitte der 1980er Jahre verstärkt Maßnahmen zur Erhaltung und Wiederherstellung dieser gefährdeten Ökosysteme durchgeführt. Wichtigste Maßnahmen sind die Freistellung überwiegend mit Kiefern bewachsener Standorte und die Wiedereinführung der Wanderschäferei. Die vorliegende Studie analysiert den Erfolg dieser Maßnahmen in zwei Natura-2000-Gebieten. Ziel der Untersuchungen ist es, mit Hilfe von Vegetationsaufnahmen an 70 Standorten mit unterschiedlicher Nutzungsgeschichte den Einfluss des Entwicklungszustandes der Waldflächen vor der Freistellung und der Zeitspanne der nachfolgenden Beweidung auf die aktuelle Vegetationszusammensetzung zu analysieren. Die Ergebnisse zeigen, dass beide Faktoren sich auf das Renaturierungsergebnis auswirken. In früher dichten Kiefernbeständen muss mit einer Zeitspanne von mindestens fünf Jahren gerechnet werden, bis die Beweidung zu einem deutlichen Anstieg von Zielarten führt. In ehemals lichteren Beständen setzt dieser Prozess früher ein. Fazit der Studie ist, dass die Offenhaltung der Standorte durch Freistellung und nachfolgende kontinuierliche Beweidung wichtige Maßnahmen sind, um die Kalkmagerrasen der nördlichen Frankenalb zu erhalten und weiter zu entwickeln.

Keywords: abandonment, indirect analysis of succession, land use history, plant species diversity, semi-dry grassland, sheep grazing, shrub encroachment, tree removal.

1. Introduction

Dry calcareous grasslands on nutrient-poor sites in Central Europe developed in most cases during centuries or even millennia of traditional land use by grazing and/or mowing (ELLENBERG 1996). Outside the Alps, natural formations of these ecosystems are found only on small, isolated sites such as rock outcrops in low mountain ranges. The high species diversity of semi-natural calcareous grasslands originates from a moderate disturbance regime together with a low nutrient availability of the soils and a long history of species immigration (POSCHLOD & WALLISDEVRIES 2002).

Land use intensification (e.g. change to fertilized grasslands), afforestation and increasing shrub encroachment following the cessation of transhumance are the main causes for the drastic decline of species-rich dry calcareous grasslands in Central Europe during recent

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decades (WILLEMS 2001, POSCHLOD & WALLISDE VRIES 2002, DIERSCHKE 2006). Since traditional land use is no longer profitable for farmers in many areas, the maintenance of the remaining, often strongly fragmented areas and the restoration of degraded sites often require the management by conservationists. In view of the increasing loss and fragmentation of calcareous grasslands, many restoration projects have been started during the last decades in order to stabilize and promote populations of specialised plant and animal species (KIEHL 2009). The reintroduction of management practices depends on former land use of the areas targeted for restoration. On formerly fertilized sites, the nutrient availability of the soil has to be reduced, which can only be achieved by mowing without fertilization or by removing the nutrient-rich topsoil (RYSER et al. 1995, VERHAGEN et al. 2001). However, due to the fact that only about a quarter of the characteristic plant species build up a long-term persistent seed bank, measures of species transfer such as hay transfer from suitable donor sites may be necessary (JESCHKE & KIEHL 2006, KIEHL & WAGNER 2006, KIEHL 2009). In abandoned or afforested dry grasslands, which often still contain target species and have never been fertilized, clear-cutting and reintroduction of mowing or grazing regimes are adequate management measures to start the restoration process.

In the Franconian Jura sheep farming was an important economic factor until the mid of the 19th century (WEID 1995). The development of dry grasslands already started during the Bronze Age (BAUMANN 2006) or even earlier. Land use was intensified during medieval times, reaching a maximum in the 19th century, when the region was the most sparsely wooded area of Bavaria (WEISEL 1971) and only c. 20% of the area was covered by forests (RAUH 2004, BENDER et al. 2005a, 2005b). The subsequent continuous reduction of sheep husbandry resulted in a dramatic decline in the extent of dry grasslands. The change in predominant land use happened between 1900 and 1960 (BENDER et al. 2005a, 2005b). During this period, the proportion of wooded areas nearly doubled. Today less than 1% of the area of the Franconian Jura is covered by species-rich dry grasslands (RAUH 2004). Similar to the Neckar Basin and the Swabian Alb in south-western Germany (BLANCKENHAGEN & POSCHLOD 2005), most of the nutrient-poor pastures of the Franconian Jura were abandoned or were afforested with pine or spruce (HAGEN 1996).

Since the mid-1980s, conservationists have tried to restore abandoned dry grasslands and to preserve those that remained. In the northern part of the Franconian Jura (Landkreis Lichtenfels), restoration started with clear-cutting of more or less dense woodlands, which was initially organised by NGOs in cooperation with local farmers. In 1998, the "Landschaftspflegeverband Lichtenfels" took over the management of large-scale grazing and reintroduced sheep transhumance because traditional sheep-farming was on the brink of collapse. Despite the existence of many sites restored by clear-cutting and subsequent grazing there is a lack of detailed investigations that analyse the resulting changes in vegetation.

The aim of our study was to bridge this gap. Therefore, we address the following questions:
– Which are the effects of secondary succession after abandonment on plant species richness and species composition?
– How do the successional stages of the woodlands before clear-cutting and the duration of the grazing period after clear-cutting influence the restoration process?
– Which conclusions can be drawn for a sustainable management of dry calcareous grasslands in the Northern Franconian Jura?

2. Study area

The study sites are located in the district Lichtenfels (Fig. 1), which includes the northern part of the Franconian Alb (Bavaria, Germany). Geologically, the region is situated at the northern end of the Franconian Late Jurassic (Malm) layer, consisting of calcareous hard sediments. The calcareous soils of the investigated sites are composed of shallow and deeper loam. The altitudinal range is between 430 and 570 m a.s.l. Mean annual temperature of the region (meteorological station Weismain) is about 7.5 °C, and the mean annual sum of precipitation is about 720 mm.

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The first period of intensive land use in the area dates to the Hallstatt and La-Tène period (700 BC – 50 BC), when the Celts built a central settlement on top of mount Staffelberg (a so-called "oppidum") with huge constructions such as walls and ramparts (ABELS 1986, ABELS et al. 1996). The historical development of calcareous grasslands in the south-eastern Franconian Jura has been well studied (NELLE & SCHMIDGALL 2003, BAUMANN 2006, BAUMANN & POSCHLOD 2008), but so far no data were available from the northern Franconian Jura.

The investigations were carried out in two areas (Table 1), the project area of the "Trockenbiotopverbund Staffelberg", which overlaps with the Natura 2000 area "Albtrauf im Landkreis Lichtenfels", and the "Weismainalb" (Natura 2000 area "Trockenrasen, Wiesen und Wälder um Weismain"). The "Landschaftspflegeverband Landkreis Lichtenfels" has organised management measures in both areas for about ten years. At many sites, trees and shrubs were removed, and two sheep flocks together with some goats now graze the sites and are rotated between the different pastures during summer. Since 2000, both areas have been grazed at least twice a year from May to August. Within the study area, different land use types occur (Table 1). As reference systems for species-rich dry grasslands, we used the sites "Wallersberg" and "Klein Ziegenfeld", which have a long history of continuous grazing by sheep.

In phytosociological terms, the calcareous grasslands of the investigated areas can be assigned to the *Festuco-Brometea* Br.-Bl. et Tx. ex Klika et Hadač 1944. The presence of several species, such as *Carex flacca*, *C. caryophyllea*, *Carlina vulgaris*, *Cirsium acaule*,

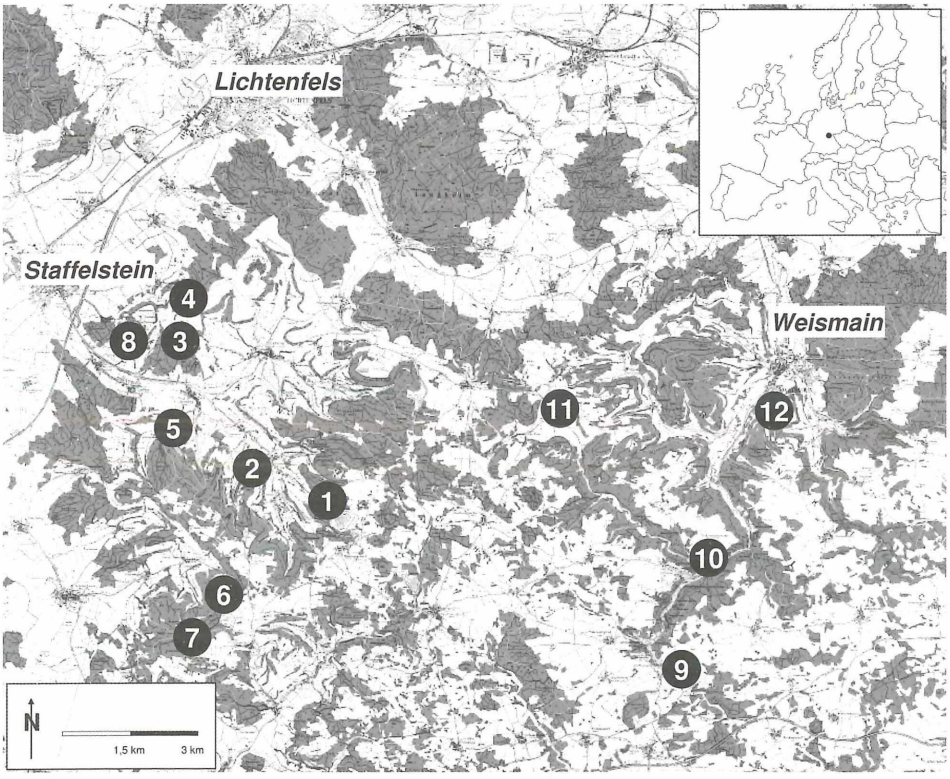


Fig. 1: Study area in the Northern Franconian Jura (district Lichtenfels, Upper Franconia, Bavaria). Dots mark the locations of the study sites (see also Table 1).

Abb. 1: Untersuchungsgebiet Nördliche Fränkische Alb (Landkreis Lichtenfels, Oberfranken, Bayern). Punkte markieren die einzelnen Untersuchungsflächen (vgl. Tab. 1).

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Table 1: Investigated areas and study sites
NSG = nature reserve. A = former woodlands, B = long-term (old) pastures. In the last column the quadrants of the German Ordnance Survey maps ("Topographische Karten 1 : 25.000") are given.

Tab. 1: Untersuchungsgebiete und Untersuchungsflächen
A = ehemalige Wälder, B = alte Weiden. In der letzten Spalte sind die „Messtischblattquadranten" angegeben, auf denen die Flächen liegen.

Study site	Code	Land use type	Status of protection	Quadrant of Ordnance Survey map
Natura 2000 area Staffelberg („Albtrauf im Landkreis Lichtenfels")				
1 Deisenstein	Ds	woodlands, pasture (A)	–	5932/2
2 Weinhügel	Wh	woodland, pastures (A)	Natura 2000	5932/1
3 Lerchenberg	Lb	pastures (A)	Natura 2000	5932/1
4 Spitzberg	Sb	woodlands, pastures (A)	Natura 2000	5932/1
5 Morgenbühl	Mb	pastures (A)	Natura 2000	5932/1
6 Treppenberg	Tb	woodlands	Natura 2000	5932/3
7 Weißer Lahma	Wl	woodlands, pastures (A)	Natura 2000	5932/3
8 Staffelberg	St	pastures (A), meadows	NSG, Natura 2000	5932/1
Natura 2000 area Weismainalb („Trockenrasen, Wiesen und Wälder um Weismain")				
9 Klein Ziegenfeld	Zf	pastures (B)	NSG, Natura 2000	5933/3
10 Wallersberg	Wb	pastures (B)	NSG, Natura 2000	5933/3
11 Köttel	Kt	pastures (A)	Natura 2000	5933/1
12 Kalkberg	Kb	woodlands, pastures (A)	Natura 2000	5933/1

Koeleria pyramidata and *Scabiosa columbaria* suggests a more specific attribution to the order *Brachypodietalia pinnati* Korneck 1974 (basiphilous semi-dry grasslands) and therein probably to the alliance *Bromion erecti* W. Koch 1926 (= *Meso-Bromion* Oberd. 1949; J. Dengler, pers. comm.). Some species can be used according to SCHMIDT (2000) as differential species of the suballiance *Meso-Bromenion* Oberd. 1957 against the *Seslerio-Meso-Bromenion* Oberd. 1957, e.g. *Briza media*, *Bromus erectus*, *Carex caryophyllea*, *Plantago media* and *Ranunculus bulbosus*.

3. Methods

3.1. Data collection

Vegetation relevés (plot size 25 m^2, n = 70) were recorded during early summer (between end of May and end of June) in 2005, 2006 and 2007. We used the method of BRAUN-BLANQUET (1964) with the modified cover-abundance scale of REICHELT & WILMANNS (1973) or a simplified pure cover scale (Table 2), and recorded only vascular plants. Each year, all sites were revisited in mid-July. The phytosociological assignment of the species was made according to ELLENBERG et al. (1992). The nomenclature of vascular plants follows WISSKIRCHEN and HAEUPLER (1998).

Based on information from the "Landschaftspflegeverband", the pastures were classified according to the period of grazing after clear-cutting. To reconstruct the approximate date of clear-cutting and the tree coverage before clear-cutting, series of aerial photographs were used. Planar terraces in the landscape were interpreted as signs of former arable fields (Fig. 3). In contrast, steep slopes were assumed never to have been used as fields. We used old photographs to gain further information on the historical land use of the sites.

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Table 2: Scales used for analysis of dominance and abundance of plant species

Tab. 2: Verwendete Schätzskalen für die Dominanz- und Abundanzanalyse der Pflanzenarten

REICHELT & WILMANNS (1973)	Simplified scale	Cover (%)	Number of individuals
+	1*	0–5	1–5
1	1*	0–5	6–50
2m	1*	0–5	>50
2a	2	>5–15	any
2b	2	>15–25	any
3	3	>25–50	any
4	4	>50–75	any
5	5	>75	any

3.2. Data analysis

Classification of vegetation was based upon a manual sorting of the relevés according to floristic similarities. In addition, a non-metric multidimensional scaling (NMDS) ordination of the vegetation data was performed with the program R, version 2.72 (R DEVELOPMENT CORE TEAM 2008). For the correlation of the relevés we used the procedure "dist" with the binary method, and the NMDS itself was calculated by the procedure "isoMDS" The successional scheme was derived from an indirect successional analysis for which we compared the investigated sites according to their vegetation structure and their past and current land use (see above). The successional stages were analysed in terms of species richness and the proportion of phytosociological groups with the program STATISTICA 6 (StatSoft 2001). As the data were not normally distributed, we used the Kruskal-Wallis test and non-parametric multiple mean comparisons to detect significant differences between the groups. The target species for dry grasslands in this study belong to the classes *Festuco-Brometea* and *Sedo-Scleranthetea* Br.-Bl. 1955 as listed by ELLENBERG et al. (1992).

4. Results

4.1. Characterisation of the vegetation

Based on all relevés, the manual classification of the vegetation relevés resulted in two main groups: woodlands and dry calcareous grasslands (Table 3 in the Supplement). Woodlands developed from dry grasslands as a result of abandonment or afforestation (Fig. 2). The most frequent species of the tree layer was *Pinus sylvestris*, whereas *Fagus sylvatica*, which indicates a further progression to deciduous forests, was rare and occurred only in two relevés. Older woodlands (Table 3, type 1) were separated from younger woodlands (type 2) by occurrence of some species of the *Querco-Fagetea* Br.-Bl. & Vlieger in Vlieger 1937 such as *Bromus ramosus*, *Galium odoratum* and *Sanicula europaea* and the almost complete absence of dry grassland species. The species composition of the herb layer of younger woodlands was similar to that of dry grasslands. Thus, the floristic differentiation between these vegetation types was only based on existence or lack of a tree layer.

Among dry grasslands, grazed habitats (Table 3 in the Supplement, types 3, 4) represent a typical land use form on nutrient-poor, calcareous soils of southern Germany, the "Wacholderheide" (NATURA 2000 habitat type 5130: *Juniperus communis* formations on heaths or calcareous grasslands). Most relevés were recorded on cleared former woodland sites, which had been overgrown by pine previously (Fig. 2). In addition to *Juniperus communis*, several species differentiated these vegetation types from mown sites, such as *Bupleurum falcatum*, *Polygala comosa* and *Prunella grandiflora*. The grazed calcareous grasslands can be further divided into two types that vary in terms of site conditions. Differential

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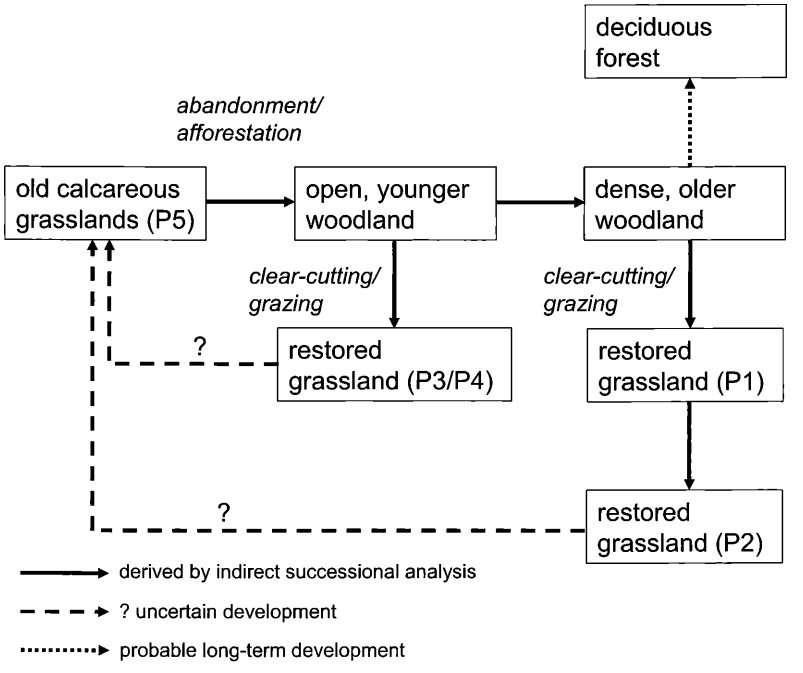


Fig. 2: Secondary progressive and regressive successional pathways of the investigated calcareous grasslands. P1 = former dense woodland, grazed < 5 years; P2 = former dense woodland, grazed > 5 years; P3 = former open woodland, grazed < 5 years; P4 = former open woodland, grazed > 5 years. P5 = old pastures.

Abb. 2: Progressive und regressive Sukzessionspfade für die untersuchten Kalkmagerrasen. P1 = früher dichte Wälder, Beweidung < 5 Jahre; P2 = früher dichte Wälder, Beweidung > 5 Jahre; P3 = früher offenere Wälder, Beweidung < 5 Jahre; P4 = früher offenere Wälder, Beweidung > 5 Jahre. P5 = alte Weiden.

species such as *Carex flacca*, *Leucanthemum vulgare* and *Prunella grandiflora* (herb layer) indicate relatively planar sites with deeper, loamy soils (Table 3, type 3). Old photographs show that many of these sites were used at least until the end of the 19th century as arable fields (Fig. 3) and were ceased approximately in the middle of the 20th century (Fig. 4). In contrast, grazed dry grasslands on steep slopes with shallow soils were always used as pastures (Table 3, type 4). These pastures are characterized by a group of species that partially were assigned to the *Sedo-Scleranthetea* (e.g. *Helianthemum nummularium, Sedum sexangulare, Teucrium botrys*). It was not possible to identify differential species for further floristic division of the grazed dry grassland, despite the available information on former land use, the density of the tree layer prior to clear-cutting, and the period of grazing after clear-cutting (see head of Table 3). On the other hand, mown dry grasslands (Table 3, type 5) contained several species typical of mesic grasslands (*Molinio-Arrhenatheretea* Tx. 1937) such as *Cerastium holosteoides, Festuca rubra, Poa pratensis* agg. and *Trifolium pratense,* which separated them from pastures. Furthermore, in these meadows *Bromus erectus* reached a higher cover than in the investigated pastures. All relevés of the mown sites were taken on former, more or less planar field terraces of the Staffelberg region (Fig. 5). In addition, two relevés originated from former arable fields (Table 3, type 6) that had been converted into sheep pastures without fertilization about ten years ago. The occurrence of species like *Carex flacca* and *Leucanthemum vulgare* indicated a floristic and edaphic similarity to the dry grassland on deeper loamy soils (Table 3, type 3), but high cover of *Taraxacum* sect. *Ruderalia* suggested a still relatively high nutrient availability (OBERDORFER 2001).

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4.2. Changes in species richness and species composition during secondary succession

The manual classification of the vegetation did not allow for an obvious floristic subdivision of grazed dry grasslands with respect to their former and current land use (see Section 4.1). Thus, for the NMDS ordination, we used only relevés of pastures for which the coverage of the tree layer before clear-cutting could be derived from aerial photos, in addition to the relevés of meadows, former agricultural fields and woodlands (n = 56). The NMDS ordination clearly separated long-term (old) pastures, younger woodlands, older woodlands, former arable fields and meadows (Fig. 6). The ordination of the relevés along axis 2 indicated that the floristic composition of the dry grassland type P1 (former dense woodland, cleared and grazed for at most 5 years) was still similar to that of old woodlands. The ordination showed no distinct separation between younger woodlands and their status after clear-cutting and subsequent grazing (Fig. 6, P3, P4). There was also a high floristic similarity between these vegetation types and the type P2, indicating that cleared former dense woodlands develop to species-rich grasslands after a grazing period of more than 5 years.

During the process of secondary succession following abandonment or afforestation from old dry grasslands (P5) via young woodlands (YW) to older woodlands (OW) (Fig. 2), species richness decreased as did the number of dry-grassland species (Fig. 7, 8). As expected, the proportion of forest species increased during secondary succession (Fig. 8). In formerly dense woodlands, species richness and the number of dry grassland species increased after clear-cutting and grazing for not more than five years (P1, Fig. 7). If restoration sites were grazed longer than 5 years (P2, Fig. 3), a further increase of species richness and number of typical dry grassland species could be expected (Fig. 7, 8). There were no significant differences between younger woodlands (YW) and cleared young woodland sites (P3, P4) in species richness and proportion of dry grassland species (Fig. 7, 8). Nevertheless, all dry grasslands restored by clear-cutting and grazing (P1–P4) exhibited a significant lower proportion of dry grassland species than old, continuously grazed pastures (P5, Fig. 7 B). At mown sites, species richness was significantly lower than at cleared and grazed sites (Fig. 7 A).

5. Discussion

5.1. Development of dry grasslands during secondary succession

Long-term changes of calcareous grassland vegetation in the Northern Franconian Jura were only studied by HAGEN (1996), who observed an increase of characteristic species of forest edges and tree seedlings in abandoned dry grasslands. However, this author intentionally excluded sites with shrub encroachment after abandonment. Therefore, long-term data from permanent plots that describe in detail the vegetation dynamics of the investigated dry grasslands during secondary progressive succession are not available. Consequently, secondary succession can be described only approximately by "space-for-time substitution" The vegetation structure of the investigated woodlands in our study generally reflects the results of HEINRICH (1998), which are based on 20-year observations of permanent plots in calcareous dry grasslands close to Jena (Thuringia). At sites of the *Bromion erecti*, the author described a rapid spread of shrubs such as *Cornus sanguinea* and *Crataegus* species, which are also common in the rather open woodlands of the study area. However, these stands were relatively species-rich and contained a high number of target species. Although many authors (e.g. SCHREIBER 1997, SCHMIDT 2000, MOOG et al. 2002, KÖHLER et al. 2005, DIERSCHKE 2006) described a decrease in light-demanding dry grassland species after abandonment, we observed this phenomenon only in older woodlands. Nevertheless, if we compare the species composition of the investigated older woodlands to that of beech forests in the vicinity of the study areas (unpublished relevés), the older pine forests are floristically still considerably different from mature stages of deciduous forests. This result corresponds with data of WILMANNS & BOGENRIEDER (1995), which indicates a low degree of similarity between the developing forests and potential natural vegetation type (*Carici-Fagetum* Moor 1952), even after a period of abandonment of 50 to 70 years.

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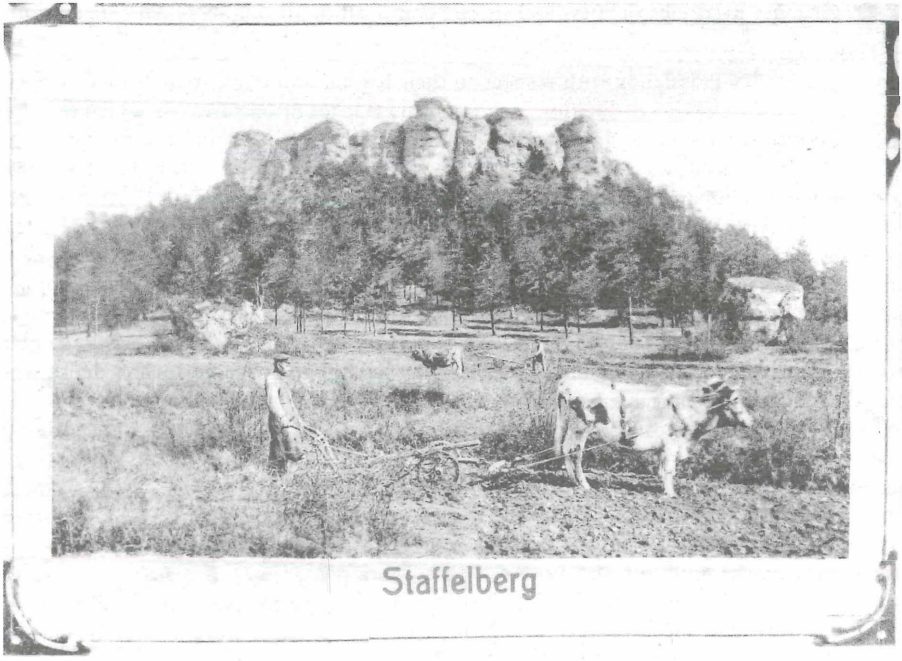


Fig. 3: View of the Staffelberg (Scheffelfelsen) at the end of the 19th century. The postcard shows a planar terrace in front of the rocks, which was used for agriculture. Source: Landschaftspflegeverband Lichtenfels e. V.

Abb. 3: Blick auf den Staffelberg (Scheffelfelsen) am Ende des 19. Jahrhunderts. Die Postkarte zeigt eine ebene Terrasse vor den Felsen, die zu jener Zeit als Acker genutzt wurde. Quelle: Landschaftspflegeverband Lichtenfels e. V.

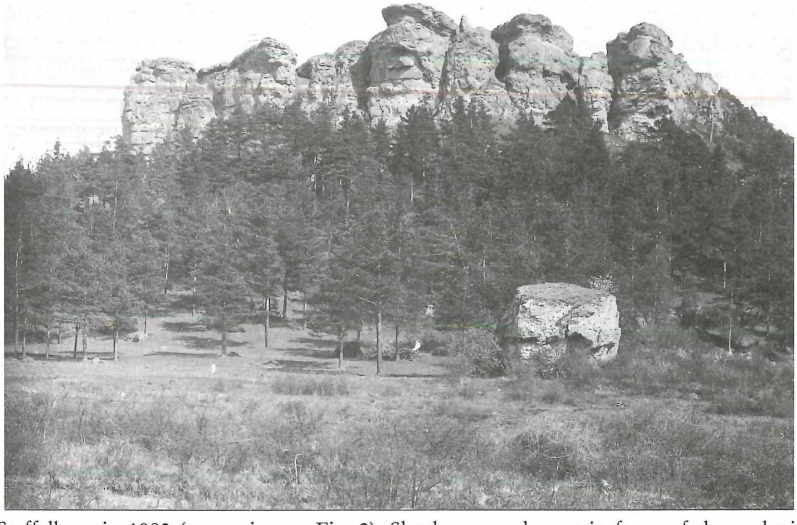


Fig. 4: Staffelberg in 1980 (same view as Fig. 2). Shrub encroachment in front of the rocks indicates abandonment. Source: Landschaftspflegeverband Lichtenfels e. V.

Abb. 4: Der Staffelberg im Jahr 1980 (gleicher Blick wie auf Abb. 2). Die aufkommenden Gehölze auf der Fläche vor den Felsen weisen auf die Brache hin. Quelle: Landschaftspflegeverband Lichtenfels e. V.

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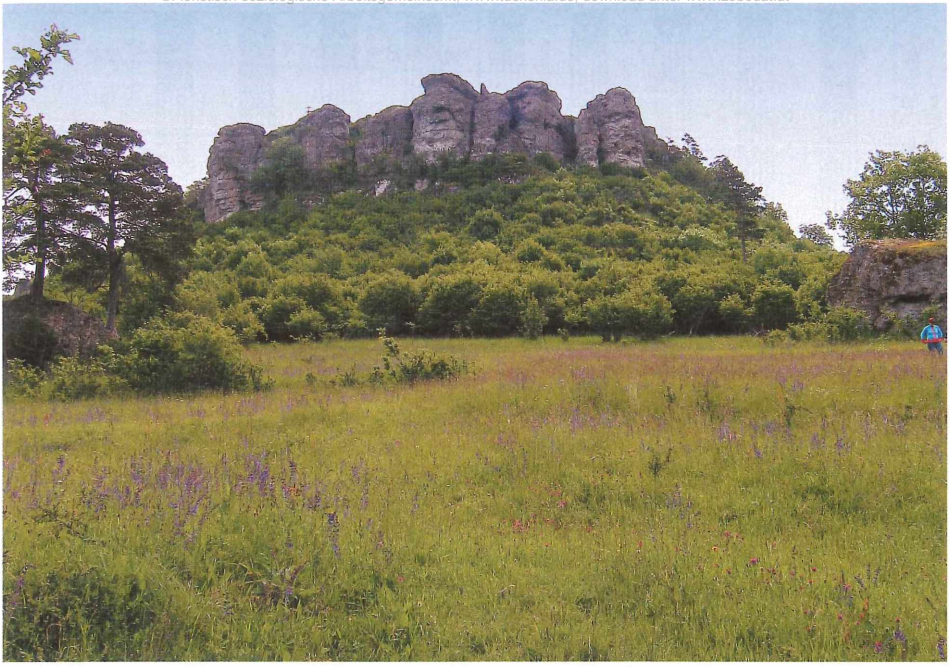


Fig. 5: Staffelberg in 2006 after implementation of a mowing regime (same view as Fig. 3). (Photo: J. Schrautzer).

Abb. 5: Der Staffelberg im Jahr 2006 nach Einführung eines Mahdregimes (gleicher Blick wie auf Abb. 3). (Foto: J. Schrautzer).

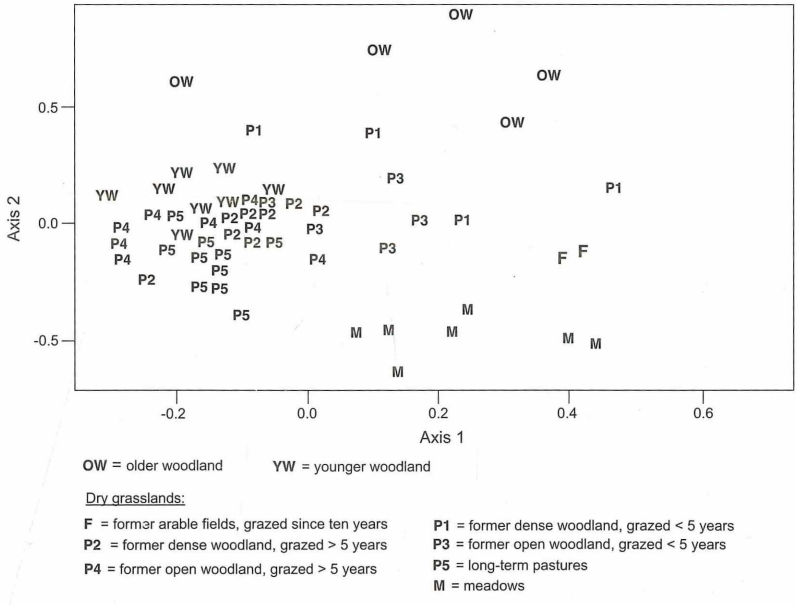


Fig. 6: Result of NMDS ordination (non-metric multidimensional scaling) for the vegetation of the investigated sites. Each point represents one relevé (total no. of relevés: 56).

Abb. 6: Ergebnis der NMDS-Ordination für die Vegetation der untersuchten Standorte. Jeder Punkt entspricht einer Vegetationsaufnahme (Gesamtanzahl der Aufnahmen: 56).

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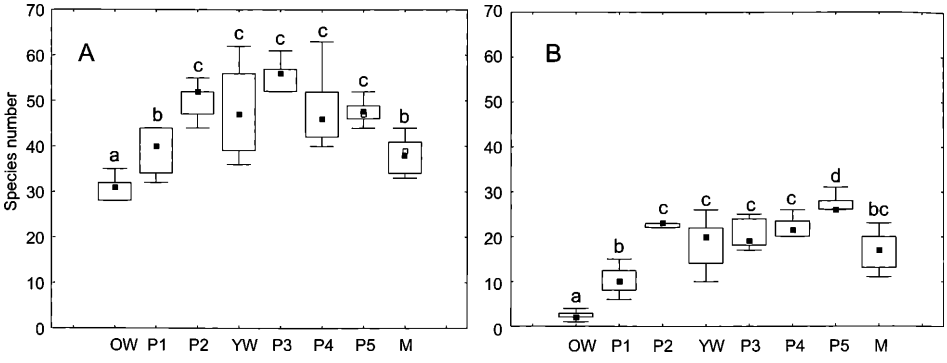


Fig. 7: Species richness (A) and number of dry grassland species (B) of sites with different vegetation structure and land use history (n = no. of relevés). Medians, Box: 25–75%; range without outlier. Kruskal-Wallis test: (A): H (7,54) = 35.045; $p < 0.001$. (B): H (7,45) = 27.95; $p < 0.001$. Different letters show significant differences ($p < 0.05$). OW = older woodland (n = 5); YW = younger woodland (n = 9); P1 = former dense woodland, grazed < 5 years (n = 4); P2 = former dense woodland, grazed > 5 years (n = 5); P3 = former open woodland, grazed < 5 years (n = 7); P4 = former open woodland, grazed > 5 years (n = 8); P5 = old pastures (n = 9); M = meadows (n = 7).

Abb. 7: Artenzahl (A) und mittlere Anzahl an Magerrasenarten (B) für Standorte mit unterschiedlicher Vegetationsstruktur und Landnutzungsgeschichte (n = Anzahl der Vegetationsaufnahmen). Mediane, Box: 25–75 %: Bereich ohne Ausreißer. Kruskal-Wallis-Test: (A): H (7;54) = 35,045; $p < 0{,}001$. (B): H (7;45) = 27,95; $p < 0{,}001$. Unterschiedliche Buchstaben kennzeichnen signifikante Unterschiede ($p <$ 0,05). OW = ältere Wälder (n = 5); YW = jüngere Wälder (n = 9); P1 = früher dichte Wälder, Beweidung < 5 Jahre (n = 4); P2 = früher dichte Wälder, Beweidung > 5 Jahre (n = 5); P3 = früher offenere Wälder, Beweidung < 5 Jahre (n = 7); P4 = früher offenere Wälder, Beweidung > 5 Jahre (n = 8); P5 = alte Weiden (n = 9); M = gemähte Flächen (n = 7).

5.2. Development of dry grasslands after clear-cutting and subsequent grazing

A reasonable evaluation of the restoration success in dry grassland ecosystems requires different prerequisites. After the loss of original vegetation by intensification or abandonment both specialized and euryoecious species could establish. Thus, target species must be defined *a priori*. In our study, species of the *Festuco-Brometea* and the *Sedo-Scleranthetea* were defined as target species for dry calcareous grasslands, which is in accordance with other investigations (BLANCKENHAGEN & POSCHLOD 2005, KIEHL & PFADENHAUER 2007, KIEHL 2009). Furthermore, if possible, reference systems should be identified to evaluate the current status of restored sites. We used old traditionally managed calcareous grassland with *Juniperus communis* as reference systems, which cover larger areas of the nature reserves "Wallersberg" and "Klein Ziegenfeld". Finally, the evaluation of restoration success should consider local and regional species pools (ZOBEL 1997). The regional species pool of dry grasslands of the Franconian Jura was not determined in this study. However, a comparison of average species numbers in phytosociological relevés between calcareous pastures of this region and comparable areas in Southern Germany showed that the mean number of target species in vegetation relevés from our reference systems (Fig. 7 B, P5) is lower (about 25–30 species on 25 m^2) than the number of target species in old calcareous grasslands of the Swabian Alb (about 30–40 species on 20 m^2, BLANCKENHAGEN & POSCHLOD 2005).

The results of our study clearly demonstrate that restoration success of abandoned calcareous grasslands after clear-cutting and grazing depends on both their developmental status before clear-cutting and the amount of time of subsequent grazing. Successful restoration of a typical species composition of calcareous grasslands following clear-cutting is possible after only a few years of grazing if target species are still present in the current vegetation. This is in accordance with findings in other European countries (PÄRTEL et al. 1998, BARBARO et al. 2001). In contrast, a grazing period of at least 5 years was necessary on

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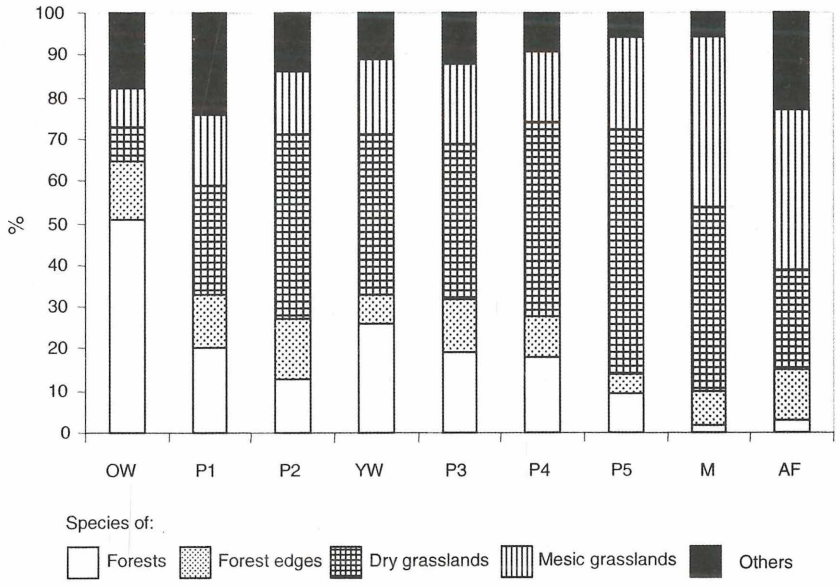


Fig. 8: Proportion of different phytosociological species groups (according to ELLENBERG et al. 1992) of sites with different vegetation structure and land use history. OW = older woodland (n = 5); YW = younger woodland (n = 9); P1 = former dense woodland, grazed < 5 years (n = 4); P2 = former dense woodland, grazed > 5 years (n = 5); P3 = former open woodland, grazed < 5 years (n = 7); P4 = former open woodland, grazed > 5 years (n = 8); P5 = old pastures (n = 9); M = meadows (n = 7); AF = past arable fields, grazed for 10 years (n = 2).

Abb. 8: Anteile verschiedener soziologischer Artengruppen (nach ELLENBERG et al. 1992) von Standorten mit unterschiedlicher Vegetationsstruktur und Landnutzungsgeschichte. OW = ältere Wälder (n = 5); YW = jüngere Wälder (n = 9); P1 = früher dichte Wälder, Beweidung < 5 Jahre (n = 4); P2 = früher dichte Wälder, Beweidung > 5 Jahre (n = 5); P3 = früher offenere Wälder, Beweidung < 5 Jahre (n = 7); P4 = früher offenere Wälder, Beweidung > 5 Jahre (n = 8); P5 = alte Weiden (n = 9); M = Wiesen (n = 7); AF = ehemalige Äcker, seit 10 Jahren beweidet (n = 2).

sites with a dense tree layer prior to clear-cutting before a considerable increase of species richness and the number of target species could be observed. This development was comparable to the results of BLANCKENHAGEN & POSCHLOD (2005), who observed the establishment of many dry grassland species 7–8 years after clear-cutting of formerly densely wooded sites of the Swabian Alb. However, the authors also discovered considerable differences between restored sites and reference areas in terms of species composition. The cleared sites were dominated by target species with a long-term persistent seed bank, whereas old pastures contained predominantly target species with a transient seed bank. In contrast to this, the species composition of most restored sites in our study is similar to that of the reference sites, which was confirmed by the results of the manual classification as well as the ordination. Therefore, we assume that after clear-cutting of previously dense pine forests many dry grassland species could invade from outside by sheep transhumance or by seed rain even though the distances of dispersal by seed rain rarely exceed 25 m for calcareous grassland species (STAMPFLI & ZEITER 1999).

Finally, it can be concluded that the potential for restoration of species-rich calcareous grasslands is still high in the investigated Natura 2000 areas, where cessation of transhumance and afforestation were the main reasons for the decline of these systems. Besides opening of the landscape by clear-cutting and the maintenance of migrating sheep flocks, no further restoration measures such as species introduction (cf. KIEHL 2009) seem to be necessary to maintain the dry grassland species pool of these areas (see also DOLEK & GEYER 2002).

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Table 3: Differentiated vegetation table of recent and former stands of calcareous semi-dry grasslands (*Bromion erecti*) in the Northern Franconian Jura. Plot size was 25 m² throughout. The assignment to phytosociological species groups according to ELLENBERG et al. (1992) is given after the species name.

Tab. 3: Differenzierte Vegetationstabelle aktueller und ehemaliger Kalkhalbtrockenrasen (*Bromion erecti*) in der Nördlichen Frankenalb. Die Größe der Aufnahmeflächen betrug einheitlich 25 m². Die Zugehörigkeit von Arten zu soziologischen Artengruppen gemäß ELLENBERG et al (1992) ist rechts von den Sippennamen angegeben.

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