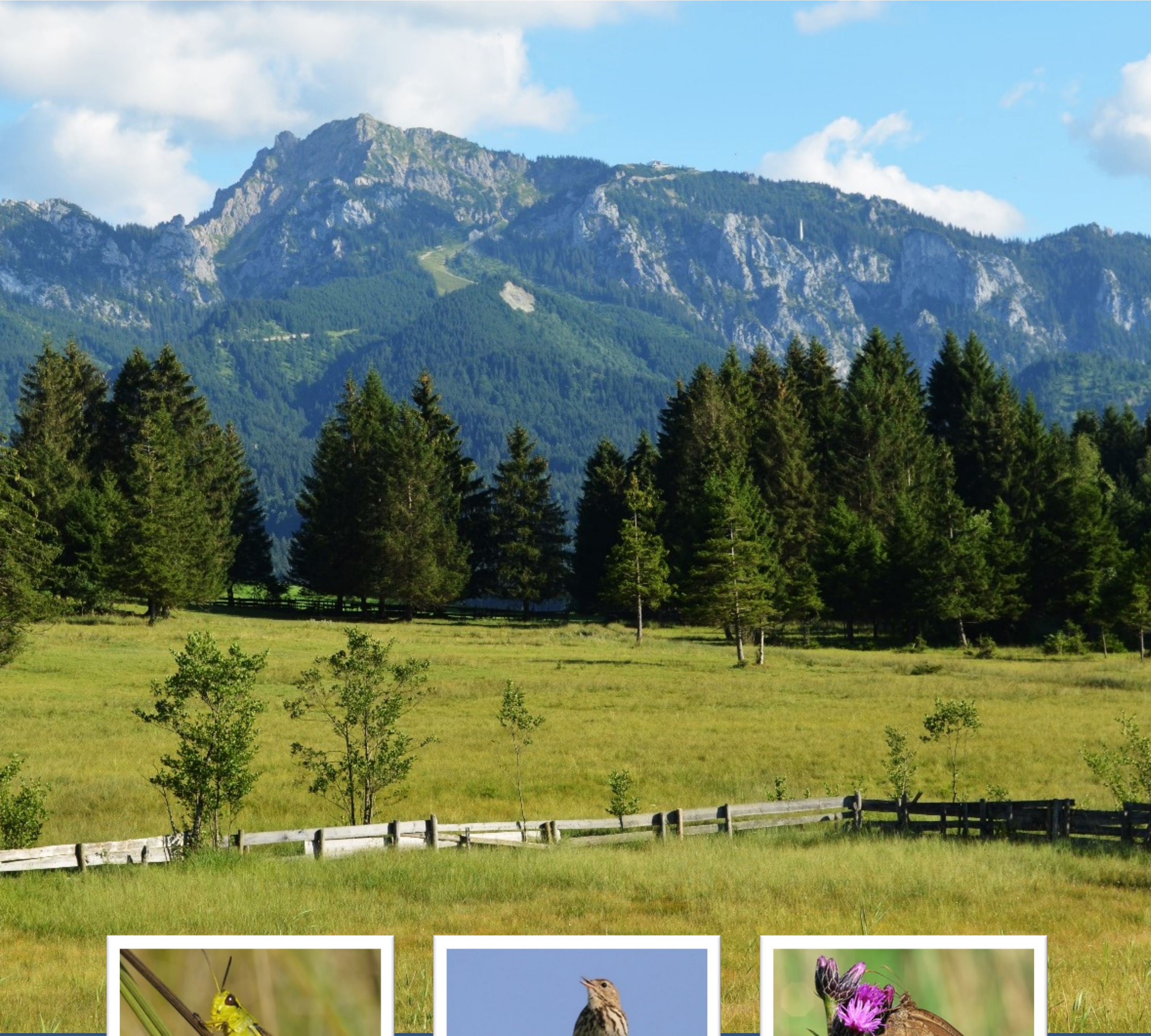

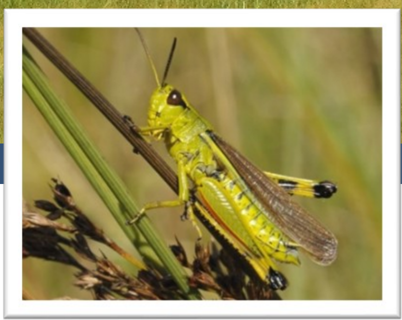

From relict to future model?

Common pastures as biodiversity refuges in the pre-alpine agricultural landscape

CINJA SCHWARZ

UNIVERSITÄT OSNABRÜCK

Front & back cover

Front: Pre-alpine landscape with the common pasture Mühlenberger Viehweide and the characteristic species (from left to right) *Stethophyma grossum* (Photo: Gregor Stuhldreher), Tree Pipit (Photo: Joachim Fünfstück) and *Minois dryas* (Photo: Thomas Fartmann).
Back: Common pasture Echelsbach Gschwend.

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Common pastures as biodiversity refuges in the pre-alpine agricultural landscape

A thesis submitted for the degree of

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Faculty of Biology/Chemistry

Department of Biodiversity and Landscape Ecology

submitted by

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Contents

Chapter 1

Introduction

Global biodiversity crisis

Humans have altered the physical environment of the earth at an unprecedented rate since the beginning of the industrial era 200 years ago (Foley et al. 2005, Rockström et al. 2009). As a result, biodiversity is declining sharply, with current rates of species extinction 1,000 times higher than the natural background rate and this trend is increasing (De Vos et al. 2014). Previous efforts to delay biodiversity loss have been inadequate, with a growing mismatch between increasing pressure on biodiversity (e.g., resource consumption, overexploitation and climate change impacts) on the one hand, and slowing responses to this development on the other (Butchart et al. 2010). Arguably, humans have triggered a sixth global mass extinction (Barnosky et al. 2011).

For terrestrial biomes, land-use change is assumed to be the main driver of the biodiversity crisis (Sala et al. 2000, Foley et al. 2005, Rockström et al. 2009). In Europe, biodiversity is strongly connected to agricultural land due to a long history of cultivating land and a diminution of natural habitats (Beaufoy et al. 1994, Phillips 1998, Vos & Meekes 1999, Plieninger et al. 2006, Donald et al. 2006, Henle et al. 2008, Kleijn et al. 2009). At present, agricultural land covers more than 40% of the European surface (EU-28, Eurostat 2017) and is very important for biodiversity conservation (BMU 2007, Henle et al. 2008). However, this is also where we see the largest decrease in biodiversity across different taxa such as plants, insects and birds, and most farmland species are highly threatened (Vickery et al. 2001, Donald et al. 2006, Flohre et al. 2011).

Agricultural land in Europe

Genesis of traditional landscapes

The agricultural landscape in Europe is the result of a long-lasting land-use history with different stages that overlay, refine and replace each other (Plieninger et al. 2006). Humans began to form the landscape by introducing grazing systems with domestic animals and arable cultures during the Palaeolithic (Bouma et al. 1998). Over time, this human impact on the landscape increased and became large-scale during antiquity (Vos & Meekes 1999). From the Middle Ages to the Renaissance, the entire European agricultural landscape was gradually exploited, with a high degree of diversity in management systems (Bouma et al. 1998, Vahle 2001). What we see as the traditional agricultural landscape was formed mainly between the Renaissance and the 19th century: Multifunctional land-use systems such as mixed agriculture, integrated forests, tree pastures and rough grazing lands, varied strongly on a small scale, where they adapted to climate, physiography and local cultures (Bouma et al. 1998, Vos & Meekes 1999). Remnants from this traditional landscape still exist today, but a large proportion has been drastically re-shaped into an industrial agricultural landscape since the industrial revolution during the second half of the 18th century (Vos & Meekes 1999).

Land-use change

Since the industrial revolution, Europe has entered a new era of agricultural management practices (Rockström et al. 2009): Land-use systems are predominantly monofunctional on a large scale, with similar production systems implemented using the same industrial methods (Vos & Meekes 1999). The majority of society is alienated from agricultural land use, which is increasingly dominated by external markets and governmental planning procedures (Bouma et al. 1998, Vos & Meekes 1999).

Thus, land-use change had two opposing effects for the agricultural landscape in Europe (Foley et al. 2005, Henle et al. 2008, Kleijn et al. 2009, Plieninger et al. 2016): On the one hand, agricultural land use was intensified on productive land which resulted in an expansion of arable land (Bakker 1989, Höchtl et al. 2005). On the other hand, in more marginal farming areas with physical or socio-economic obstacles, agricultural land fell into disuse (Plieninger et al. 2016). Both intensification and abandonment led to a dramatic decline of traditional land-use systems and promoted the homogenization of the landscape with severe negative effects on nature conservation and biodiversity (Beaufoy et a. 1994, Bouma et al. 1998, Kleijn et al. 2009).

Today, few traditional land-use systems remain in Central Europe, especially in areas where land-use change is impeded due to marginal environmental conditions (e.g., in uplands, mountains and wetlands) or specific socio-economic, cultural, or political causes (e.g., land property conditions) (Beaufoy et al. 1994, Brown 2006, Plieninger et al. 2006). The co-development of land use, ecosystems and species over such a long period of time is globally unique (Pykälä 2000, Hampicke 2006, Stenseke 2006). However, the remaining systems are decreasing rapidly because of the increasing economic importance of off-farm labour for descendants of the farmers and an increasing depopulation of marginal areas (Cocca et al. 2012).

Value of the remaining traditional land-use systems

Nowadays, traditional land use is often synonymous with low intensity farming because characteristics of both are (i) low external input (e.g., nutrients, agrochemicals), (ii) sparse land drainage, (iii) low mechanisation, (iv) slow rate of land-use change and (v) low output per hectare with minimised nutrient emission, water loss and reuse of production waste (e.g., dung as fertilizer) (Beaufoy et al. 1994, Velthof et al. 2014, Plieninger et al. 2016). Often, spatially and temporally differentiated rotational principles exist with alternating periods of human impact and of regeneration (Plieninger et al. 2016). Livestock farming is usually performed with regional heritage livestock breeds in low stocking density and with a limited use of concentrate feeds (Beaufoy et al. 1994, Velthof et al. 2014).

Consequently, most traditional land-use systems (i) are rich in structures, (ii) offer many ecological niches, (iii) support a well-adapted wildlife due to long continuity of management systems and (iv) have a high biodiversity with many rare species (Pykälä 2000, Lederbogen et al. 2004, Hampicke 2006). Thus, traditional land-use systems have a high priority and a special importance for European nature conservation (Bakker 1989, Stenseke 2006). Although there is a general desire to preserve traditional land-use practices and cultural landscape, only a small proportion of area is protected or funded nowadays and thus preserved for the future (Beaufoy et al. 1994). Due to the great regional variation in traditional land use, each system has evolved its own characteristics and diversity that requires differentiated considerations (Beaufoy et al. 1994).

Common land

For many centuries, the use of common land was a central element of traditional agriculture in Europe (Brown 2006). In the past, most of the pasturelands were commonly used under the condition of equality for all members of a community (Helfrich 2009, EFNCP 2021). Sharing land ensured a livelihood especially for small farms with little land ownership because the costs could be reduced e.g., by sharing the construction and upkeep of fences, or the herding of livestock (Lederbogen et al. 2004).

As part of the land-use change, common pastures have sharply decreased in value and extent over the past two centuries (Lederbogen et al. 2004, Brown 2006). Fundamental changes in social and political conditions led to the increasing pursuit of private property and thus to a separation and fragmentation of common land (Beaufoy et al. 1994, Brown 2006). One of the major changes made in this context was the distinction of open- and woodland (Lederbogen et al. 2004). The consequences for agricultural biodiversity were devastating because structure, composition and functioning across different scales became more and more homogeneous (Cardinale et al. 2012).

Today, only remnants of the historical common pastures with their traditional management have survived, most of them in agriculturally marginal areas (Brown 2006, Plieninger et al. 2006). Due to the vulnerability of this land-use type and its potential for the conservation of biodiversity, I focus my dissertation on one of the main areas of common pastures in Central Europe.

Study area

The study area – a stronghold for common pastures in Central Europe – is situated in the pre-alpine region (hereafter called pre-Alps) of southern Germany in the Federal State of Bavaria (Figure 1) (Pille et al. 2003, Lederbogen et al. 2004). For my dissertation, I have chosen twelve traditionally managed, large-scale common pastures in that region (Table 1).

The study area is located between 750–900 m a.s.l. at the northern edge of the Alps (LfU 2020a). There, a molasse basin formed during the alpine orogenesis since the Cretaceous and received the ablated fine sediments, sands and gravel from the Alps (Doppler et al. 2004). In interaction with sea-level fluctuation until the Miocene, this led to two great shifts between marine and freshwater molasse (Doppler et al. 2004). The molasse basin is divided into the folded molasse, which forms part of the alpine nappe structure and the foreland molasse (LfU 2020a, Doppler et al. 2004).

During the Würm – the last glacial period in the Alps – glacier advances formed a young moraine landscape: Glacial erosion and accumulation of moraines, tills and meltwater sediments developed a small-scale heterogeneous landscape (LfU 2020a). Special features of the study area are drumlins: Large hills facing north-east/south-west, streamlined with the glacier flow (LfU 2020a).

The climate of the pre-Alps is cool and wet with a mean annual temperature of 7.7 °C and an annual precipitation of 1,336 mm (meteorological station Bad Kohlgrub 742 m a.s.l.; period: 1992–2019; DWD 2020). The sunshine dura-

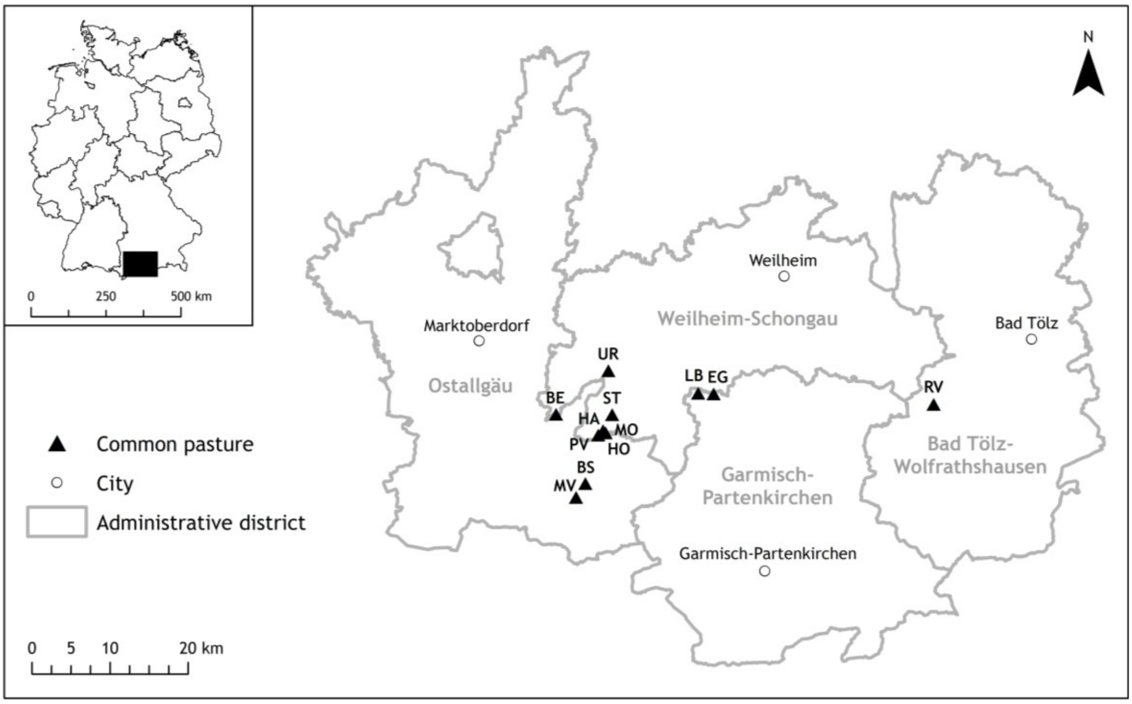

Figure 1: Location of the study area and common pastures in Upper Bavaria (southern Germany). For the abbreviation of the common pastures see Table 1.

tion is comparatively high for Germany with an average of 1,600 to 2,000 hours per year (period: 1961–2019; DWD 2020). In the pre-Alps, small-scale climate differences prevail based on relief and altitude (Lederbogen et al. 2004). Furthermore, extreme weather events like summer thunderstorms, winter fog, late frost and snowfall through until May are characteristic of this region (Lederbogen et al. 2004).

Due to the climate and landscape morphology, the area is characterised by a small-scale mosaic of different soil types: The most common soil types are brown earth, luvisol and pararendzina on moraine accumulations and drumlins, and stagnosol, gley and mire in valleys and depressions (LfU 2020b). The scale and variety of mires make the pre-Alps the most important stronghold for mires in Central Europe (Succow & Jeschke 1990, Ackermann et al. 2012).

In this region, small-scale alternating environmental conditions led to a small-scale mosaic of land use, which is particularly impacted by dairy farming (BfN 2012). In the past, pastures included the whole range from subjacent mires to protruded woodlands, which usually covered the glacial deposits, so a wide range of semi-natural habitats developed (BfN 2012). For a long time, the rural population relied on farming on such rather low-yield land at low costs because of a lack in transport possibilities and long-life food preservation, and a generally low productive capacity in the agricultural sector (Beaufoy et al. 1994, Lederbogen et al. 2004). Some of the once extensive common pastures still exist, with relatively stable livestock pasturing in the study area (BfN 2012). These common pastures are characterised by fluent transitions between open and forest landscapes and the presence of extended mire (Scholle et al. 2001).

However, land-use change has not failed to leave its marks: Until the 19th century, pastures were used predominant-

Table 1: Overview of common pastures and research content of the three papers in this thesis: Fieldwork took place on patches of 25 ha (Paper I) and plots of 500 m² (Paper II, III). HA and MO are remaining areas of a former common pasture, which is currently managed with traditional methods by one shareholder. District: GAP = Garmisch-Partenkirchen, OAL = Ostallgäu, TÖL = Bad Tölz-Wolfratshausen, WM = Weilheim-Schongau; management: R = Rotational grazing system, P = Permanent grazing system (May–October).

	Berghofer Söldner	Bernbeurer Viehweide	Echelsbach Gschwend	Hachegger Viehweide	Holzer Viehweide	Lettigenbichl	Moosreitner Viehweide	Mühlenberger Viehweide	Premer Viehweide	Rieder Viehweide	Urspringer Viehweide	Viehweide Steingädele
Abbreviation	BS	BE	EG	HA	HO	LE	MO	MV	PV	RV	UR	ST
District	OAL	WM	GAP	WM	WM	GAP	WM	OAL	WM	TÖL	WM	WM
Area (ha)	68	27	80	15	32	56	5	54	121	56	53	34
Management	R	R	R	R	P	R	P	P/R	R	P	R	R
Paper I: Common pastures are important refuges for a declining passerine bird in a pre-alpine agricultural landscape.												
Tree Pipit												
Territorial mapping[1]	■	■	■		■	■		■	■	■	■	■
Environmental parameters												
Biotope types[2]	■	■	■		■	■		■	■	■	■	■
Borderline density[3]	■	■	■		■	■		■	■	■	■	■
Landscape diversity[4]	■	■	■		■	■		■	■	■	■	■
Paper II: Conservation of a strongly declining butterfly species depends on traditionally managed grasslands.												
Minois dryas												
Oviposition-site mapping[5]			■					■		■		
Territorial mapping[6]	■		■			■		■		■		
Environmental parameters												
Grazing pressure[7]	■		■			■		■		■		
Nectar plants[8]	■		■			■		■		■		
Sunshine duration[9]	■		■			■		■		■		
Vegetation structure[10]	■		■			■		■		■		
Vegetation types[11]	■		■			■		■		■		
Paper III: Traditional grazing management creates heterogeneous swards and fosters grasshopper densities.												
Grasshoppers												
Assemblage mapping[12]	■		■	■		■	■	■	■	■		
Environmental parameters												
Grazing pressure[7]	■		■	■		■	■	■	■	■		
Sunshine duration[9]	■		■	■		■	■	■	■	■		
Vegetation structure[10]	■		■	■		■	■	■	■	■		
Vegetation types[11]	■		■	■		■	■	■	■	■		

1 According to Bibby et al. (2000)
2 According to Riecken et al. (2006)
3 Between open and forest landscape
4 Shannon Index according to O'Neill et al. (1988)
5 Sampled in a radius of 30 cm around oviposition and random sites
6 Sampled with a standardized transect walk (Pollard & Yates 1993, Weking et al. 2013)
7 Measured as number of cow and horse droppings
8 Method according to Krämer et al. (2012), based on Leopold (2001) and Corwell & Futuyuma (1971)
9 Measured with a horizontoscope after Tonne (1954)
10 Included different vegetation layer covers, density and height
11 Using character and differential plant species according to Oberdorfer (1992), Dierßen & Dierßen (2008)
12 Sampled with box quadrat of 2 m² placed randomly 10 × per patch (Gardiner et al. 2005, Gardiner & Hill 2006, Fartmann et al. 2008)

ly in summer, with daily movement of livestock (oxen, horses, dairy and young cattle) and ancillary uses (peat working, removal of timber, firewood, leaves for bedding and grasses for winter feed) (Lederbogen et al. 2004). Since the industrialisation, some productive mineral soils have been drained, levelled and fertilised in contrast to less productive mires (Lederbogen et al. 2004). Furthermore, ancillary uses were largely discontinued (Lederbogen et al. 2004).

However, the dominant form of land management has been maintained until today: Common pastures are still used for raising dairy cattle in low stocking capacities of 0.5–2.0 livestock units per hectare on extensive rotational or permanent pastures throughout the summer (Lederbogen et al. 2004). This land use is of existential importance for the majority of shareholders of the pastures in the study area (Lederbogen et al. 2004).

Indicator species

Using indicator species is an established method in environmental research to (i) assess the abiotic and biotic state of an environment, (ii) identify key information about complex ecosystems and (iii) depict the impacts of environmental change on habitats, communities and ecosystems (Dufrêne & Legendre 1997, McGeoch 1998, Dale & Beyeler 2001, Siddig et al. 2016).

Therefore, in my thesis I chose to work with indicator species that (i) represent the community of valuable open and semi-open habitats on common pastures in the study area, (ii) are sensitive to environmental changes, (iii) respond to these changes in a known and predictable manner, (iv) indicate an impeding change in ecosystems, (v) are declining or threatened and in need of protection and (vi) are determinable with standardised, proven and practicable methods (Dale & Beyeler 2001, Lederbogen et al. 2004, Siddig et al. 2016). Based on these criteria, I selected indicator species from the classes of birds (e.g., Donald et al. 2006, Lederbogen et al. 2004, Gregory et al. 2004, Graham et al. 2017, Newton 2017) and insects (e.g., Lederbogen et al. 2004, Fartmann & Hermann 2006, Poniatowski & Fartmann 2008, Krauss et al. 2010, Schirmel et al. 2010) because they cover a wide span of ecological demands on different spatial scales and avoid an oversimplified understanding of interactions (Dale & Beyeler 2001).

Birds

Birds respond to environmental changes at moderate spatial and temporal scales (Gregory et al. 2004). They are mainly sensitive to changes in breeding habitats and food supply (Vickery et al. 2001, Benton et al. 2002, Newton 2004). Due to their position on top of the food chain, their assemblages reflect alterations of producers or consumers (Gregory et al. 2004).

A suitable indicator bird for this thesis is the Tree Pipit (*Anthus trivialis*): It is strongly specialised in semi-open habitats with fluent transitions between open and forest landscapes that are key elements of the traditional used systems in the study area (Loske 1987a, Gregory et al. 2004, Südbeck et al. 2005). Furthermore, it is representative for other species which need the same habitat (e.g., other farmland birds like the endangered Red-Backed Shrike [*Lanius collurio*]) (Lederbogen et al. 2004).

INSECTS

Insects are excellent indicator species for grasslands because they are short-lived and respond rapidly to environmental changes (Schirmel et al. 2010, Poniatowski et al. 2018). In less fragmented landscapes like the study area, habitat quality has been mentioned as a major driver for insect distribution and diversity (Krämer et al. 2012, Löffler & Fartmann 2017, Münsch et al. 2018, Poniatowski et al. 2018). Habitat quality depends largely on the availability of sufficient host, nectar or food plants, sufficient vegetation structure and microclimate (Poniatowski & Fartmann 2008, Munguira et al. 2009, Stuhldreher & Fartmann 2018). In this thesis, I focussed on the less mobile group of Orthoptera (hereinafter termed 'grasshoppers') and the highly mobile butterfly species *Minois dryas*. Grasshoppers have a high functional significance in grasslands due to their key role as herbivores and prey (Samways 2005). Consequently, I chose them to gain insights into the state of the whole ecosystem.

Butterflies – with their exceedingly complex habitat requirements – are declining more strongly than many other taxonomic groups (Thomas et al. 2004, Thomas 2005). They are a major model group in ecology and biodiversity conservation (Watt & Boggs 2003, Ehrlich & Hanski 2004). Particularly *M. dryas* is severely affected by land-use change due to its specialisation on the nutrient-poor open mires that are a key element of the common pastures in the study area (Ebert & Rennwald 1991, van Swaay et al. 2006). It is representative for other species of secondary usage-dependent open habitats that make up a large part of all threatened species in Germany (Lederbogen et al. 2004).

Knowledge gaps

The main reasons for current levels of biodiversity loss are habitat destruction and habitat loss as result of land-use change (Sala 2000, Jantz et al. 2015). Thus, one of the main tasks for mitigating the global biodiversity crisis now is to identify and conserve agricultural systems with high biodiversity. This thesis contributes to this by analysing the biodiversity value of traditionally used common pastures in the pre-Alps. Carefully selected indicator species show the relevance of this habitat for the threatened community of farmland species in Central Europe (Quinger et al. 1995, Lederbogen et al. 2004, van Swaay et al. 2006, Streitberger et al. 2012). Knowledge gained from this thesis should contribute to conserving existing biodiversity hotspots.

A further task for the mitigation of biodiversity loss is to outline processes and functional connections between land-use practice and biodiversity. Despite the once global distribution of common pastures, not much is known about the relationship between this farming system and the demands of most species living in it (Beaufoy et al. 1994). To contribute to closing this gap, I focussed on how relationships between plants, invertebrates and birds have developed and the resulting dependence of many highly specialist species on a relatively stable, albeit human-modified environment (Beaufoy et al. 1994). A detailed area-wide systematic analysis of the habitat preferences of farmland species like Tree Pipit, *M. dryas* and grasshoppers on common pastures compared to the surrounding landscape is still missing. Thus, the relevance of grazing for their conservation on common pastures in general and on different grassland and mire types in particular is largely unknown.

This thesis is the first study using a systematic and quantitative approach on a multi-taxa level considering vertebrate and invertebrate species and drivers for biodiversity for common pastures in the pre-Alps. Furthermore, the ecological research presented here contains the largest number of common pastures with the largest spatial extent conducted so far in this area. The few existing studies are mostly descriptive (Lederbogen et al. 2004) or consider only one common pasture (Bhattarai et al. 2004, Rosenthal & Lederbogen 2008), or a single taxon (Anthes et al. 2003, Grüneberg 2003, Harry et al. 2005, Rosenthal 2010, Fumy et al. 2020). Therefore, generalisations can only be made to a limited extent. Studies which are comparable in scope to this thesis in other parts of Central Europe are exceptions so far (Kostrzewa 2004, Sutcliffe 2013).

Aims of the thesis

The main aim of my thesis is to examine whether and to what extent common pastures contribute to biodiversity conservation in the modern agricultural landscape of Central Europe. There is some evidence which indicates that they serve as refuges for declining wildlife (Lederbogen et al. 2004) – but to date, quantifiable research is missing

In addition, I examine how traditional long-time grazing affects habitat quality for declining farmland indicator species. In this context, I pay particular attention to mire ecosystems due to their vulnerability concerning land use and the special role of the pre-Alps for their conservation. Further, I focus on transitions between forest and open landscapes because they are sharply separated as a consequence of land-use change. With my research and the knowledge gained, I hope to raise attention for the common pasture as a valuable land-use type. Hence, I address the following research questions:

Importance of common pastures in the modern agricultural landscape of the pre-Alps

- How does land-use change affect landscape, habitats and biodiversity?
- Are common pastures important refuges for farmland species and biodiversity hotspots?

Grazing influence on the habitat quality of common pastures

- How does grazing affect habitat quality for farmland species and biodiversity?
- What are the key drivers for farmland species and biodiversity in the study area?

Implications for conservation

- Which management recommendations for the conservation of farmland species and biodiversity can be derived from the findings?

Outline of the thesis

This thesis consists of three papers, each of which focuses on the aforementioned questions for one indicator species or group, i.e., (i) Tree Pipit (*A. trivialis*), (ii) dryad (*M. dryas*) and (iii) grasshoppers. In the first paper, I quantify Tree Pipit territories on common pastures and compare them to the surrounding landscape. I analyse in detail which key factors determine habitat quality for the Tree Pipit. Territories and home-range scale are regarded separately due to different demands. In addition, I discuss the importance of common pastures for the conservation of this species.

The second paper focuses on the habitat and oviposition-site preferences of *M. dryas* in common pastures and the surrounding landscape (land-use types: Fallow, mown once, mown twice or more often). I differentiate between grasslands on mineral soil, fens, transition mires and raised bogs within the land-use types. I then discuss the relevance of common pastures and give, where appropriate, management recommendations for the conservation of *M. dryas*.

The third paper addresses the impacts of common pasturing on grasshopper assemblages. For a comparison between common pastures and the surrounding landscape, I consider species richness, density and indicator species. I analyse drivers for the composition of grasshopper assemblages and give implications for conservation.

In the last chapter, I draw together the findings from the three papers to provide a synthesis of my research on a multi-taxa level. Finally, I develop perspectives for management and biodiversity conservation.

Chapter II

Comparison of common pastures and control plots

Paper I

Common pastures are important refuges for a declining passerine bird in a pre-alpine agricultural landscape

SCHWARZ C, TRAUTNER J, FARTMANN T (2018)
Journal of Ornithology 159: 945–954.

doi.org/10.1007/s10336-018-1561-0

Abstract
Agricultural landscapes play an important role in biodiversity conservation. The Tree Pipit (*Anthus trivialis*) was formerly a widespread breeding bird in European farmlands. However, today, its numbers are sharply declining in most European countries. The aim of our study was to compare territory densities of Tree Pipits in common pastures and control plots in the surrounding pre-alpine agricultural landscape in southern Bavaria (Germany). Additionally, we determined the drivers of territory and home-range establishment in Tree Pipits.

Habitat composition in common pastures and control plots reflected distinct differences in land-use intensity. Common pastures had larger areas of nutrient-poor habitats and higher landscape diversity compared to control plots. In line with this, we detected a clear response of Tree Pipits to differences in habitat composition. Territories were nearly exclusively found in common pastures. Within the common pastures, Tree Pipits preferred those parts that had a higher landscape diversity and, additionally, at the territory scale, larger areas of groups of trees.

The common pastures are important refuges for the threatened Tree Pipit in the pre-alpine agricultural landscape of the study area. In contrast to the control plots, the common pastures provided (i) sufficient suitable song posts and (ii) heterogeneous vegetation with appropriate nesting sites and a high availability of arthropod food resources. Our study corroborates findings from other studies across Europe highlighting the prime importance of traditionally used wood pastures for the Tree Pipit and biodiversity in general.

Common pastures are important refuges for the threatened Tree Pipit in the agricultural landscape of the pre-Alps (Photo: Joachim Fünfstück).

Characteristic habitat for Tree Pipits with sufficient song posts in a diverse landscape on the common pasture Lettigenbichl.

Paper II

Conservation of a strongly declining butterfly species depends on traditionally managed grasslands

SCHWARZ C, FARTMANN T (2021)
Journal of Insect Conservation 25: 255–271.

doi.org/10.1007/s10841-020-00288-2

Abstract

Introduction: Due to land-use intensification at productive soils and abandonment of marginal farmland, biodiversity has dramatically declined throughout Europe. The dryad (*Minois dryas*) is a grassland butterfly that has strongly suffered from land-use change across Central Europe.

Aims/Methods: Here, we analysed the habitat preferences of adult *M. dryas* and the oviposition-site preferences in common pastures located in mire ecosystems of the German pre-Alps.

Results: Our study revealed that plot occupancy was equal at common pastures and control plots. However, the abundance of *M. dryas* was higher at common pastures, although the composition of vegetation types did not differ between the two plot types.

Discussion: Open fens and transition mires traditionally managed as common pastures or litter meadows (= meadows mown in autumn to obtain bedding for livestock) were the main habitats of *M. dryas* in our study area. They offered (i) sufficient host plants (*Carex* spp.), (ii) had a high availability of nectar resources and (iii) a vegetation that was neither too sparse nor too short. In contrast, both abandonment and intensive land use had negative impacts on the occurrence of the endangered butterfly species.

Implications for Insect Conservation: Based on our study and other recent research from the common pastures, we recommend to maintain the current grazing regime to foster biodiversity in general and *M. dryas* in particular. Additionally, where possible, abandoned fens and transition mires adjacent to common pastures should be integrated into the low-intensity pasture systems. The preservation of traditionally managed litter meadows is the second important possibility to conserve *M. dryas* populations.

Minois dryas strongly prefers fens and transition mires on common pastures (here on *Serratula tinctoria*) (Photo: Thomas Fartmann).

Characteristic oviposition habitat of *M. dryas*: The stick marks the position of the egg in a fen on the Mühlenberger Viehweide (left). The egg was dropped during flight between sedges and rushes on the moss layer (right) (Photo: Gregor Stuhldreher).

Paper III

Traditional grazing management creates heterogeneous swards and fosters grasshopper densities

SCHWARZ C, FARTMANN T (2021)
Insect Science (accepted)

doi.org/10.1111/1744-7917.13041

Abstract

Common pastures were once the dominant type of land use in many European regions. However, during the past 150 years, they have declined dramatically. Recent studies have shown that they are hotspots for rare plant, butterfly and bird species in the study area, the Bavarian pre-Alps (southern Germany). However, studies on the value of these pastures for Orthoptera (hereinafter termed 'grasshoppers') have been scarce. Here, we studied the effects of traditional summer grazing in common pastures on grasshopper assemblages.

Our study revealed that grasshopper species richness did not differ between common pastures (N = 57) and controls (N = 57). By contrast, density of all and threatened species varied between common pastures and controls in all plots and within the two vegetation types with the highest grasshopper abundance, grasslands on mineral soil and fens. Two threatened species, *Pseudochorthippus montanus* and *Stethophyma grossum*, were identified as indicators for common pastures; controls had no indicative species. Traditional low-intensity grazing in common pastures has resulted in open and heterogeneous swards with some bare ground, a low cover of litter and an intermediate vegetation height favouring high densities of grasshopper species in general and threatened species in particular. This is especially true for the two most productive vegetation types, grasslands on mineral soil and fens.

To promote biodiversity in general and grasshopper densities in particular, we recommend maintaining traditional cattle grazing (stocking capacities: 0.5–2.0 livestock units/ha) in common pastures. Where possible, this grazing regime should also be introduced in the surrounding landscape.

The vegetation type 'grassland on mineral soil' on the common pasture Echelsbach Gschwend.

The vegetation type 'fen' on the common pasture Mühlenberger Viehweide.

The vegetation type ‘transition mire’ on the common pasture Berghofer Söldner.

The vegetation type ‘raised bog’ on the common pasture Echelsbach Gschwend.

 

Pseudochorthippus montanus (left) and *Stethophyma grossum* (right) are indicator species for common pastures in the pre-Alps (Photos: Thomas Fartmann, Gregor Stuhldreher).

Chapter III

Summary and Synopsis

Importance of common pastures in the modern agricultural landscape of the pre-Alps

HOW DOES LAND-USE CHANGE AFFECT LANDSCAPE, HABITATS AND BIODIVERSITY?

The biodiversity crisis which is driven by land-use change is clearly present in the pre-alpine agricultural landscape: Bavarian grasslands declined by about 3.9% between 2003 and 2012, which is above the German average of 3.6% (BfN 2014). In addition, only 5–13% of the current grasslands in the study area have a high nature value (HNV), i.e., are rich in species and ecological valuable due to low-intensity management (Matzdorf et al. 2010). This proportion is below the nationwide average of 16.8% (Matzdorf et al. 2010).

Traditionally used common pastures in the pre-Alps are one form of such low-intensity farmland with century-long management continuity (Lederbogen et al. 2004). But they decreased sharply as a result of land-use change (personal messages, Waldherr 2000): The Mühlenberger Viehweide (MV), for example, declined by 62% between 1818 and 2004 (Lederbogen et al. 2004). Areas excluded from the original pasture were directly affected by land-use change and either went fallow or became intensively used grasslands (own observation).

The comparison between remaining common pastures and surrounding grasslands in this thesis clearly shows the consequences of land-use change in our modern agricultural landscape: Surrounding grasslands – no matter whether intensified or abandoned – are largely (i) homogeneous on both landscape and habitat scale, (ii) poor in nutrient-poor habitats, (iii) sparsely populated by birds and insects and (iv) unsuitable for biodiversity conservation. Exceptions are other low-intensity land-use systems that make up only a marginal part in the pre-Alps nowadays. In the context of this thesis, these systems comprise exclusively traditionally managed hay and litter meadows that are closely linked to the existence of common pastures providing fodder and litter as bedding for cattle and horses in the winter-season.

ARE COMMON PASTURES IMPORTANT REFUGES FOR FARMLAND SPECIES AND BIODIVERSITY HOTSPOTS?

The results from this study show that the modern agricultural landscape in the pre-Alps is largely unsuitable as a habitat for farmland species, threatened species and species- and individual-rich assemblages. With its systematic approach at a multi-taxa level, this thesis demonstrates the value of common pastures as refuges in the modern agricultural landscape. Thus, the few remaining common pastures in the study area are of outstanding importance for the conservation of wildlife species and farmland biodiversity as a whole in the pre-Alps. My findings are in line with other studies across Europe, which emphasise the crucial relevance of traditionally used pastures for wildlife conservation (e.g., Moga et al. 2009, Diaz et al. 1997, Pinto-Correia & Mascarenhas 1999, Lederbogen et al. 2004, Streitberger et al. 2012, Helbing et al. 2014).

Specifically, I show that farmland birds, represented by the Tree Pipit, reach significantly higher abundances on common pastures compared to the surrounding landscape (Paper I), where their occurrence is alarmingly low. Equally, common pastures meet the complex demands of threatened butterfly species like

M. dryas throughout their life cycle (Paper II, see below). They occur with high abundances on common pastures and allocated hay and litter meadows. Moreover, I show for the entire assemblage of grasshoppers that abundances of all species – and particularly of those under threat – are significantly higher on common pastures in contrast to the surrounding landscape (Paper III).

Grazing influence on the habitat quality of common pastures

HOW DOES GRAZING AFFECT HABITAT QUALITY FOR FARMLAND SPECIES AND BIODIVERSITY?

Although the importance of traditional low-intensity farmlands for biological conservation is increasingly coming to the force, there is still a gap in knowledge about how different forms of management in distinct areas concretely affect habitats, species and assemblages (Bunzel-Drüke et al. 2009). One of the most controversially discussed aspects in this context is the influence of grazing on mire ecosystems (e.g., Küchler et al. 2009, Groom & Shaw 2015). Livestock grazing affects habitats not only through browsing, but also through lying, wallowing, trampling and urine or fecal deposition (Milchunas et al. 1988). Studies provide different insights depending on mire type, local site conditions and idiosyncrasies of grazing regimes, amongst others. Consequently, a carefully differentiated systematic consideration is necessary, which has largely been missing for my study area and my study taxa. Due to the regional specifics, a differentiation in the mire types of fen, transition mire and raised bog is necessary. The grazing influence on the different mire types cannot be considered without looking at grasslands on mineral soils, as they make up large parts of most common pastures and have a special value for the overall foraging behaviour of livestock.

Fens make up the largest part of the mire types on common pastures considered in this thesis. Among the mire types, grazing pressure is highest in fens; however, it is significantly lower than in grassland on mineral soil (Figure 11). In fens, the grazing regime results in (i) higher covers of shrubs and Cyperaceae and (ii) a rather denser and higher field layer than in surrounding fens. Fens are strongly preferred by Tree Pipits due to the fluent transition between open and woodland habitats that provide (i) sufficient song posts and (ii) heterogeneous vegetation with appropriate nesting sites and a high availability of arthropod food resources (Paper I), such as grasshoppers (Pätzold 1990). Grasshopper densities are twice as high on common-pasture fens compared to surrounding fens (Paper III). Grasshoppers favour fens due to (i) the high covers of Cyperaceae as food and (ii) the vegetation structure with high and dense parts as shelter. In addition,

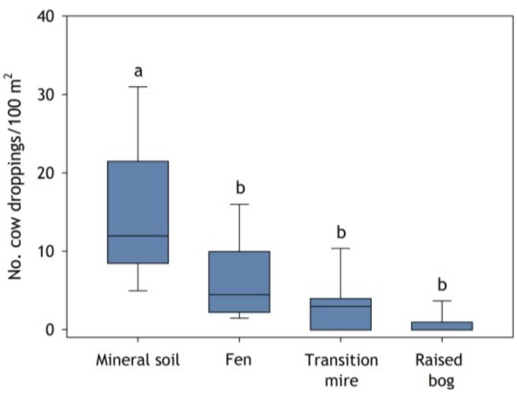

Figure 2: Number of cow droppings (mean value ± SE) in open and semi-open habitat types on common pastures based on data of Paper II and III. Differences were tested using Generalized Linear Mixed-effect Models (GLMM) with *subarea* as a random factor. Different letters indicate significant differences between vegetation types.

fens are strongly preferred habitats for *M. dryas* because they provide (i) sufficient host plants (*Carex* spp.), (ii) a high availability of nectar resources and (iii) a vegetation that is neither too sparse nor too short (Paper II).

Transition mires are the second largest mire ecosystems on common pastures. Grazing pressure is rather low (Figure 11). They clearly differed from transition mires outside the common pastures due to (i) more heterogeneous structures with a mosaic of open soil and high vegetation, (ii) higher covers of Cyperaceae and shrubs and (iii) lesser cover of herbs. Additionally, transition mires on common pastures are frequently closely interlocked with fens (own observation, Lederbogen et al. 2004). Thus, a range of species – even those with less mobility – can benefit from the offer of both habitat types. This is particularly favourable for a species like *M. dryas*, which has complex and changing requirements during its life cycle and whose main habitat are both vegetation types on common pastures (Paper II).

Raised bogs have large extents on a few common pastures but are completely missing on others. In contrast to fen and transition mire, they are less interlocked with other mire types and grazing pressure is very low due to inadequate fodder values (Figure 11) (own observation, Lederbogen et al. 2004). Sphagnum mounds build up a nearly closed surface on raised bogs, both on common pastures and in the surrounding area. All surrounding raised bogs discussed in this thesis are disused. Due to the low grazing pressure, there are only few differences between pastures and surrounding fallows: On pastures, the surface is occasionally interrupted by livestock trampling, which creates good germination conditions for shrubs like *Picea abies* and *Pinus x rotundata* (own observation, Lederbogen et al. 2004). The analyses in Paper II and III confirm that grazed raised bogs have (i) more shrubs, (ii) less cover of herbs and (iii) a lower vegetation density. In contrast to the other mire types, grazing leads neither to an improvement of the habitat quality for farmland species nor to an increase in biodiversity. Only few and predominantly highly specialised species (e.g., *Metrioptera brachyptera*) prefer raised bogs anyway; in the study area, they have been shown to prefer disused raised bogs (Paper III).

Grassland on mineral soil occupies a special position within the common pastures because here traditional management has partially changed as a consequence of the land-use change. Lederbogen et al. (2004) already observed that nearly half of the common pasture on mineral soil within their study area (pre-Alps and calcareous fringe of the Northern Alps) had been fertilised and drained to improve productivity. My observations confirm this development and that grazing pressure on mineral soil is significantly higher than in the mire types as a consequence (Figure 11). Yet even on mineral soil, the current management creates a structural heterogeneity with both (i) open soil and sparse vegetation and (ii) ruderal patches with tall rushes and herbs that are largely missing in the surrounding area. There, mineral soil grasslands are predominantly intensively mown. This thesis shows that especially grasshoppers prefer grazed grasslands on mineral soil, which is evident from high densities of all and threatened species (Paper III). Conversely, threatened farmland species like *M. dryas* prefer predominantly nutrient-poor habitats, but benefit to some extent from grassland on mineral soil if it is closely connected to main habitats in fen or transition mires.

What are the key drivers for farmland species and biodiversity in the study area?

The high landscape diversity on common pastures is a key driver for the existence of farmland species in the pre-Alps. Birds like the Tree Pipit and butterflies like *M. dryas* can satisfy the complex demands during their life cycle there. My thesis shows that Tree Pipits benefit strongly from the fluent transition between open habitats and woodland on common pastures, which offers suitable song posts, lookouts and sites for nesting and foraging (Paper I). In the agricultural landscape of Central Europe, the radical separation of forest and open habitats is a major threat to farmland birds (Moga et al. 2009). Also lesser mobile species like butterflies benefit from the high landscape diversity with small-scale mosaics of habitat types on common pastures. It facilitates the use of diverse resources: *M. dryas*, for example, has its main habitats in fen and transition mire, but it benefits strongly from nectar resources on adjacent grassland on mineral soil (Paper II). In the modern agricultural landscape of Central Europe, however, transitions and close connections of habitats are largely missing (Benton et al. 2003, Babai & Molnár 2014, Wielgolaski et al. 2017).

A further key driver that fosters farmland species and biodiversity on common pastures in the pre-Alps is the high availability of nutrient-poor open and semi-open habitats. Fens and transition mires are widespread habitats of all common pastures in the study area; however, they are largely missing in the surrounding agricultural areas. These habitats are strongly preferred by insects due to their (i) high abundances of nectar sources, (ii) high covers of sedges that are frequently needed as a food source and (iii) structural heterogeneity with a small-scale mosaic of high and dense field layer vegetation and of sparse plant cover with open soil (Paper II, III). Biodiversity is particularly high in parts with higher grazing pressure that supresses the accumulation of litter and the emergence of too many shrubs. Because of these favourable habitat conditions for insects, fens and transition mires are extremely valuable for foraging of insectivorous farmland birds.

In view of climate change, landscape and structural heterogeneity within habitats become even more important: They serve as buffers during extreme climate events and as an opportunity for claiming new habitats (Fartmann et al. 2021).

In summary, the key drivers for farmland species and biodiversity on multi-taxa scale in this thesis are (i) a high landscape diversity with some but not too many trees and shrubs in smooth transition to semi-open and open habitats, (ii) a high availability of open and semi-open nutrient-poor habitats – particularly fens and transition mires – and (iii) a high structural heterogeneity on habitat scale due to an appropriate grazing regime that favours Cyperaceae and flowering plants but suppresses accumulation of litter as well as vegetation that is too high and dense.

Implications for conservation

WHICH MANAGEMENT RECOMMENDATIONS FOR THE CONSERVATION OF FARMLAND SPECIES AND BIODIVERSITY CAN BE DERIVED FROM THE FINDINGS?

My thesis revealed the high importance of common pastures for the conservation of farmland species and biodiversity in the pre-alpine agricultural landscape. Consequently, my main recommendation is to protect the remaining common pastures with their traditional management. Despite the predominantly century-long continuity in management, the pressure on common pastures through land-use change is already visible today: Several parts of mineral soil grasslands are being improved through fertilization and drainage to enhance productivity and fodder value for livestock (own observation, Lederbogen et al. 2004). Consequently, the grazing regime changes on the entire pasture, and the vulnerable balance between grazing pressure, vegetation development and wildlife animals is at risk of being disturbed. While improved grassland is more frequented by livestock, other parts – especially mires – are less frequented (Figure 11).

As my thesis shows, grazing is particularly necessary to avoid succession and to conserve the extraordinary biodiversity of fens and transition mires. Therefore, I recommend stopping the improvement of grassland on mineral soil. Where this is not possible, the development of grazing behaviour in connection with the influence on farmland species and biodiversity should be monitored. A suitable extent of grazing in mires is individual for each common pasture, depending on (i) the proportion of improved mineral soil grassland, (ii) the proportion of fens and transition mires and (iii) the shape of each pasture that affects accessibility (cf. Lederbogen et al. 2004).

Furthermore, I recommend integrating fens and transition mires adjacent to common pastures when they are either fallows or intensively managed. The integration of adjacent grasslands on mineral soil should be carefully vetted: If they are improved, livestock may prefer grazing mainly in these parts, whereas less nutrient-rich parts become abandoned (see above). However, it is advisable to monitor the grazing behaviour of livestock carefully with each change in the form of management.

While this thesis makes the positive influence of grazing on fen and transition mire on common pastures obvious, a positive influence on raised bogs has not been detected. Raised bogs are extreme habitats which are poor in species and individuals – and also in livestock (Figure 11). The only characteristic species for raised bogs was the grasshopper *Metrioptera brachyptera* that prefers fallows in contrast to grazed bogs (Paper III). Otherwise, I found no differences between grazed and abandoned raised bogs with regard to study species and assemblages. To conclude, grazing on raised bogs does not seem to be relevant for biodiversity conservation and should not be prioritised. Yet where grazing intensity changes and a higher grazing pressure is to be feared for raised bogs, the consequences for highly adapted assemblages have to be monitored so that actions can be taken rapidly where needed (e.g., fencing off raised bogs, reducing stocking capacity).

In view of the consequences of climate change, it is particularly beneficial to maintain and restore high water levels on common pastures. Hydrologically intact mires are more resilient to climate change and thus habitats can be conserved (Essl et al. 2012).

Finally, an aim for conserving farmland species and biodiversity is to preserve and enlarge a network of large and well-connected traditionally used areas. In the modern agricultural landscape of Central Europe, ecologically valuable traditionally used grasslands are usually highly fragmented which obstructs the spreading and exchange of flora and fauna (EEA 2011). In addition to common pastures, traditionally managed hay and litter meadows – as part of the traditional livestock farming in the pre-Alps – should be preserved, enlarged and connected within the habitat network.

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