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Editorial: Origin, conservation, and restoration of the threatened European grassland ecosystem in the Anthropocene

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Editorial on the Research Topic
Origin, conservation, and restoration of the threatened European grassland ecosystem in the Anthropocene

The European continent boasts a rich tapestry of natural and semi-natural grasslands, formed through intricate interactions between humans and nature, representing not only biodiversity hotspots but also invaluable cultural heritage (Poschlod and WallisDeVries, 2002). While based on a recent estimate, Europe harbors more than 650 thousand square kilometer of permanent grasslands, on average only up to a half of this area is covered by grasslands of high natural value (HNV) (Dengler et al., 2020). Beside of the area loss and fragmentation, both intensification and abandonment of traditional extensive land use, as well as the steadily increasing urbanization threaten the species composition and diversity of these ecosystems (Habel et al., 2013; Dengler et al., 2014). As we navigate the complexities of the Anthropocene, these ecosystems face unprecedented impacts, compelling us to challenge our historical approaches to conservation and restoration. In recent years, scientific research has delved deep into understanding the diverse array of European grasslands. From some intact large and continuous grassland stands (e.g. some steppes in Eastern Europe), to patches nested within urban sprawls and the emergent green roofs adorning urban landscapes, researchers have unraveled the unique ecological dynamics and management challenges associated with each type of grassland.

With the Research Topic "Origin, Conservation, and Restoration of the Threatened European Grassland Ecosystem in the Anthropocene", we set the stage for a journey through the nuanced landscapes of European grasslands, offering an overview of recent scientific endeavors and a call to action for the preservation and restoration of these unique ecosystems, as well as the integration of urban and novel grassland ecosystems in a global conservation strategy. The findings of the 14 studies presented in this Research Topic underline the importance of recognizing the heterogeneity within European grasslands. Whether it is the biodiversity-rich semi-natural grasslands, spawning mediterranean and temperate dry

grasslands (Martin et al., Ewert et al., Blight et al., Köhler et al., Jaunatre et al.), floodplain and hay meadows (Sommer et al., Dellicour et al.), montane grasslands (Helbing et al., Durbecq et al.), loess and sand steppe fragments of the Pannonian forest steppe region (Szitár et al.), the intricate dynamics of urban green spaces (Fernandes et al., Gros et al.) or the emergent novel ecosystems such as green roofs or solar parks (Lambert et al., Rivière et al.), those ecosystems present both similar and own sets of challenges and opportunities for conservation, management and restoration. Preservation of large fragments, targeted management, and innovative restoration techniques offer pathways towards safeguarding the ecological integrity of natural and semi-natural grasslands.

Landscape complexity and configuration are key factors for the conservation of grassland biodiversity. Grassland fragments, in loess steppes and sand steppe fragments, exhibit diverse vegetation compositions influenced by the size of fragment and landscape connectivity (Szitár et al.). Both types of grasslands rely on the persistence of clonal perennial specialist and generalist species in small and isolated patches to mitigate fragmentation effects. These results are well in agreement with Deák et al. (2018), who found that generalist species were not affected but specialist species with a good dispersal strategy were the most affected by isolation via the lack of appropriate dispersal vectors in the landscape. Ewert et al. demonstrate for the first time the importance of European dry grassland fragments for bats under certain local and landscape compositional conditions in a heterogeneous agricultural region of Germany. By underlining the value of structurally heterogeneous dry grassland fragments acting as potential stepping-stones in intensively used farmland areas, they challenge the current management goals of dry grasslands, aiming to reduce shrub and tree encroachment. Besides, their results also highlight the necessity of connectivity networks in agricultural landscapes. To go further in the study of connectivity, Blight et al. explore how recent technological advances in movement ecology (passive RFID tags), make it possible to track the individual movements of three small ground-dwelling beetle species in a Mediterranean dry grassland. While the study highlight limitations of using passive tags to track the movements of small terrestrial beetles, it helps predicting the ability of species to recolonize degraded areas, enabling appropriate restoration actions to be designed based on landscape ecology principles.

Livestock grazing, that is used in conservation practice to mimic natural grazing regimes provided by wild large herbivores is also recognized as a major management driver of the composition of plant communities in natural and semi-natural grasslands. So far, very few studies have analyzed its impact on micro-scale patterns of biodiversity and vegetation dynamics. Martin et al. present the first overview of the multiple effects of grazing and soil characteristics on plant communities of micro-patterns at the micro-local scale in Mediterranean dry grasslands. They demonstrate that there is no one-size-fits-all strategy to influencing the trajectory of the plant communities and one of the main levers of restoration strategies, changing grazing pressure, may have contrasting effects depending on the community type. Moreover, Köhler et al. indicate how megaherbivore grazing, that aims to substitute extinct wild grazers, should be considered for restoration of temperate dry grassland. Year-round horse grazing as a relatively new grassland restoration tool has the potential to enhance floristic biodiversity of dry calcareous grasslands not only in the short, but also in the long term. Finally, Durbecq et al. demonstrate that, in mountain grasslands of the French Alps, initial grazing exclusion is not necessary for restoration success under current livestock density.

Restoration of European natural and semi-natural grasslands is a major challenge and face multiple questions relative to the diversity of techniques and to success monitoring. Sommer et al. show that long-term monitoring of restoration projects is necessary, as factors determining restoration success may only become evident in the long term. When restoring floodplain meadows with transfer of seed-containing plant material from species-rich donor sites, a widely used method to restore semi-natural grasslands, the positive effect of soil preparation on the number and cover of target species, which is regularly reported in short-term studies, diminishes over time, while the effects of local site conditions become more important. The importance of long-term monitoring is also confirmed in dry grassland where Köhler et al. reveal that short-term evaluation of restoration schemes can be misleading, particularly at slow-changing indicators such as dry calcareous vegetation types and slow-growing and long-lived species or those exhibiting high interannual population fluctuations such as many orchid species. Not only monitoring but also definitions of adequate restoration targets is important to promote restoration of grasslands in a changing world. Dellicour et al. show how restoration of hay meadows faces challenges in defining relevant reference ecosystems and adapting restoration techniques for the present-day ecological and socio-economic context.

Natural and semi-natural grassland restoration success is also under the control of a diversity of socio-environmental factors and requires fine-tuned methods adapted to the socio-economic context. Restoration efforts for degraded temperate lowland hay meadows show varying success rates, with techniques such as passive restoration mowing, active fresh hay transfer, and sowing of threshing material being implemented based on the initial level of degradation and proximity to well-preserved meadows (Dellicour et al.). Either abiotic, biotic and dispersal filters drive the limitation to recovery in Mediterranean dry grassland more than 40 years after an intermediate period of arable use (Jaunatre et al.). In afforested landscapes, tree removal, hay transfer and resumption of grazing or mowing are typical measures to re-create species-rich grasslands. The application of these restoration measures is effective in re-establishing target communities of different taxa (vascular plants and three insect taxa (leafhoppers, true bugs, and grasshoppers)) for German montane grasslands (Helbing et al.). Durbecq et al. highlight also the complex interactions among seed sowing, grazing regimes and soil disturbance on restoration success of mountain grasslands in the Southern French Alps. A strong grazing-by-soil disturbance interaction show that a combination of both is the best strategy to restore this grassland type.

In urban environment, landscape configuration, targeted management, and innovative restoration techniques are also key drivers for enhancing biodiversity of urban grassland. Gros et al. illustrate the importance of considering factors that act at both local and landscape scales when identifying the drivers of plant

communities in urban grasslands in Western France. Mowing practices and landscape composition do not affect the richness or diversity of plant species but significantly influence the composition of communities. Landscape composition favors plant species according to their strategies, preferential habitats, and life spans. Furthermore, diversification of management practices limits the establishment of non-native species and induces a wider range of functional strategies. Moreover, the application of seed mixes with regional native species allows the promotion of native flora in Mediterranean peri-urban green areas, enhancing the potential of these spaces as tools for biodiversity conservation and diminishing the risk of introducing exotic species with invasive ability (Fernandes et al.). In the Mediterranean context and given the small number of native seed mixes tested, this study represents an innovation and provides practical insights into grassland rehabilitation, contributing to the improvement of plant diversity management in peri-urban and urban Mediterranean areas.

Novel opportunities for grasslands such as green roofs and novel land uses such as solar parks, also offer opportunities to strengthen the ecological network for grassland biodiversity while not replacing historical natural and semi natural grasslands. Lambert et al. explore how the increasing construction of solar parks may provide an opportunity to restore or even create semi-natural grasslands. Solar parks allow the establishment of semi-natural grassland communities, but solar panels partially disintegrate the relationship between climate and plant species composition. Ecosystem services provided by soil organisms such as carbon storage, nutrient regulation, and soil conservation, are thus hampered by solar panels. The ecological integration of solar parks to favor the establishment of semi-natural grasslands needs to limit the effect of panels on plant communities and soil quality. In an urban area, Riviere et al. explore how extensive green roofs support native biodiversity analogous to natural or semi-natural habitats like grasslands, highlighting their potential for urban biodiversity enhancement. The study shows the importance of seed banks in the dynamics of green roof vegetation and demonstrates that native species on green roofs exhibit similar behavior as in their natural environment.

The Research Topic demonstrates that it is imperative to learn the lessons obtained from scientific studies as we stand at the crossroads of grasslands conservation and restoration in the Anthropocene. By embracing the complexity and diversity of European grasslands and drawing upon the wealth of knowledge generated by recent research, we can chart a course towards a more sustainable coexistence with nature. Through concerted efforts, informed decision-making, and a shared commitment to stewardship, we can ensure the resilience and vitality of European grasslands for future generations.

Author contributions

GM: Conceptualization, Writing – original draft, Writing – review & editing. PT: Conceptualization, Validation, Writing – review & editing. AB: Conceptualization, Validation, Writing – review & editing. KK: Validation, Writing – review & editing. TD: Conceptualization, Validation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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