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The cultural landscape "Rechnitzer Weingebirge" (Burgenland) as a Green Infrastructure site

Evaluation of the Green Infrastructure performance based on a functional assessment of landscape elements

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J.Bitsch

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ABSTRACT

Cultural landscapes can be valuable sites of a European Green Infrastructure (GI) network. Being multifunctional areas, they simultaneously benefit both the local wildlife and humans as they provide habitat for species, maintain natural processes and are agricultural areas that supply local communities with resources. In doing so, they can contribute to main political goals in Europe, such as stopping the ongoing loss of biodiversity, protecting healthy ecosystems and their functions and (re)connecting fragmented landscapes. Natural and semi-natural landscape features enhance the ecological quality of cultural landscapes and increase the landscape’s connectivity as well as its capacity to provide multiple ecosystem services (ES). The Rechnitzer Weingebirge, a small-structured cultural landscape at the Green Belt in Burgenland, was chosen as a study area for a functional assessment of the site’s GI value. The GI features that were recorded during a mapping of the landscape were used to evaluate the overall site performance. The study area was subdivided into four areas of investigation to depict different conditions within the cultural landscape. The GI features were assessed with regard to three key factors of GI; the level of naturalness, the degree of connectivity between GI features and the ES the GI features provided. It was shown that areas directly at the Green Belt differed from areas located farther away, in that they contained a larger number of GI features which, moreover, tended to have higher levels of naturalness and were better connected. In contrast, no clear differences between the four areas regarding the GI features’ capacity to provide ES were found. However, the overall high performance of the areas underlined the value of the cultural landscape as a GI site. Finally, an index of GI performance was developed that can be easily applied to evaluate the functional value of GI features for a specific area. Moreover, the index can be a useful tool to compare the performance of landscape features in similar sites as, for instance, cultural landscapes in other sections of the Green Belt.

ZUSAMMENFASSUNG

Kulturlandschaften können wertvolle Elemente eines Europäischen Grünen Infrastruktur (GI) Netzwerks sein. Als multifunktionale Gebiete erbringen sie zeitgleich wertvolle Leistungen für die Tierwelt als auch für Menschen. Sie stellen Habitate für bedrohte und seltene Arten zur Verfügung und in ihnen ist die Erhaltung natürliche Prozesse sowie eine Bewirtschaftung, die der lokalen Bevölkerung Ressourcen zur Verfügung stellt, gleichzeitig möglich. Somit tragen sie zur Erreichung wesentlicher politischer Ziele auf europäischer Ebene bei: den fortschreitenden Biodiversitätsverlust zu stoppen, gesunde Ökosysteme und deren Funktionen aufrechtzuerhalten und fragmentierte Landschaften in Europe (wieder) miteinander zu verbinden. Natürliche und halbnatürliche Landschaftselemente verbessern die ökologische Qualität von Kulturlandschaften, erhöhen den Grad der Vernetztheit der Landschaft sowie deren Fähigkeit, Ökosystemdienstleistungen (ÖSD) zu erbringen. Das Rechnitzer Weingebirge, eine klein-strukturierte Kulturlandschaft am Grünen Band im Burgenland, diente als Beispiel für die Evaluierung des funktionellen Wertes einzelner GI Elemente innerhalb des Gebietes. Die während einer Kartierung erhobenen GI Elemente wurden in vier verschiedenen Abschnitten des Gebietes auf Schlüsselkriterien der GI - die Natürlichkeit, die Vernetzung mit anderen Elementen und die erbrachten ÖSD - hin untersucht. In Übereinstimmung mit den formulierten Hypothesen konnte gezeigt werden, dass sich die Untersuchungsflächen am Grünen Band qualitativ von solchen in weiterer Entfernung vom Grünen Band unterschieden. Erstgenannte wiesen mehr GI Elemente auf, die zudem natürlicher und besser vernetzt waren. Insbesondere eine Fläche die nicht am Grünen Band, dafür aber in der Nähe intensiv genutzter Tieflagen lag, hatte eine niedrige GI Leistung. Ein Vergleich der erbrachten ÖDS konnte im Gegensatz dazu keine signifikanten Unterschiede zwischen den untersuchten Gebieten zeigen. Die im Allgemeinen hohe ökologische Qualität des Rechnitzer Weingebirges bestätigte seinen hohen Wert als Teil der regionalen GI. Abschließend wurde ein Index der GI Leistung erstellt. Angepasst an die lokalen Gegebenheiten kann dieser von Experten und Stakeholdern dazu genutzt werden, die GI Leistung einzelner Landschaftselemente zu ermitteln. Der Index kann zudem ein sinnvolles Instrument sein, um die GI Leistung von Landschaftselementen verschiedener Gebiete, zum Beispiel weiterer Kulturlandschaften am Grünen Band, miteinander zu vergleichen.

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Keynote of the author

Large areas of Europe are shaped by human activities (Tieskens et al. 2017) that changed the pristine character of the natural land. Pristine and wild areas that formerly stretched over large areas were thereby transformed and are presently reduced to decreasingly small areas. Landscapes are complex phenomena (Leader-Elliott et al. 2004) that represent the interactions between anthropogenic and natural processes that take place within these areas. The structure of landscapes reflects the techniques that were used to cultivate these lands for centuries (Tieskens et al. 2017; UNESCO World Heritage Centre n.d.). The protection of wild areas and native ecosystems are crucial to sustain natural processes. However, the heavy impact of present-day societies on ecosystems and their ability to recover, on wildlife, the climate system and more, calls for new strategies that create ways of sustainable living on Earth. Native landscapes combined with areas, where the human use of the landscape and the protection of natural processes can coexist and support each other, are needed. As such, cultural landscapes can be positive examples of practices that use the landscape as a resource, sustain ecological processes and the natural character of the landscape. This thesis focuses on positive examples of cultural landscapes, that support vital functions for wildlife as well as for human societies.

"It is clear that we are on a threshold of change in nature protection. There is a need to think multi-level and consider the integration of conservation into many other policies and sectors in order to achieve the new biodiversity 2020 goals" (Karhu 2011, p. 21).

"Working with nature and in harmony with the local landscape to deliver essential goods and services through GI projects, using a 'place-based' approach, is cost-effective and preserves the physical features and identity of the locality" (European Commission 2013, p. 3)[1].

[1] Source according to: Territorial Agenda of the European Union 2020. Towards an inclusive, smart and sustainable Europe of diverse Regions. Informal ministerial meeting of ministers responsible for spatial planning and territorial development. 19 May 2011, Hungary.

A | INTRODUCTION

1. Thematic framework

The loss of natural areas in Europe in the last century has led to a major decline in biodiversity (Van der Sluis et al. 2016), which caused profound changes on Earth that affected, and further will affect, the resilience of ecosystems. As such, the protection of ecosystems and natural areas are main tasks current and future societies need to deal with. Healthy and resilient ecosystem are our natural capital and the planet's "life insurance" (European Commission 2011, p. 1). They offer habitat for wildlife, they produce fresh air, clean water, food and energy. Intact natural systems are furthermore the basis of sustainable economic prosperity and a source for recreation and spiritual enrichment. Thus, healthy ecosystems and natural areas are necessities to human well-being and health (European Commission 2011; de Groot 2006).

A main threat for ecosystems is fragmentation: the separation and isolation of natural areas and their populations. Growing cities, enlarged road infrastructure and the conversion of natural into arable land causes a loss of connectivity between formerly continuous landscapes. Their capacity to provide habitat for wildlife and the increasing risk for populations is thereby dramatically reduced. Connectivity between habitats is especially important for species to adapt, for instance via migration, to changing environmental conditions like an increased pressure on ecosystems caused by climate change. The European Biodiversity Strategy[2] introduces Green Infrastructure (GI) as a tool to maintain ecosystem services (ES) and to restore degraded ecosystems (European Commission 2011a). Since 2013, a European strategy on GI[3] has provided a political framework to implement GI from the local to the multi-national level. The Natura 2000 network, that protects habitats and species based on the European Birds Directive (1979)[4] and the Habitats Directive (1992)[5], is supposed to serve as the backbone for the GI network (European Commission 2013).

[2] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Our life insurance, our natural capital: an EU biodiversity strategy to 2020

[3] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Green Infrastructure (GI) — Enhancing Europe's Natural Capital

[4] Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.

[5] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

Not only protected areas are important elements of the GI network; urban and rural areas also provide environmental features that contribute to the GI network. They enhance the quality of life for city inhabitants and for wildlife in human dominated areas. Establishing GI in cities is a way to especially improve single-purpose grey infrastructure by complementing it with green features like green roofs, that often provide sustainable and cheap technical solutions (European Commission 2013; Kirby & Russell 2015; Pakzad & Osmond 2016). GI is important to increase the connectivity between protected areas, which are the core areas of the GI network. Corridors are a crucial component in directly connecting protected areas. Furthermore, natural and semi-natural areas can create a transition between these core areas and the surrounding landscape, for instance by buffering them against intensively used farmland. Areas that are multifunctional, in the sense that they provide habitat functions, cultural functions and production functions at the same time, are of special importance for the GI network, because they equally fulfil needs of humans and wildlife. These functions are the basis for the multiple services, that ecosystems provide and that benefit human societies in many ways (Nature and biodiversity - Environment - European Commission; European Environment Agency & Schweiz 2011; de Groot 2006).

Urban GI and large networks of protected areas have been the target of extensive research lately, whereas rural areas, that cover large areas of Europe, have come to the forefront just recently. Almost all rural areas can be considered cultural landscapes, because they were altered by humans (Tieskens et al. 2017). Landscape structures in rural areas often represent changes in the ecology and the history of human interventions, that have shaped the natural processes and the physical appearance of the landscape (The Cultural Landscape Foundation; UNESCO World Heritage Centre n.d.). Landscapes are complex phenomena, that “reflect human activity and are imbued with cultural values”(Leader-Elliott et al. 2004). More specifically referred to as cultural landscapes, these types of landscapes are often in contrast to native landscapes (Benedict & McMahon 2006), which are less dominated by human interventions. Cultural landscapes comprise a large variety of different lands. They are usually heterogeneous and consist of a mosaic of other land use types (Turner et al. 2014). In the Rechnitzer Weingebirge, which was researched within this thesis, extensive practices were used to manage the land. Extensively managed cultural landscapes[6] are, in contrast to intensive agricultural lands, often characterized by smaller fields and a more diverse landscape structure. Field brushes, hedgerows and field margins improve the quality of the landscape for wildlife. These elements often disappear from intensive agricultural areas in the course of the cultivation of the land with heavy machinery. These landscapes have an especially high ecological value due to their richness in small landscape elements that can function as areas of refuge for wildlife (Helmholtz-Zentrum für

[6] An extensive agriculture is distinguished from an intensive use of the landscape by employing smaller amounts of labour and capital, and a lower input of fertilizers, herbicides and insecticides (Encyclopedia Britannica).

Umweltforschung GmbH n.d.; European Academies Science Advisory Council & Deutsche Akademie der Naturforscher Leopoldina 2015). As a site of GI, human dominated landscapes can provide many services to wildlife and humans, and thereby combine multiple purposes in one area. Cultural landscapes that are extensively managed are positive examples how the cultivation of land can be combined with the conservation of nature. Landscape functions and the benefits for human society are especially tangible in cultural landscapes, because people more directly interact with the landscape. To study cultural landscapes with regards to their potential as sites of GI, is crucial to raise awareness for their importance for a GI network (Tieskens et al. 2017).

An indicator to measure the ecological quality of an area is its "naturalness". Areas are considered natural when they are not measurably influenced by humans. Naturalness is "the quality of being natural" (Machado 2004, p. 95). It expresses the level to which processes occur naturally without anthropogenic influence. It is ranked from natural virgin to artificial (Machado 2004). In the context of nature conservation, the term naturalness is used in two ways: first, as a conservation value on its own and, second, as a parameter to describe the state of ecosystems. A ranking of the natural state of ecosystems is important. A ranking is still meaningful in assessing the value and developing management goals for an area, even though we only have limited knowledge about the complexity of interactions in ecosystems (Machado 2004).

2. A brief description of the Rechnitzer Weingebirge

The Rechnitzer Weingebirge, a small, hilly area in Burgenland, directly situated at the Austrian-Hungarian border, is a cultural landscape which represents main characteristics of an extensive land use. Meadows rich in species, hedgerows of shrubs and trees, field brushes, orchard meadows and vineyards alternate and form a mosaic-like landscape pattern. More intensively used areas, for instance pastures that are mowed several times per year, intensive and large vineyards, houses and gardens are also part of the cultural landscapes but are not the primary function in the Rechnitzer Weingebirge. Still a landscape that is dominated by continuous human activities, the landscape of the Rechnitzer is characterized by extensive land use, as compared to other agricultural areas. As a consequence, the Rechnitzer Weingebirge is a good example to illustrate that extensively used cultural landscapes are important GI sites. They are multifunctional areas that can provide small networks of natural and semi-natural features. They provide several ES for local communities. In my research, landscape elements with a high ecological value were selected and functionally assessed based on the key indicators of GI.

Several meadows in the Rechnitzer Weingebirge are known for their biodiversity and were honoured by the Naturschutzbund Österreich during a campaign called "NATUR VERBINDET". This campaign has the protection of Austrian cultural landscapes as a main goal (naturschutzbund Österreich). The land use practices in the area evolved over a long time and were adapted to the specific environmental conditions of the area. The steep slope in the upper part of the Rechnitzer Weingebirge prevented the usage of heavy machinery and required extensive cultivation techniques. A mixture of calcareous and siliceous soils, alternating wet and dry patches and a generally small humus layer further contributed to the fact that the Rechnitzer Weingebirge was never used for intensive agriculture.

The Rechnitzer Weingebirge furthermore plays a special role in the entire landscape setting due to its vicinity to the Green Belt. Military zones near the Green Belt, that were formerly in the Iron Curtain, were often spared from agricultural activities, acting as areas of refuge for wildlife. A generally lower intensity of disturbances often enabled natural processes to (re)develop which, in turn, formed a diverse landscape structure. The Green Belt very likely was a decisive factor that positively affected the landscape of the Rechnitzer Weingebirge, and specifically areas that directly border the corridor. Moreover, the cultural landscape can positively affect the conditions for wildlife and plants that find habitat in the Green Belt, because natural landscape elements like hedges and field brushes can increase the connectivity between the Green Belt and the adjacent areas. Furthermore, the cultural landscape buffers the Green Belt against areas that are dominated by more intensive land use practices.

The goal of this work is to use common methods, like a landscape mapping, that are widely used in the field of nature conservation, to assess the functional value of landscape elements in the Rechnitzer Weingebirge. An assessment scale based on the main indicators of GI is used to evaluate the potential of landscape elements of high ecological value that characterise the area. The value of the Rechnitzer Weingebirge as a GI site is measured, based on the performance of these elements.

3. Research questions and hypotheses

The functional assessment of landscape elements can provide insights into the value of a cultural landscape as a GI site. Even though the Rechnitzer Weingebirge is generally characterized by land use practices of low intensity and a small structured landscape pattern, there are likely to be differences concerning the ecological quality of landscape elements in different locations within the Rechnitzer Weingebirge (like previously indicated: distance from the Green Belt, different conditions for the cultivation of land).

The following research questions were posed:

1) Which land use types are crucial for a high performance of the Rechnitzer Weingebirge as a GI site? How can they be categorized as elements of GI (GI features)?

2) GI features of which functional group dominate in which areas? How do the areas at the Green Belt differ from those farther away relative to the coverage of GI features?

3) How do the GI features in the four areas differ with regards to their performance based on key indicators of GI (naturalness, connectivity and ES)? Is a combined index of all indicators a meaningful tool to depict GI performance?

The following map illustrates the main factors that affect different sections of the landscape in the area.

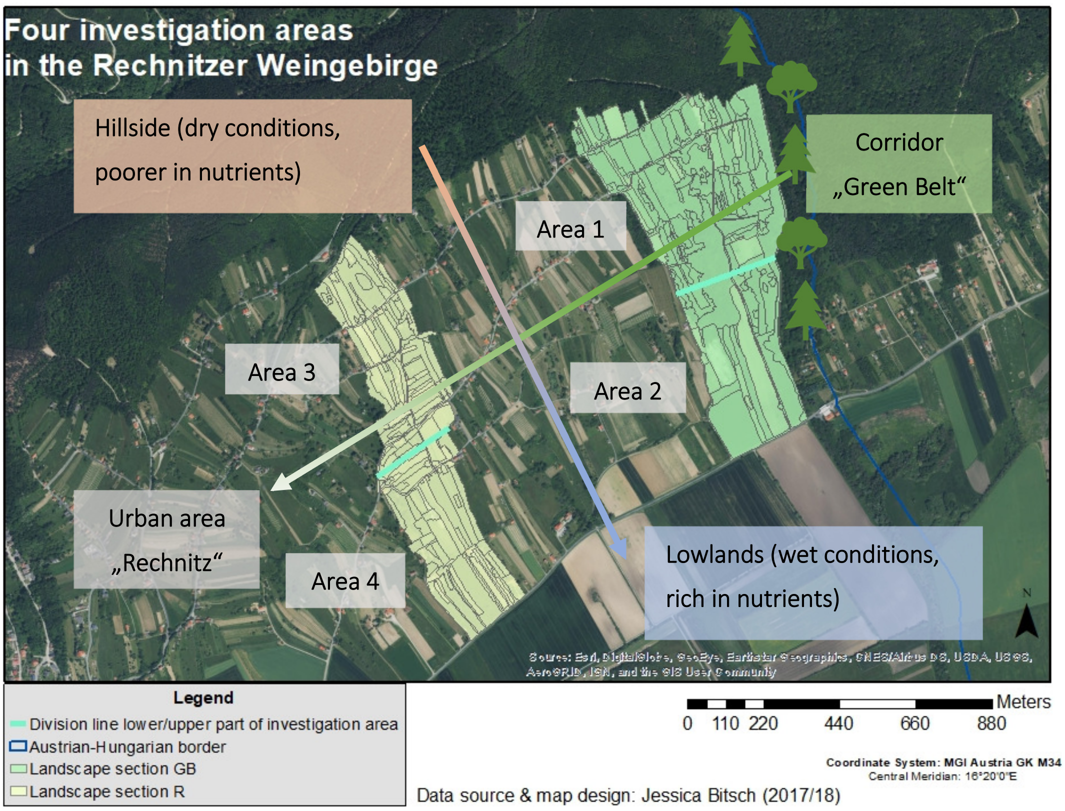


Figure 1: The four areas that were investigated in the Rechnitzer Weingebirge.

Area 1: at the Green Belt, upper part *(GB_upper):* the northern and eastern sides are bordered by forests, the western and southern sides are connected to the cultural landscape.

Area 2: at the Green Belt, lower part *(GB_lower):* the eastern side is mainly bordered by forest and partly bordered by gardens towards the lowlands, the western and northern sides border the cultural landscape, the southern border is the municipal road, separating the cultural landscape from intensively used agricultural fields.

Area 3: in the centre of the cultural landscape, upper part *(R_upper):* the northern border is forest, the southern, eastern and western borders are cultural landscape.

Area 4: in the centre of the cultural landscape, lower part *(R_lower):* the northern, eastern and western sides border the cultural landscape, the municipal road forms the southern border, followed by agricultural fields on the other side of the street.

With increasing distance from the Green Belt, intensive land uses are expected to increase likewise. Consequently, a decrease in the landscapes’ performance in terms of key factors of GI is expected in two directions:

1) from the Green Belt towards the city which is the western border of cultural landscape (indicated by the green arrow in figure 1)

2) from the forests at the northern border to the lowlands in the south of the cultural landscape (indicated by the blue arrow in figure 1)

Due to the Rechnitzer Weingebirge vicinity to the Green Belt and to forests at the northern border we expect to find a high number of extensive meadows, hedges and other landscape elements with a high level of naturalness in the areas closer to the Green Belt. At the same time, the higher abundance of extensive meadows leads to an increase in connectivity between these meadows. Moreover, the conservation management on meadows at the Green Belt is likely to maintain a high level of naturalness of landscape elements. Furthermore, a larger number of hedges and field brushes in areas close to the Green Belt creates a well-connected network of landscape elements with a high vegetation cover. Based on these effects, the areas at the Green Belt are supposed to be able to provide more ES compared to areas where landscape elements are less natural and less connected. In contrast, the usage of fertilizers and herbicides might affect the quality of areas close to intensive agriculture in the lowlands. Landscape elements in the lower parts of the Rechnitzer Weingebirge are easier to access and cultivate because they are less steep, that is why they are less natural and more fragmented. Furthermore, water and nutrients accumulate in the lower parts of the hill, thereby favouring rich pastures in contrast to the upper parts, where dry grasslands are more likely. However, the fact that small dry and wet patches are interspersed here and there indicate a heterogenous land use pattern due to the different types of vegetation occurring on them. GB_upper is likely to have the best results, because it is bordered by the Green Belt on the eastern side and by forests on the northern side. GB_lower and R_upper both should have a slightly lower GI performance compared to GB_upper, because only one side is bordered by forest. The strong positive impact of the Green Belt on GB_lower is probably reduced by impacts of the intensively used lowlands, whereas the lower side of R_upper is bordered by cultural landscape that buffers the area against the lowlands. It is further assumed that R_lower has the lowest GI performance because it is not connected to forest at all and is furthermore close to the intensively used lowlands.

4. Activities to promote Green Infrastructure in Europe

GI is a concept to support healthy and sustainable ways of living in cities and rural areas and, at the same time, to connect green areas in the form of a network, including a variety of protected areas and environmental features: “Green Infrastructure takes a natural approach, where interdependent elements support each other to ensure long-term sustainability. It shows us how to avoid the overexploitation of natural resources, and how to manage and use ecosystems to serve economic, social and nature conservational purposes at the same time in a balanced way“ (Karhu 2011, p. 8). GI gained fast growing attention during the last decade as a strategic tool for conservation management and a literature on GI in different contexts was published (Kirby & Russell 2015; Karhu 2011b). The book “Green Infrastructure: Linking Landscapes and Communities” by Benedict and McMahon, was published in 2006 and is considered a pioneer work in the field of GI in the United States. It presents GI as a new, holistic and strategic approach in conservation and suggests main principles to design GI (Benedict & McMahon 2006). Case studies could give first insights into implementation tools and indicators to measure GI performance. Especially as GI gained importance as cost-effective alternatives to monofunctional grey infrastructure in cities, particular indicator sets to measure performance of urban GI have been developed (Pakzad & Osmond 2016).

The conception of a network of multifunctional areas is influenced by various disciplines and is moreover a transdisciplinary approach, integrating the perspectives of practitioners from different countries. As a result, GI-related terminology is differently used, depending on the disciplinary and spatial context. With the European GI Strategy, launched in 2013, the European Commission offered a political framework to facilitate a clear communication of GI and coherent implementation processes in Europe (European Commission 2013). Besides forwarding a working definition of GI, the strategy proposed the establishment of a financial support systems that should facilitate processes to implement GI at different scales. The identification of areas with a high value for the GI network and the analysis of existing gaps in the current network are further activities that are fostered by the EU to promote a coherent network of GI (Jantke et al. 2011; European Commission 2013).

Since GI became more popular as a tool to improve the infrastructure in cities and rural areas, many projects of different size and with different aims depending on the local setting and management goals were launched (Karhu 2011). These projects use a wide array of natural and artificial features, that complement GI on a European, national, regional or local scale. For a coherent management of the GI network (European Commission 2013), which’s importance was highlighted in the EU GI Strategy, schemes and guidelines need to be developed to bundle the large variety of different implementation strategies and understandings of GI. Planning guides and training manuals for practitioners were developed to support these processes (Davies et al. 2006; Civic & Siuta 2014). In addition, so called “knowledge hubs” – one of them the CEEweb for biodiversity and the ECNC being the other - work at the interface of political institutions, science and practice to stimulate the communication between different stakeholders (ECNC; CEEweb for Biodiversity; Civic & Siuta 2014; CEEweb for Biodivesity & ECNC 2013).

The European Green Belt is probably the most well-known initiative in the field of GI and transboundary nature conservation in Europe. The Green Belt does not only connect natural areas from the Barents Sea to most southern parts of Europe, is also reconnects cultures that were formerly parted by the Iron Curtain during the Cold War. In contrast to large natural areas in the Scandinavian parts of the Green Belt, Central Europe is dominated by cultural landscapes (European Green Belt Association e.V.). Hence, cultural landscapes are, on the one hand, part of the Green Belt. On the other hand, they can support the protection of the corridor in that they buffer the corridor from impacts of intensively used lands.

The management of green areas should encompass efforts to increase the performance of the sites for a European GI network. For that, easy and suitable tools are needed to assess the functional value of already exiting landscape structures and elements that favour the GI performance of a site, complemented by instruments to increase the performance of a site. The goal of the project MaGICLandscapes, the University of Vienna in cooperation with further project partners, is to develop strategies and elaborate action plans to enhance existing resources of GI in Central Europe. The promotion of sustainable land use and the provision of local experts in different case study areas with tools are main fields of work of the project (Interreg CENTRAL EUROPE Programme).

B | THEORETICAL BACKGROUND

1. Green Infrastructure

1.1. A network of Green Infrastructure for Europe

Healthy ecosystems and their life-supporting services like the provision of habitat for wildlife or the production of oxygen, soils or products like wood and crops are crucial for life on earth. In order to conserve biodiversity, which is the product of as well as the basis for healthy ecosystem processes is in strong decline on a global scale. Hence, the European Biodiversity Strategy has set a target of maintaining and enhancing ecosystems and their services by 2020. In the strategy, GI is proposed as an instrument to restore degraded ecosystems: a minimum of 15 % of degraded ecosystems need to be restored (European Commission 2011b). Furthermore, by connecting green areas into a network, fragmentation which is one of the main driving factors for the loss of biodiversity, can be counteracted. A GI network is “a physical network that links conservation areas and other types of open spaces to maximize the natural functions of the landscape and protect the species that live there; often, green infrastructure networks also provide diverse benefits and services to people and communities” (Benedict & McMahon 2006, p. 282). In the European GI strategy, GI is defined as

> *“a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. […] It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas” (European Commission 2013, p. 3).*

The definition gives focus to the natural and semi-natural character of important areas for the GI network. These areas are connected with further environmental features, like green bridges or restored sites, so that exchange processes between different elements can take place. Such a network is further supposed to deliver a variety of ES. GI areas, often described as multifunctional areas, conflate different land uses in one area, thereby fulfilling multiple purposes at the same time. The fact that GI recognises the value of natural areas for healthy ecosystems and the human well-being makes a powerful communication tool out of the approach, by the help of which the awareness to protect natural areas and processes can be raised. Therefore, the EU GI Strategy emphasizes the importance of an integrated view of ES for a balanced approach to implement GI (European Commission 2013).

The multifunctional nature of rural areas underlines that a high ecological quality and the use of landscapes as natural resources must not be diametrically opposed (CEEweb for Biodivesity & ECNC 2013; Liquete et al. 2015). A network of protected areas and urban green areas as elements of GI is complemented by multifunctional rural areas, where the ways to use the land define the areas functionality as a GI site. Landscapes which are shaped by human interventions can be more precisely referred to as cultural landscapes (UNESCO World Heritage Centre n.d.; Tieskens et al. 2017; The Cultural Landscape Foundation n.d.). Not only protected areas, but also cultural landscapes have the potential to provide vital services for nature, wildlife and people (Benedict & McMahon 2006). Cultural landscapes, with landscape structures that are often represented by a juxtaposition of intensively and less intensively (in the following referred to as "extensively") lands, can provide natural landscape elements that function as habitat or stepping stones within the broader landscape matrix.

A main goal which is mentioned in the European GI Strategy is to maintain and enhance the connectivity for species of European importance, with a special focus on Natura 2000 areas (European Commission 2013). Connectivity means "the creation of functionally contiguous blocks of land or water through linkage of similar ecosystems or native landscapes; the linkage of trails, communities, and other human features" (Benedict & McMahon 2006, p. 280). Efforts to increase the connectivity between elements of the GI network can be put into practice at different scales: large, transnational corridors that connect protected areas, green bridges that enable species to cross motorways and a system of hedges that pulls through areas dominated by agricultural fields are all examples of the successful implementation of GI.

There are manifold approaches to implement GI at a European, national, regional or local scale. Naumann et al. developed a typology to classify different projects of GI in Europe. In the following table, their main findings are summarized and complemented by a characterization of GI initiatives throughout the world by Roe and Mell (Benedict & McMahon 2006; Roe & Mell 2013; Naumann et al. 2011).

Table 1: Summary of the main characteristics of GI projects in Europe.

Characteristics	Implementation
Variety of GI elements	- Core areas (especially Natura 2000) - Healthy ecosystems (outside Natura 2000 areas) - Natural and artificial connectivity features - Restoration zones - Landscapes with focus on the provision of ES
Integrated landscape planning	- Consideration of the (biological and physical) context of the ecosystem - Cooperation of stakeholders that are involved in the project
Connectivity	- Provision of links between local or regional GI elements

	- Connectivity between (specific) Natura 2000 sites - Analysis of needs concerning habitat connectivity of target species
Multifunctionality	- Analysis and enhancement of ES - Focus on creation of multifunctional landscapes - Support of local biodiversity and ecosystem resilience with GI elements - Cost-effectiveness of GI compared to grey infrastructure
Prioritisation of GI	- Integration of the GI concept into regional development plans - Protection of GI is prioritized over development goals
Holistic approach	- Flexibility of the GI concept allows implementation on different scales - Linking of single GI elements into a local or regional network - Awareness for human-nature-interactions in landscapes - Consideration of ES trade-offs
Scientific basis	- GI planning includes robust knowledge from various fields like landscape ecology and spatial planning
Partnership approach	- Integration of local stakeholders - Common planning process - Community-based solutions
Different scales	- Strategic considerations of national and regional GI networks - Site based importance
Long-term orientation	- Cost-effectiveness of GI compared to grey infrastructure Management as integral part of the area and strategic approach over time - Protection of local ES and healthy ecosystems

GI, a concept and even more a practical tool, can be applied on various scales, from local to international (Van der Sluis et al. 2016; Naumann et al. 2011; Karhu 2011b). The concept’s suitability for a broad application is its strength and a huge challenge at the same time: the higher the number of involved stakeholders and projects with a specific background get, the more complex becomes a coherent management of the network. The existing projects are often lacking spatial coherence and the prioritized species or habitats are often determined on a national level. The realization of a trans-European network of GI depends on the ecological knowledge, the coordination of political frameworks and measures on a superordinate level and an effective sectoral cooperation (Van der Sluis et al. 2016).

1.2. Network design and Green Infrastructure elements at different scales

Figure 2 shows the continuum between GI in urban and rural settings and indicates the implementation practices of GI at different scales. To focus on the spatial attributes of landscapes is the basis for land use planning and consequently for planning activities related to the construction of GI networks (Allen 2012). Whereas in urban settings, measures that improve the living conditions of city inhabitants by improving the functionality of grey infrastructure are of prime importance, GI elements in rural areas mainly provide habitat for species, increase the connectivity of ecological networks for instance with wildlife corridors create landscapes with working structures that allow for a multifunctional use of the landscape.

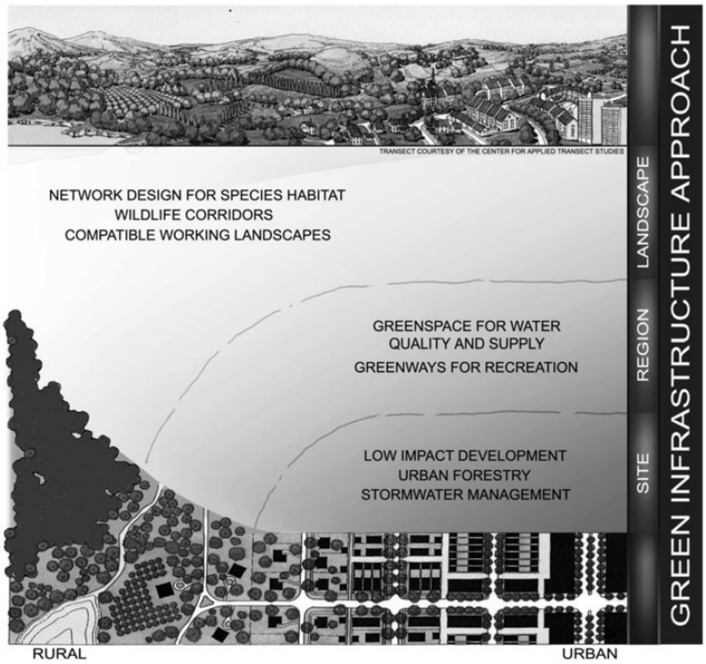


Figure 2: GI measures in the continuum from rural to urban areas of GI on the level of sites, regions and landscapes (Allen 2012).

A network of GI integrates urban and rural areas, native and restored ecosystems, small and large, natural and artificially constructed elements into one network. These elements are classified into main components. Hubs are often large elements, including core areas of GI like reserves but also natural and semi-natural areas and smaller habitats. The core areas, the central elements of the network, contain natural ecosystems and habitats of high quality. Hubs protect ecological processes and natural landscape elements. Basically, hubs should be large enough to provide for local species populations and function as a source for the emigration of species to landscape elements in the surrounding. Hubs can considerably vary in form and size, ranging from large reserves to restored sites or community parks. The connectivity between hubs is maintained by links, e.g. large corridors or smaller wildlife passages. Sites, smaller than hubs, contribute to the ecological and social functions on a regional and local level. They do not necessarily be attached to the network. Still, sites are crucial for

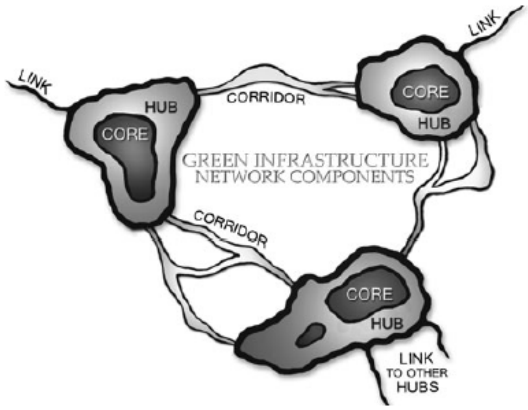


Figure 3: Elements of a GI network (Allen 2012).

protecting wildlife and habitats and are especially important for environmental education and a nature-based recreation (Benedict & McMahon 2006; Allen 2012).

Hubs, the building block of the GI network, maintain ecological functions and therefore need to fulfil specific criteria: they should be the least-fragmented and largest elements of an especially high ecological quality. Their minimum size depends on already established protected areas, on the remaining open space and the occurrence of rare, threatened and endangered species. If possible, hubs should be complete units with smooth borders. It cannot be avoided that smaller, human dominated areas create "gaps" within hubs or between them, hence, these areas should be the target of restoration activities. Hubs should furthermore represent the natural patterns of the area and provide adequate starting and ending points for landscape links. Planners should consider that primarily similar ecosystems should be connected, and that links can also create ecological traps, if large and pristine hubs are linked to smaller and degraded hubs without enough habitat for species. Besides, not only the dispersal of target species but also the one of invasive species can be facilitated when links between hubs are established (Benedict & McMahon 2006).

Corridors can be migration zones and habitats at the same time. Traditionally, the term "corridor" was mainly used to describe large wildlife passages, but in the context of GI links can likewise include smaller landscape elements like hedges, field brushes and many more (Helmholtz-Zentrum für Umweltforschung GmbH). Hedges or overgrown fences can function as guiding elements for species in a landscape; furthermore they enhance the aesthetic value of the landscape and help to maintain the capacity of the ecosystem to provide ES (Drobnik et al. 2013).

1.3. Natura 2000: "backbone" for a trans-European Green Infrastructure network

The Natura 2000 network is referred to as "the backbone" of the GI network in the EU GI Strategy (European Commission 2013). At present, the Natura 2000 network covers 18 % of the land surface of the European Union (EU) (Van der Sluis et al. 2016). At Natura 2000 sites, the two main European Directives in the field of nature conservation, namely the Habitats Directive (1992) and the Birds Directive (1979), are put into practice, and populations of rare and threatened habitats and species protected. Natura 2000 sites are considered core areas for the GI network. Natura 2000 sites are getting more and more isolated due to the fragmentation of landscapes. A network of GI can help to reconnect these core areas (European Commission 2013) and to integrate Natura 2000 sites into the surrounding landscapes. Cultural landscapes can be part of Natura 2000 areas. Zones of land uses with low inputs of fertilizers, herbicides and general a lower rate of disturbances can buffer natural and protected zones. Landscape elements that have a high natural state can enhance the ecological quality of cultural landscapes and the presence of presence of connectivity features increase the permeability of the landscape matrix, thereby increases the possibility for species to have healthy population in landscapes mainly used by humans.

Moreover, areas outside of the Natura 2000 network, especially cultural landscapes that cover large areas of Europe, need to be integrated into the trans-European GI network (Karhu 2011; Helmholtz-Zentrum für Umweltforschung GmbH). The GI network can be considered an "add on" to the Natura 2000 network. To incorporate Natura 2000 areas and multifunctional landscapes into one network is seen as a new conservation vision for the 21th century (Benedict & McMahon 2006; Karhu 2011).

1.4. Approaches to identify and assess European Green Infrastructure

Green spaces like parks, greenways and other types of undeveloped and open spaces, can preserve valuable ecological functions and benefit human societies (Benedict & McMahon 2006). However, their contribution to the GI network differs with respect to the functionality and ecological value of the green area. The need to assess and categorize green areas according to their GI functionality is widely recognized. Clear evaluation schemes are essential for planning and decision-making processes. Apart from the present land use patterns, possible future land use changes must be taken into consideration for an evaluation of potential green areas to conserve habitats for wildlife and to provide multiple ES (Benedict & McMahon 2006; Liquete et al. 2015).

Liquete et al. introduce an approach for a pan-European study in order to identify and map potential GI areas. The authors propose an identification of relevant ES and key species or functional groups for an indicator-based assessment. Core habitats for these species' groups are mapped and a connectivity analysis performed subsequently. In this way, potential corridors for wildlife can be identified. In the case of ES, only regulating and maintenance ES were selected to ensure that the main target of GI, to protect elementary landscape functions as basis of biodiversity, is ensured. The results, both of the mapping of ES and core areas, are normalized in order to be transferable into a common evaluation scheme. Subsequently, the identified GI areas are classified according to the developed scheme and ordered into a core (areas with high values) and a subsidiary (areas with moderate values) GI network. Areas in the subsidiary network are target of future restoration measures to improve their capacity to provide valuable ecological functions (Liquete et al. 2015). The described method can also be used to identify and assess GI elements on the regional or local scale. By selecting local target species and relevant ES, the indicators can be tailored to the needs and conditions within a specific area. Local experts can further define suitable thresholds for a regional core and a subsidiary GI network (Liquete et al. 2015).

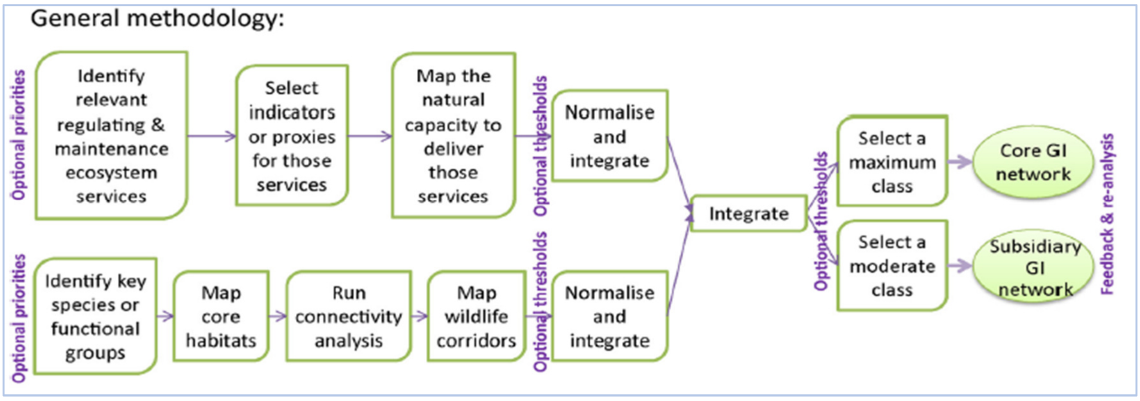


Figure 4: Methodology to identify valuable sites of GI (Liquete et al. 2015).

The previously introduced methodological approach reflects the multifunctional nature of the GI network: the provision of ES and the provision of habitats of high quality for wildlife are both important factors that define the quality of GI sites. The development of significant indicators is an iterative process including practical expert knowledge, scientific knowledge as well as legal and political parameters[7]. The varying understanding of GI, which stills prevails in different European countries despite of communication efforts, as well as significant differences in size, design and priorities of GI projects influenced by economic, political and ecological conditions, complicate the development of universally applicable methods to assess the GI performance of areas. The following list gives a rough perspective of certain aspects that determine the performance of a GI site (personally adjusted after Benedict et al. 2006):

- Larger areas are to be preferred over small areas as habitat provision often increases with area
- Existing high diversity of species and habitats is an important basis for healthy ecosystems
- The site is a natural area or includes natural and semi-natural landscape elements which are the basis for the capacity of the landscape to provide vital services
- If not natural, the site has potential to be restored or ecologically enhancement
- Natural communities are represented at the site
- Rare/fragile landscape elements and species that should be protected occur on the site
- The site represents typical regional biocoenosis
- Data (historical and recent) on species and habitats is available
- The site is connected with the surrounding landscape
- Conspicuous elements that can create overall appreciation for nature conservation in the region are present on the site

[7] A sustainability indicator set to measure GI performance in urban areas was developed by Pakzad & Osmond 2016.

2. Landscape functions and services

2.1. Landscapes and ecological networks

A landscapes is "a mosaic of ecosystems or land uses that possess common attributes that are repeated across a large area" (Benedict & McMahon 2006). Thereby, the definition of a landscape already incorporates the idea, that humans, to a strong degree, shape native natural areas. Opposed to landscapes that have been altered for human use, native landscapes describe areas, where protected, managed and restored native ecosystems can interact naturally and thereby is characterized by natural functions of the land (Benedict & McMahon 2006, p. 283). The work of Forman and Gordon (Forman et al. 1988), which was fundamental for landscape ecology, classified the elements that exist within a landscape into "patches", "corridors" and the "matrix". A patch is a small, compact, either simple or complex habitat, that, concerning resources, disturbances or age, differs from the surrounding landscape. Corridors are linear elements which can have a connecting as well as a fragmenting effect on the landscape. They function as habitats, conduits, filters for organisms and material flow, they are source and sink likewise. The matrix forms the landscape background and thus is generally good connected. The length and shape of boundaries and the porosity of the landscape matrix are the main determinants for its functionality (Wrbka et al. 2003).

The previously defined landscape elements are the smallest functional and structural entities that can be distinguished within a landscape. Their functionality strongly affects the overall ecological quality of a landscape. An unequal distribution of resources, either caused by natural disturbances or anthropogenic activities like cultivation, often leads to spatially heterogeneous landscapes. Landscapes that are dominated by human land use mostly show a mosaic-like pattern and the existing landscape elements mostly have sharp boundaries, whereas in natural systems, landscape elements are arranged in a gradient-like pattern, sharp and soft boundaries included (Wrbka et al. 2003). Disturbance is defined as the (total) deprivation of biomass either caused by natural incidences or by anthropogenic activities. The strength and the periodicity of the disturbances strongly impacts the ecological quality of the landscape. When singular disturbance incidences (e.g. wind breaks) occur, the succession that starts subsequently, generates intermediate landscape elements, that are replaced by elements of a higher succession level after a short time. These landscapes are characterized by a dynamic change of the dominant vegetation. In contrast, if disturbances occur periodically, highly persistent landscape elements are created, because succession processes are repeatedly interrupted. Different disturbance qualities thus lead to a selection of those species, that can adapt to the present disturbance regime (Wrbka et al. 2003). Single GI features can be important stepping stones and habitats in a landscape matrix with periodic disturbances.

The design of ecological networks is primarily determined by species-specific factors such as mobility, areal requirements, landscape structure change and land use intensity. These networks are majorly important for habitat specialists and mobile species with a big areal need (Van der Sluis et al. 2016). In Europe, different strategies to protect ecological networks by the help of environmental planning were established. Western European countries aimed at the establishment of ecostabilizing[8] functions, whereas the protection of special valuable sites and threatened species were addresses in Central Eastern Europe. As a consequence, a trans-European network of GI needs to deal with very different conditions and designs of ecological networks: “this diversity also implies that exchanges are needed on the variety of contexts in which the ecological greenway networks are developed: the diversity of socio-economic contexts, different cultures, and perceptions of nature” (Jongman et al. 2004, p. 316).

The two main functional aspects of landscapes are the connectivity, the capacity of the landscape to connect sub-populations of a metapopulation, and the connectedness, that is the structural linkage between landscape elements. Both are the main driving factors for dispersal and persistence of species in a landscape (Jongman et al. 2004). Furthermore, a variety of indicators exists: for instance, keystone species (key stone species fundamentally define the nature of an ecosystem, their absence would lead to dramatical changes in the ecosystem) or indicator species (these species are especially sensitive to environmental changes and give early warnings when the quality of the ecosystem is negatively affected) (National Geographic Society 2017) can be used to describe ecological networks. Further factors that influence ecological networks are the rate of anthropogenic disturbance and the presence or absence of invasive species. What unifies more pro-active and restrictive strategies to maintain and develop ecological networks is the concept of ”multipurpose” natural areas within the networks (Jongman et al. 2004). Thereby, the conception of ecological networks can be seen as a precursor for the multifunctional character of a GI network in Europe.

2.2. Structural and functional connectivity

Connectivity refers to the capacity of the landscape matrix to facilitate species movement processes. A connected landscape, in the sense of GI, is the opposite of fragmentation. The better connected a landscape, the less vulnerable it is in matters of natural and human disturbances (Benedict & McMahon 2006). As a rule, the more alike the landscape matrix is to the structures in the habitat the more the connectivity within these landscapes is facilitated. The availability of

[8] The “ecostabilisation principle” is a holistic concept developed by Rodoman that came up in the 1970ies. Rodoman’s concept is a functional zoning of landscape elements into natural zones and zones of intensive land use. The natural zones on the one hand and restoration zones as well as intensively used zones (agriculture, industry, urban areas) on the other hand should be strictly delimitated. All natural zones were to be united into one coherent network (Jongman et al. 2004).

so-called microhabitats that resemble main habitat characteristics increase the permeability of the matrix, especially for species that are low mobile. To connect open spaces with forest habitats, a mosaic like combination of habitat, resembling patches, can be used in half-open corridors (Kreutz et al.).

In behavioural ecology, the behaviour of a species is the link between species related processes like species movement or resource exploitation and present landscape patterns. Connectivity of landscape elements that are crucial for a species group is an indicator for the degree to which "a landscape facilitates or impedes movement along resource patches" (Taylor et al. 1993, p. 571) and is referred to as functional connectivity. The former is to be distinguished from structural connectivity, which is the physical contiguousness of landscape elements (Bélisle 2005).

Effective strategies to maintain the connectivity between habitat patches are specific for different species, especially depending on their mobility. Less mobile species need local connectivity structures and larger patch sizes. Species of medium mobility (e.g. butterflies) have a stronger need for a permeable landscape matrix on a regional a national level. For highly mobile species like birds the provision of qualitative core zones on an international scale might be sufficient. Thus, it is necessary to address connectivity on different scales – from (inter)national to regional to local scale (Drobnik et al. 2013). To increase the connectivity of patches is a demanding management goal: the establishment of corridors that structurally connect habitat of one species can lead to fragmentation of the habitat of another species due to different habitat requirements. For instance, habitat of open-land species might get fragmented by the creation of a corridor for forest species (Aßmann et al. 2011).

Besides a decrease in habitat size or the complete extinction of habitats, changes of land use patterns in the surrounding area lead to landscape fragmentation. Due to a general intensification of land use practices, species-rich lowland and mountain hay meadows were converted into pasture. The use of machines is another reason for a lower functional connectivity especially for plant communities, because livestock formerly distributed diaspora during grazing. The quality of the landscape matrix is an important factor for the functional connectivity between habitats of species: a landscape matrix that is permeable facilitates the movement of species between different landscape elements (Benedict & McMahon 2006).

In the context of a GI network, connectivity can be addressed differently on a local or a national scale. On a broader scale, corridors connect core areas of the GI network. On a smaller scale, the existence of natural and anthropogenic connectivity feature in a landscape can contribute to the establishment of a small-scale network of GI. Thereby connectivity refers more to the permeability of the landscape matrix created by connectivity features.

2.3. Multifunctionality and ecosystem services

Ecosystems and the natural and semi-natural landscapes that support natural processes deliver a wide range of goods and services. As multifunctional landscapes, they are often referred to as our “natural capital” (de Groot 2006, p. 175). Therefore, the maintenance and enhancement of the capacity of ecosystems to provide services is a main goal within the Biodiversity Strategy (European Commission 2011b). In the context of GI, the term “multifunctionality” is often used to describe the capacity of landscapes to provide multiple ES at the same time. The concepts of multifunctionality and ES (and ES bundles[9]) are closely related, though not identical. Research in the field of ES and GI apply “functions” and “services” differently, whereby GI functions often include specific ES (Hansen & Pauleit 2014).

Table 2: Multifunctionality and the relationship to the ES concept.

Characteristics	Multifunctionality	ES bundles	ES synergies & trade-offs
Spatial coincidence of ES	Yes	Yes	Not essential
Temporal synchronicity of ES	Yes	Yes	Not essential
Causal interrelationship between ES	Not necessary	Not necessary	Essential
Potential vs actual ES delivery	Potential	Potential	Actual

The concept of ES stresses the benefits humans derive by natural processes in ecosystems. Thereby ES also reflect the interactions between the natural and anthropogenic sphere. The assessment of the provided ES in an areas is important but not sufficient to comprehensively estimate the areas value for the GI network (Lele et al. 2013). Multifunctionality describes “the characteristic of ecosystems to simultaneous perform multiple functions, that might be able to provide a particular ES bundle or bundles” (Berry et al. 2016, p. 1). Multifunctionality especially contrasts with monofunctional grey infrastructure, e.g. streets, buildings without green roofs. Multifunctionality is further characterised by the fact that conservation goals and economic considerations can be aligned. Even though the (economic) benefits of ES are useful to raise awareness for the importance of the protection of multifunctional GI, research indicates that enhancing ES must go along with the protection of biological processes. Exclusive emphasise on benefits of ES for humans ignores the intrinsic value of ecosystems and the fact that healthy ecosystems are the basis for our lives (Mouchet et al. 2014; Salomaa et al. 2017; Berry et al. 2016).

[9] ES bundles are “a set of associated ecosystem services that are linked to a given ecosystem and that usually appear together repeatedly in time and/or space” (Berry et al. 2016).

To ensure the contribution of GI to the goals of the Biodiversity Strategy, ES that have high synergies with biodiversity enhancement need to be in the centre of attention and the landscapes capacity to deliver these services ensured (Salomaa et al. 2017). The provision of ES is used as an indicator to assess the multifunctional value of GI (Csaplovics 2018).

The following graphic illustrates the interactions between agriculture, management of the wider landscape and ecosystem services.

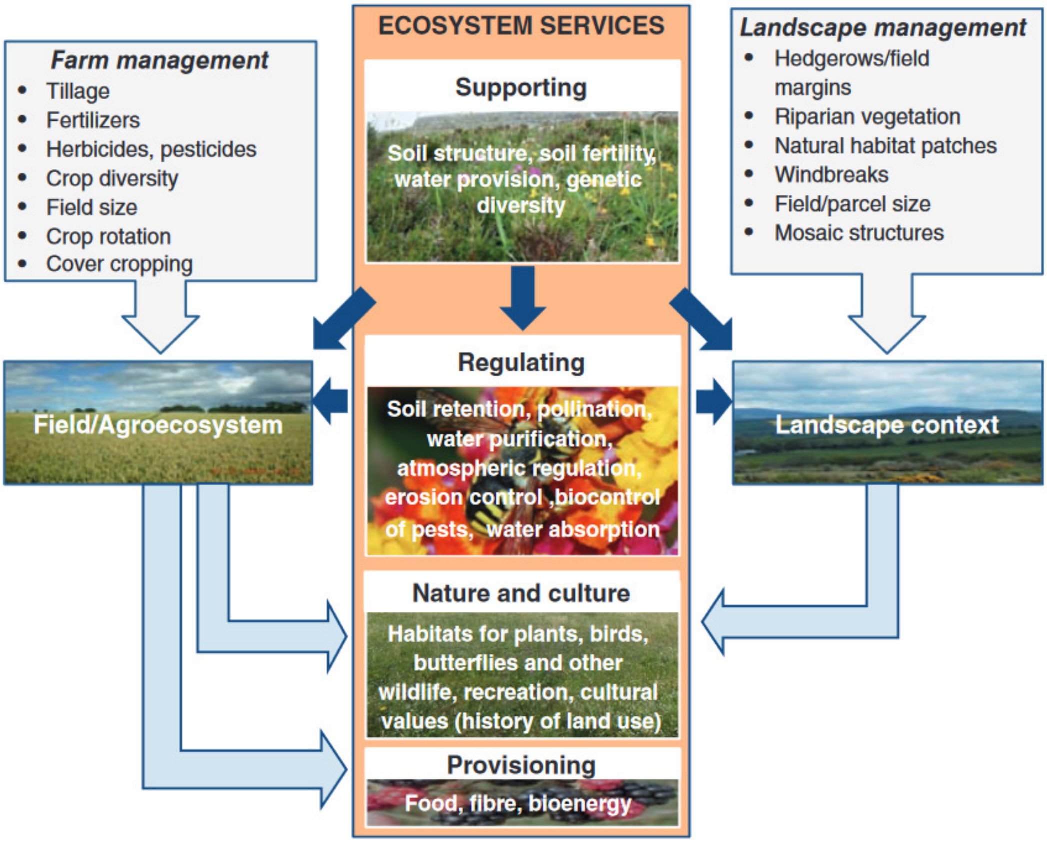


Figure 5: Interactions between agriculture, management of the wider landscape and ecosystem services, adapted from Power 2010, Aisbett and Kragt 2010 (European Academies Science Advisory Council & Deutsche Akademie der Naturforscher Leopoldina 2015).

3. Cultural landscapes: potential sites of Green Infrastructure?

3.1. The value of multifunctional landscapes for a Green infrastructure network

Cultural landscapes are the product of human exploitation of landscapes and thereby a reflection of human-nature interactions that took place for centuries. According to UNESCO, cultural landscapes are “combined works of nature and humankind, they express a long and intimate relationship between peoples and their natural environment” (UNESCO World Heritage Centre n.d.) and are representative for different regions of the world. Some reflect specific techniques that were used to cultivate and shape the land that sustained and conserved biological diversity (UNESCO World Heritage Centre n.d.). Although UNESCO applies the term cultural landscapes to outstanding examples of “the creative genius, social development and the imaginative and spiritual vitality of humanity”[10] (UNESCO World Heritage Centre n.d.), all cultural landscapes express the history of human use of the landscape. The term describes the process of turning wild nature into arable land that is mainly used to produce different resources. The distinction of “nature” and “cultural landscapes” on a linguistic level was accompanied by a separation in thought and in actions of the ostensible diametrical processes of “protecting nature” and “using nature”. Nowadays, there is still a different perception of protected areas and areas where human land use is dominant (Schuster & Bayerische Akademie für Naturschutz und Landschaftspflege 2008).

In the context of cultural landscapes, the human use of the landscape is the prerequisite for their existence. However, less intensified landscapes still conserve landscape elements, that enhance the landscapes’ quality and habitats within these landscapes (Helmholtz-Zentrum für Umweltforschung GmbH – UFZ 2016). Because in cultural landscapes the extensive exploitation of natural resources and the preservation of natural landscape elements do not contradict each other, cultural landscapes are examples of the synergetic effects of the use and the protection of land. As such, they complement strict conservation measures in protected areas. The multifunctional nature of cultural landscapes fundamentally supports their importance as elements of a GI network.

Cultural landscapes that are close to natural ecosystems are highly complex systems. Natural processes themselves are interconnected in many ways, often challenging science and the human understanding in general of the underlying processes and functionalities. When human interactions come into play, dynamics get even more diverse and are therefore hard to keep track

[10] Currently, 102 properties on the World Heritage List have been nominated as cultural landscapes (UNESCO World Heritage Centre n.d.).

with. Natural cultural landscapes as culmination of complexity and dynamics are highly challenging objects for ecological research (Hochegger & Aschenbrenner 1999).

3.2. Factors that influence the quality of habitats for wildlife in cultural landscapes

In landscapes that are dominated by a mosaic-like landscape pattern, habitat boundaries are abundant and affect the habitat quality gradually from the centre to the edge of a habitat patch. How species respond to these habitat edges – gradual versus abrupt, avoidance versus matrix penetration – is imperative for understanding animal movement, species persistence and community structures in fragmented landscapes (Pe’er et al. 2011).

The structural configuration of a landscape has a strong impact on the local biodiversity and the structure of species communities. Whereas the presence of species is notably determined by habitat quality, the structure of the surrounding landscape has strong influence on the species diversity within a patch (“matrix-effect”) (Dauber et al. 2003). Dauber et al. showed that variations in species richness on patches with different land uses, e.g. arable land and fallow land, could not sufficiently be explained by internal factors; for instance, the habitat quality. In a study with 20 plots of grassland with different land uses, the influence of intra-patch variables and matrix variables on ants, wild bees and plant species were analysed. Matrix variables, e.g. the proportion of different land-use types as neighbouring patches were analysed within a 50 m and a 200 m radius of the grassland. From their observations the authors concluded that external factors like spatio-temporal dynamics and matrix effects had a stronger impact on species within all patches. The richness of plant species of a patch was mainly influenced by the quality of the patch. Highest values were found on south-exposed slopes and humid soils. The quality of the surrounding matrix played a crucial role for colonisation processes after patch disturbances. The richness of species of wild bee was determined by intra-patch and matrix variables likewise, pointing at the complex habitat requirements of the species group. The species richness of wild bees was higher on grasslands the surrounding landscape was covered with arable land, hinting towards the importance of available alternative food resources in times when grasslands were mowed. The study showed that the intensity of the relationship between landscape elements and specific species groups is an important predictor for species richness. Matrix variables like the area percentages of different land-use types had a strong impact on species richness for many species groups. This especially applies for landscapes where the landscape structure is closely correlated with the cultivation of land that influences the local ecological conditions (Dauber et al. 2003). As a general conclusion, enhancing the quality of the landscape matrix is an important step toward increasing the connectivity within an area and towards the conservation of the local biodiversity in cultural landscapes.

Extensive cultural landscapes are often dominated by open fields which are interspersed with hedges and field brushes. Exactly this half-open landscape structure is a prerequisite to provide habitats for a variety of species. Forests offer different microclimatic conditions compared to smaller field brushes, hedgerows or field margins between meadows and farmlands. Especially the edges of landscape elements, so-called ecotones are rich in biodiversity. Species which prefer the conditions in the inner zones of copses share their habitat with species hunting on the fields and use field brushes as retreat zones. Especially borders of hedges and shrubs which are rich in flowers are important sources of nectar and pollen for insects (Netzwerk Land c/o Umweltdachverband Gmbh 2014). Different studies in various European countries could show that at least 10 % of the agriculturally used fields must provide important ecological services in order to sustain the local wildlife. GI features like hedgerows bordering agricultural fields or field margins that are rich in flowering plants can considerably increase the landscapes capacity to provide structures for species in a landscape matrix that is dominated by an agricultural use (Bundesamt für Naturschutz, n.d.). Whereas the loss of natural and semi-natural habitats in intensive agricultural areas led to a decline on pollinators (especially bees), organic farming and extensive agriculture can sustain woodlands and semi-natural grasslands that provide a spill-over of these pollinators into adjacent farmland. Thereby pollination services are increased. Especially flower resources like field margins and hedgerows provide sources of food after crop flowering (European Academies Science Advisory Council & Deutsche Akademie der Naturforscher Leopoldina 2015).

3.2. Opportunities and challenges for the conservation management

To protect the natural heritage of Europe, existing nature conservation strategies need to be reconsidered and extended. Conservation strategies often focus the establishment and maintenance of protected areas. Such approaches will not be sufficient to protect ecosystems and their services, because climate change and a strongly increased land intensity ask for holistic approaches, that include multifunctional areas into conservation practices (Helmholtz-Zentrum für Umweltforschung GmbH n.d.).

GI is depicted as an efficient tool to strategically plan and strengthen conservation efforts within and outside of national boundaries, providing ecological, social and economic benefits. By offering objectives with a scientific basis it can help communities to focus on the congruence of environmental and economic goals (Benedict & McMahon 2006). It can mitigate fragmentation and unsustainable land use and can function as a modern approach to nature conservation, focusing on ES and landscape planning and meeting future exigencies (Karhu 2011).

The first step in the establishment of a GI network is to set specific goals to which the GI should contribute. To visualize present and planned GI elements on a map can help to establish connections between these elements. Grouping the mapped landscape elements into hubs, sites and links is the base work that needs to be done before arranging them into a network; for instance, by using GIS capabilities. Including the knowledge of local stakeholders can increase the establishment of a powerful GI network. Whereas in urban areas, GI has a strong focus on human wellbeing and cost-effective replacement of monofunctional grey infrastructure, in rural settings preserving natural areas, enhancing healthy ecosystems and increasing the connectivity between GI features is the main goal of GI. "A healthy ecosystem within a green infrastructure environment has the ability to increase the delivery of ecological and cultural services to improve human health and wellbeing at both individual and community scales" (Pakzad & Osmond 2016, p. 72).

The GI concept is a holistic approach at its core. It recognizes the fact that space is getting more and more scarce and that the conservation of nature needs to be expanded to the broader countryside. Its integrative character is the strength of the concept, but a challenge to implement in practice. The management of human-nature interactions in a complex network of green areas is a sophisticated task that requires reliable biological data. Transferable strategies on how to manage ecosystems with a focus on GI can help practitioners and facilitate coherent action. Because the management of areas in terms of its functionality as GI does not exclude community well-being but aligns it with the protection of biodiversity, GI is also communication tool for important conservation goals. It has a "translating function" about the importance of wildlife rich habitats to planners and private businesses, thereby affecting future decisions concerning regional development (Garmendia et al. 2016). To be efficient, GI needs to be transformed from an appealing concept into a tool that is easy to apply in practice and yet scientifically sound. Cameron and Blasnuša demonstrate that little consideration is given to a specific design of GI areas and the identification of crucial ES, even in political strategies and project plans that especially deal with the implementation of GI (Cameron & Blanuša 2016). With GI, an appreciation of nature in environmental governance can increase (Salomaa et al. 2017). A main challenge within the GI concept is the fact that not to let nature conservation goals get drown in claims on land by different stakeholder (Cameron & Blanuša 2016). The lack of strict and deliberate evaluation of baseline measures and long-term indicators in GI projects minimize the potentials of GI to align biodiversity conservation and restoration of ecosystems with the provision of ES. Roe & Mell criticize that "outcomes of land use and environmental plans are rarely monitored and assessed [...] thus it is difficult for practitioners and policy makers to learn from mistakes or pass on the benefits form learning what actually works" (Roe & Mell 2013, p. 659). The lack of dedicated financial support, expertise, tools to assess the quality of green spaces and effects on ES often constrain effective GI work (Garmendia et al. 2016; Cameron & Blanuša 2016). Furthermore, GI project designs often lack scientific habitat selection methods and specific guidelines on how to implement GI (Garmendia et al. 2016; Cameron & Blanuša 2016).

C | THE "RECHNITZER WEINGEBIRGE": AN EXAMPLE OF GREEN INFRASTRUCTURE?

1. Patterns of land use in the Rechnitzer Weingebirge

Photo: View on the Rechnitzer Weingebirge, source: http://www.rechnitz.at

The Rechnitzer Weingebirge is a small structured cultural landscape known for its floristic and faunistic richness and also for its scenic views with a combination of vineyards and orchard meadows. Extensive meadows, especially rich in biodiversity, were awarded as outstanding examples of flowering areas by the "NATUR VERBINDET" campaign of the Naturschutzbund Österreich. Franz Ulber, a local farmer, is responsible for the management of the meadows. The Rechnitzer Weingebirge, rich in landscape structures like hedges, field brushes and flowering patches, that are constantly decreasing from agricultural landscapes, is a good example of a cultural landscape, where biodiversity conservation and land use is successfully combined. With high personal commitment and experience, Franz Ulber, in collaboration with further local experts, manages protected sites in the region and develops techniques to combine conservation and agriculture. The Rechnitzer Weingebirge has a special setting: it is located between the Green Belt and Rechnitz. The Green Belt stretches over a length of 12.500 km from the Baltic Sea to the Black Sea. Military zone close to the former Iron Curtain were less exposed to agricultural intensification. Due to a lower human intervention, nature was left nearly undisturbed in many areas. Today, the corridor connects natural landscapes and cultural landscapes throughout Europe, thereby protecting and connecting pristine habitats. It further encourages the collaboration of different cultures for a common purpose (Grünes Band Deutschland n.d.).

Formerly, the area was cultivated by farmers who worked in the Hungarian lowlands and owned small parcels of land at the slopes of the Geschriebenstein. The area was mainly used for extensive viticulture and orcharding. Hard conditions for cultivation due to hillside location and thin humus layers favoured extensive cultivation methods. The small house, that are transformed into residential houses or wine cellars, were probably used to store tools and food. Hedges, probably used to produce wood in former times, still pervade the landscape mosaic. Remnants of stonewalls and clearance cairns from former field demarcations are often overgrown by hedges or field brushes. Field brushes have remained as a sign of former forests. Based on this type of land use, the area grew to a small structured cultural landscape, where meadows, vineyards and orchard meadows still alternate in a mosaic-like pattern. The land ownerships in the municipality are based and organized according to an urbarium[11]. Forests, meadows and pastures have been private property of the local community, who divided the land and the benefits that were generated into units. These agricultural communities partially still exist nowadays and have official legal status and their ownership of the properties is granted by the legal system of Austria (Urbarialgemeinde Apetlon 2018).

Figure 6: Excerpt from the Franciscan cadastre (mapped between 1817 – 1861), showing the former land use in the Rechnitzer Weingebirge (Bundesamt für Eich- Und Vermessungswesen).

[11] The term urbarium is derived from Old or Middle High German and was used in economic, administrative and legal issues. The urbarium is a register in which the land ownership in a defined area was organized and the rights and benefits that were connected with the ownership of these lands recorded (Urbarium 2018).

Today, the combination of different land uses on a small scale is still characteristic for the area. Structural landscape elements like hedges and field brushes, cut through the cultural landscape. Extensive meadow orchards, semi-arid grasslands rich in biodiversity as well as small vineyards characterize the landscape scenery. The area is well-known for its wine taverns and has evolved into a tourist destination. The urban spurs of Rechnitz stretch into the cultural landscape and the whole area is accessible via paved roads. Fields of lower intensity more often have fields margins, which provide flowering plants for insects and especially pollinators, whose population densities and range are in constant decrease (Kleijn & van Langevelde 2006).

Characterised by small landscape structures, the Rechnitzer Weingebirge forms a visually uniform part of the landscape which contrasts with the surrounding landscape, mainly intensively used agricultural fields, urban area and forest. Forests around the Geschriebenstein, the highest mountain of Burgenland with 884 m of height (Burgenland Tourismus GmbH n.d.), form the Northern border of the cultural landscape. To the south, the Rechnitzer Weingebirge is bordered by a highway, followed by large homogenous agricultural fields.

2. Ecological setting and status of conservation

The Rechnitzer Weingebirge is located at the most Eastern part of the Alps and the Penninicum. It is part of a unique geological setting: the so called Rechnitzer Window, which is the only geological window that is covered by Neogene sediments. The main rock components are Bündnerschiefer, lime and clay sediments of the Alps. Typical metamorphic sediments in the Rechnitzer Window are calcareous phyllite, greenschist and quartz phyllites (Dunkl & Demeny 1997). The Pannonian climate is another crucial factor that influences the vegetation in the Rechnitzer Weingebirge. Species need to adapt to the generally hot and dry conditions in the summer and equally need to deal with frost periods during the winter. Even though temperatures are a bit more moderate in the southern sub-illyric parts of Burgenland, the Rechnitzer Weingebirge is located in a special setting with dry and hot conditions due to its southern exposure and slope condition. The climax vegetation, that is mainly defined by the contrasts between summer and winter conditions in an area, are dry-warm mixed oak forests (Naturschutzbund Burgenland n.d.). In warmer areas, oak forests with *Quercus cerris* and *Quercus petraea* are typical, whereas in slightly colder and less dry areas forests with *Quercus petraea, Quercus robur* and *Carpinus betulus* prevail (Hübl 1979). Other typical tree species of this forest community are *Acer campestre, Tillia cordata, Prunus avium* and *Fraxinus excelsior.*

The Rechnitzer Weingebirge is part of the Natura 2000 site Bernstein-Lockenhausen-Rechnitz[12]. The forest associations of Natura 2000 site Bernstein-Lockenhausen-Rechnitz protected under the Habitats directive are *Galio sylvatici-Carpinetum* (FFH habitat type 9170). Most of them have a good conservation status (Lazowski 2014). Especially in sites of shallow soil depths located at the Geschriebenstein and on southern-exposed slopes, small patches of xerophilous oak forests with *Quercus pubescens* and *Castanea sativa* can be found (Amt der Burgenländischen Landesregierung). The Natura 2000 site is characterized by alternating areas of open habitats and habitat with a high vegetation cover. *Festuco-Brometalia* (FFH habitat type 6210[13]) are especially abundant in areas influenced by the dry Pannonian climate. Semi-arid grasslands are mainly formed by traditional agricultural land use and, as remnants of the historical cultural landscape, they represent natural, secondary habitats. This habitat type is characterized by poor nutrient availability and periodic dry conditions. To conserve these habitats, management is needed to avoid scrub encroachment of the area. Grasslands of this type can be found especially close to the Green Belt in the Rechnitzer Weingebirge. Grasslands are interspersed with special rocky geotopes, where dry grassland vegetation is dominant. Semi-arid grasslands often occur in combination with other biotope types, especially orchard meadows, hedges, field brushes and different meadow types (Lazowski 2014). Within the Natura 2000 site, habitats of this type have an excellent conservation status (A), but nearly half of them are threatened by changes in the landscape use (abandonment or intensification). As a result of the mapping of FFH habitats in 2014, connectivity is proposed as a management goal for the area, particularly between status A patches and associations of *Festuco-Brometalia*, thereby following the main idea of local ecological network. The Rechnitzer Weingebirge is mentioned as one of the habitats that should be part of such a network (Lazowski 2014).

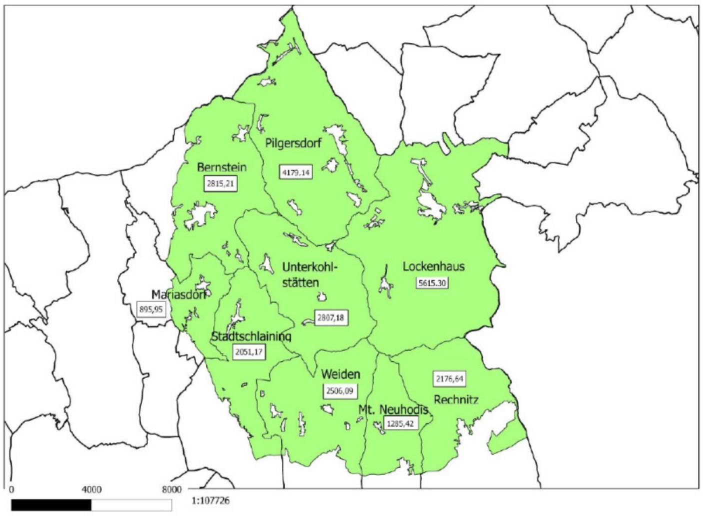


Figure 7: Natura 2000 site "Bernstein-Lockenhausen-Rechnitz", including the political borders and area of each municipality (Lazowski 2014).

[12] The Natura 2000 site is nearly congruent with the landscape conservation area Bernstein-Lockenhausen-Rechnitz (LGBl. Nr. 19/1972), that exists since 1972, that is subject to the Naturschutz- und Landschaftspflegegesetz 1990 of the Burgenland.

[13] Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*). Priority habitats if remarkably orchid stock (JNCC).

Semi-humid and dry oat grass meadows are another important habitat type (FFH habitat type 6510[14]) within the research area. Mesophilic and temporarily dry meadows and nutrient-rich meadows of low land use intensity are important habitats that characterize the landscape scenery. Cultivated grasslands are mainly hay meadows and only occasionally pastures. The ecological value of cultivated meadows depends on the intensity and the connectivity with the landscape matrix. From a conservation point of view, the size of the area and, first and foremost, its management are crucial for developing species-rich vegetation. 20 % of the meadows have an excellent conservation status, 55,6 % of them have a good conservation status. Extensification, increase in connectivity, establishment of buffer zones and grazing are favoured conservation management measures (Lazowski 2014).

The Rechnitzer Weingebirge is part of the Austrian-Hungarian Naturpark Geschriebenstein – Irottkö, which was founded in 1996 as the first nature park in Burgenland. Its office is located in the city of Rechnitz and provides information about the flora and fauna of the area and is a contact point for tourists (Verband der Naturparke Österreichs n.d.).

<u>Previous research in the area</u>

Based on a detailed mapping of dry grasslands in Burgenland during a project period between 2004 and 2007, a management concept for dry grasslands was worked out. Dry grasslands in the Rechnitzer Weingebirge are often small units within a larger grassland complex. Most dry habitats are nutrient-poor with *Arrhenaterum elatius*, *Anthoxanthum odoratum*, *Bromus erectus*, *Briza media* and *Avenula pubescenc* (Roth 2007). The results revealed that only 38 % of all mapped landscape elements are not acutely threatened. About half of them are protected under Natura 2000 or other protection mechanisms. Another project was carried out on waysides as biodiversity hotspots in the Naturpark Geschriebenstein-Irrotkö. During the project, bee and grasshopper mappings took place. The mapped area expanded further than the Rechnitzer Weingebirge into the city area and the lowlands south of the Rechnitzer Weingebirge. As an improvement to the management of the area the authors recommended increasing the number of field margins. They are important refuge areas and elements that connect the landscape for species (Michalek et al. 2014). During the project “Erhaltung von Trockenrasen und Magerstandorten” (Fiala 2013), one grassland was mapped that was especially rich in species, directly at the Hungarian border. *Iris variegata*, *Dictamnus albus* and *Orchis pallens* were some highlights of the local vegetation. Also, the heraldic animal of the Green Belt initiative, *Polysarcus denticauda* (order of Orthoptera), was observed (Fiala 2013).

[14] Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*) (JNCC).

3. The campaign “NATUR VERBINDET”

The campaign “NATUR VERBINDET” is organized by the Naturschutzbund Österreich with the goal to promote the importance of cultural landscapes as hotspots of biodiversity. Landscape elements like hedges and flowering patches are constantly disappearing from agricultural lands, with negative effects on the quality of habitats and the species richness. To raise awareness for the topic, the campaign recognizes exceptionally biodiverse and well-managed meadows as best-practice examples.

A meadow of 1,7 ha at the Hungarian border, that was especially rich in (rare and protected) species, with more than 200 plant species occurring on the site, was awarded[15] by the campaign “NATUR VERBINDET“ (naturschutzbund Österreich) for its outstanding ecological preciousness. The meadow provides habitat for 29 bird species and various species of grasshoppers, bugs and dragonflies. *Dictamnus albus*, *Iris variegata* and *Galatella linosyris* are some of the local botanical rarities (naturschutzbund Österreich). This species richness is fostered by extensive land use, conservation-oriented monitoring, the general richness of landscape elements of high quality and the climatic and geological conditions of the site. In this area, hedges, field brushes, ruderal areas, dry and semi-humid areas that stretch along the Austrian-Hungarian border offer diverse structures, which provide habitats for a variety of species. Besides, a mixture of humid and dry patches and siliceous and calcareous rocks can be found in the Rechnitzer Weingebirge, with a general tendency of humid conditions in the lower parts and dry conditions in the upper parts (personal conservation with Franz Ulber), contribution to very diverse conditions in a small area.

The meadow that was awarded is managed by Franz Ulber, a farmer, who is committed to aligning agriculture with nature conservation. His family has owned some of the meadows for over 20 years. His father started to cooperate with the municipality by carrying out conservation measures on public spaces. His personal motivation is to restore meadows in the Rechnitzer Weingebirge and connect them with similar habitats nearby. The meadow at the Rechnitz cemetery is another meadow managed by Franz Ulber, which aims at creating habitats for butterflies. Franz Ulber is in charge of the management of further meadows in the Rechnitzer Weingebirge and in protected areas nearby, where he manages the land in close collaboration with Stefan Weiss. To increase the connectivity between these areas is an important management goal. They created management plans with specific measures for each meadow, developing practical expertise in managing extensive meadows in a sustainable way. Most of the

[15] Qualification criteria to be awarded by “NATUR VERBINDET” meadows must have a minimum number of native wild flower species. Management criteria are late mowing, removal of mowed material, no fertilization and no application of pesticides. The minimum requirements correspond with the UBB (Umweltgerechte und biodiversitätsfördernde Bewirtschaftung) measures (naturschutzbund Österreich; Landwirtschaftskammer Niederösterreich).

meadows are mowed once per year in autumn. In specific cases, meadows are mowed twice per year and, as additional conservation measures, young woods are cut to reduce scrub encroachment to prevent the extinction of semi-dry grasslands. The mowing interval for meadows, which is especially important for insects, is set every two years. Most meadows in the Rechnitzer Weingebirge are subject to contractual nature conservation[16]. Furthermore, the management of specific landscape elements is promoted by ÖPUL (personal conversation with Stefan Weiss and Franz Ulber).

The management performed by local experts in the Rechnitzer Weingebirge shares the main vision of GI to conserve hotspots of biodiversity and to integrate their conservation into land use practices. The awareness for the high value of the area is high not only among the local experts but also under inhabitants of the Rechnitzer Weingebirge. Thematic trails, information boards and guided botanical excursions provide information about botanical rarities and more general conservation related topics. During a project of Rewisa (Verein REWISA-Netzwerk n.d.), seeds were collected on extensive meadows that are managed by Franz Ulber. The compiled seed mixtures (specialist and ruderal species) are used to cultivate this specific species composition in other areas, what stresses the speciality of meadows of the Rechnitzer Weingebirge. Furthermore, the Naturschutzbund Burgenland runs two projects on dry grasslands in the Rechnitz area, for which dry grasslands were purchased and subsequently restored. Looking to the future, it does not seem constructive to purchase further areas, as most areas are already part of the ÖPUL project and managed by different farmers. The entire Rechnitzer Weingebirge is used quite extensively, as the slope orientation does not allow for intense land use. Although the entire area of Rechnitz is generally rich in ecologically valuable small structures, a precise mapping of the landscape in the Rechnitzer Weingebirge would be useful to identify nutrient-poor grasslands which could be connected to each other. It is equally important to research possible areas in Hungary with which the area can be linked (personal conversations with Haring, Herist; Michalek; Schau; Ulber; Weiss [17]).

[16] Nature conservancies collaborate with property owners in that they pay a conservation oriented agricultural use within a defined contractual period.

[17] Fr. Haring: collects medically valuable plants, member of the former “Bach-Blüten” seminar centre in the R. Weingebirge.
Hr. Herist: winemaker in Rechnitz, owns parcels in the Rechnitzer Weingebirge.
Hr. Michalek: director of the Naturschutzbund Burgenland and representative of the regional group in Oberwart.
Hr. Schau: botanist and employee of REWISA. He collects plants seeds (specialists and generalists) from meadows especially rich in biodiversity in the Rechnitzer Weingebirge (mainly managed by Franz Ulber).
Hr. Ulber: local farmer and responsible for the management of extensive meadows.
Hr. Weiss: expert for Natura 2000 management, supports Franz Ulber regarding a nature conservation based management of extensive meadows.

4. Visual impressions of the mapped landscape elements in the areas


GB_upper: young orchard meadow with extensive undergrowth (mowing interval: 1 year).
Photo: Jessica Bitsch


GB_lower: winner of "NATUR VERBINDET": Large extensive meadow, directly at the Green Belt (left-hand side) including single trees and hunting stand.
Photo: Jessica Bitsch


GB_upper: small garden with naturally designed seating area and pond.
Photo: Jessica Bitsch


GB_upper: hedgerow of trees buffers an extensive meadow.
Photo: Jessica Bitsch


R_upper: extensive meadows in vicinity to small vineyards, orchard meadows and residential buildings.
Photo: Jessica Bitsch

Photo: Jessica Bitsch

Photo: Jessica Bitsch

Information boards.

R_lower: mosaic of different types of land use: vineyards, (orchard) meadows and hedgerows.

Photo: Jessica Bitsch

R_lower: hedgerow of trees with native species.

Photo: Jessica Bitsch

R_upper: rocky patch with dry grassland vegetation on extensive meadow, exemplar of praying mantis (mantis religiosa).

Photo: Jessica Bitsch

R_upper: extensive meadow, including old trees and field brushes.

Photo: Jessica Bitsch

Information board.

Photo: Jessica Bitsch

R_upper: small vine cellar, typical for the Rechnitzer Weingebirge.

Photo: Jessica Bitsch

Small structured landscape: mixture of extensively and intensively used lands, residential housing, interspersed with hedges and orchard meadows.

Photo: Jessica Bitsch

5. The Rechnitzer Weingebirge as a site of Green Infrastructure

As demonstrated in former research projects, the Rechnitzer Weingebirge is an areas of high conservation value. Due to the small structured landscape pattern and the presence of connectivity features, the cultural landscape has the potential to function as a habitat of high quality for a variety of species. Even though the Rechnitzer Weingebirge is generally characterized by a low intensity use, areas at the Green Belt appear especially rich in extensive meadows, field brushes, hedges and even small forest patches, all landscape elements are disappearing as a result of intense agriculture.

Including a GI perspective into the management of the site, that is consistent with the definitions of the European Commission, means to put focus on the naturalness, the connectivity and the provision of ES of landscape elements. To assess the level of naturalness of the Rechnitzer Weingebirge, landscape elements with a special importance to the performance of the GI were assessed with regards to their level of naturalness. Furthermore, connectivity was assessed not with other protected sites but within the landscape, based on the presence of connectivity features and the mean distance between GI features. Finally, the selected GI features were assessed regarding their capacity to provide ES. The goal of this thesis is to assess specific landscape elements regarding their GI performance.

The Rechnitzer Weingebirge is considered a practice example from which valuable techniques can be derived as how to reconcile biodiversity conservation with extensive agricultural land use and tourism. With his strong personal commitment, Franz Ulber is a positive example for how conservation management and farming can be mutually supportive. According to Naumann et al., a local project initiator is someone, who has gained the local community’s trust and can support the implementation of a GI project (Naumann et al. 2011).

Even though the conservation management in the Rechnitzer Weingebirge is not specifically based on GI principles, it complies with characteristics are repeatedly found in GI related projects (Naumann et al. 2011):

- <u>Critical mass</u>: Single components like individual trees or habitat patches are mainly considered as part of GI if they reach a certain scale or connectivity with other features. In the case of the Rechnitzer Weingebirge, connectivity features and habitat patches form a mosaic like ecological network. Thus, in its entirety, the Rechnitzer Weingebirge has a good performance as GI site. Thus, biodiversity is fostered by protecting habitats and by increasing the permeability of the landscape. Furthermore, due to its particular setting, the Rechnitzer Weingebirge is a transition zone between the Green Belt and the urban area of Rechnitz with more intense land uses. Thus, the Rechnitzer Weingebirge buffers negative impacts from the city on pristine nature close to the Green Belt.

- Benefits to people: The GI approach is strongly linked to the benefits that ecosystems provide for people. The Rechnitzer Weingebirge is shaped by its traditionally extensive cultivation management, mainly providing vineyards and orchard meadows. With its scenic atmosphere, the area has a high quality for tourists as well as for the local population.
- Multifunctionality: GI areas are supposed to serve people and nature as they align the provision of ES with biodiversity conservation. As dry grasslands especially rich in biodiversity rich are located in the Rechnitzer Weingebirge, providing habitat to a wide array of protected species in combination with its use for agriculture and housing multifunctionality is given.
- Substitutability with grey infrastructure: Substitutability of grey with green infrastructure is especially common for urban areas, where GI is favoured over grey infrastructure, as it fulfils a wider range of services and is often more cost-effective. For the Rechnitzer Weingebirge, a rural area, substitutability of grey infrastructure is not necessary, but in a broader sense, a landscape rich in structures and habitat patches is to be favoured over intensively used, homogenous land. Existing hedges and field brushes can contribute to the control of pests and can reduce the need for pest control measures (European Academies Science Advisory Council & Deutsche Akademie der Naturforscher Leopoldina 2015).
- Co-ordinated interventions: The idea of a GI network is based on common efforts especially when different areas are connected with each other. Stakeholders should work collectively in order to organise a GI project. In the case of Rechnitzer Weingebirge, a cooperation of various stakeholders is realized. Beyond that, a dedicated integration of the GI management into spatial planning would be important.

Naumann et al. indicate that not all projects to which the above-mentioned criteria apply call themselves GI projects, but apply names in accordance with the project objectives, e.g. habitat restoration. GI projects can be further characterized by the scope of measures to reach the project goals: holistically orientated projects pursue integrated GI sites with local networks of GI features, whereas sectoral approaches focus on single GI features that enhance the quality of a specific landscape section. The research results of the thesis are expected to illustrate whether the GI structures in the Rechnitzer Weingebirge correspond to a holistic approach, which is to be preferred for the area in order to create a local ecological network, that sustain meadows rich in biodiversity and a network of hedges and field brushes.

D | METHODS AND MATERIALS

1. Methodological outline

The main idea of the thesis is to functionally assess specific landscape elements in the Rechnitzer Weingebirge (later referred to as GI features) with regards to their GI performance, to show the importance of the entire area as a GI site. The functional assessment of the GI features in the Rechnitzer Weingebirge is based on the following key aspects: the level of naturalness, the connectivity between different GI features and the provision of ES[18]. These indicators were derived from the key principles of the proposed GI network defined by the European Commission in the EU GI Strategy and were further redefined in accordance to the developed assessment method of the project MaGICLandscapes (European Commission 2013; Csaplovics 2018). Within the project, three key factors form the basis of the GI assessment: 1) the classification of different types of GI regrading broader habitat types, 2) the naturalness of GI elements and 3) the functionality of GI elements in terms of the provision of ES (Wrbka & Danzinger 2018). The data that was needed for the assessment was collected during a biotope mapping in the Rechnitzer Weingebirge. Afterwards, specific landscape elements that were defined as elements of GI (referred to as GI features in the context of this thesis) were analysed according to their functional value for the local GI. An extensive mapping of the landscape of the entire Rechnitzer Weingebirge was not feasible due to time limitations. Hence, two sections of the landscape were selected for a detailed investigation of landscape elements. The following figure shows the location and extension of the two landscape sections GB and R.

[18] For the relationship of the term ES and multifunctionality see B.2.4.

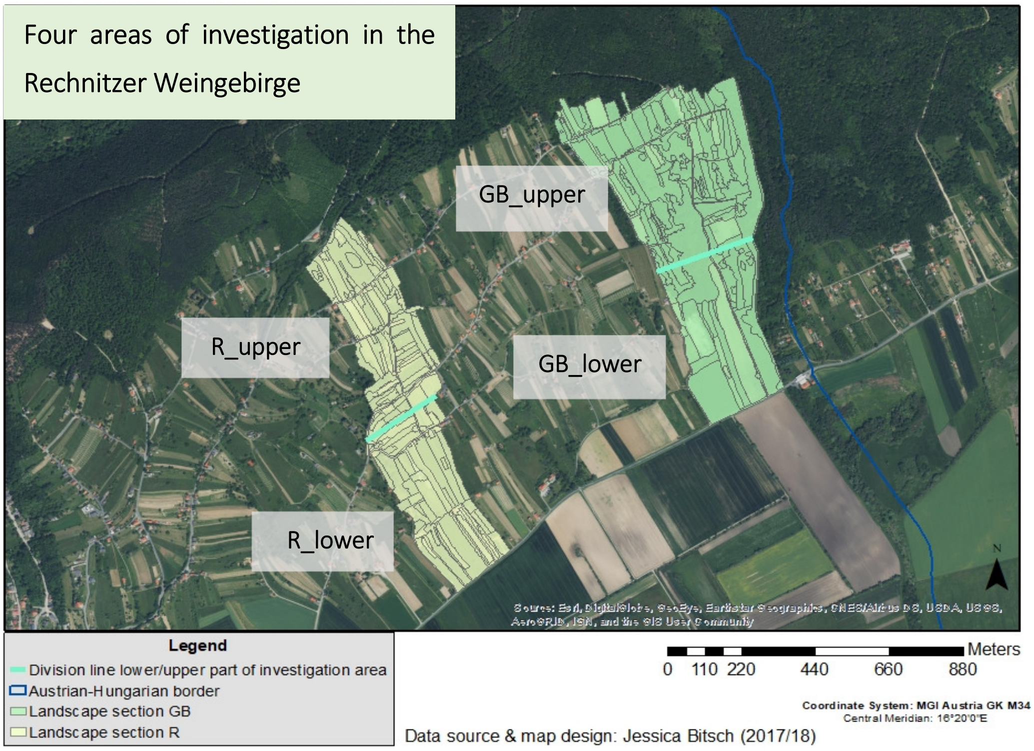


Figure 8: Location of the four areas that were investigated in the cultural landscape Rechnitzer Weingebirge.

Landscape section GB, coloured in green, is at the eastern border of the cultural landscape and is directly adjacent to the Green Belt. The landscape section R is coloured in yellow and can be found to the west in a distance of one kilometre.

The decision to select two landscape sections, one at the Green Belt and in farther distance and therefore closer to Rechnitz was based on the idea that different areas in the Rechnitzer Weingebirge favour more intensive land use practices than other and are furthermore characterized by different ecological conditions. Generally, areas close to the Green Belt should be the least disturbed. In addition, the meadows that are managed by Franz Ulber, that are characterized by their high biodiversity, are close to the Green Belt. The landscape section closer to Rechnitz represents an area that is stronger affected by land use practices of higher intensity. The different shape and extension of the two landscape sections that are visualised in figure 9 are compared in the following table.

Table 3: Location and size of the landscape sections GB and R.

	GB (Green Belt)	R (Rechnitz)
Location	Eastern part of the Rechnitzer Weingebirge, bordering at the Green Belt	In the centre of the Rechnitzer Weingebirge, 1 km to the West of the Green Belt
Area	364.358,00 m²	243.466,36 m²
Shape	Length: 900 m	Length: 1.100 m

	Width: 500 m [upper part] / 250 m [lower part]	Width: 250 m
All mapped landscape elements	175 polygons	175 polygons
Green Infrastructure features	62 polygons	29 polygons

In a second step, the landscape sections GB and R were subdivided into a lower and an upper part, based on the idea that the surrounding landscape has an important impact on the quality of a landscape segment. The exact borders of the four areas that were investigated were set in the field, they followed the natural features in the respective area. As a consequence, the four areas have a different shape and of varying size. GB_upper is the biggest area, whereas GB_lower, R_upper and R_lower are similarly large.

2. Field work

Mapping tools and analyses that are usually used in conservation management can provide an assessment framework that can facilitate the analysis of landscapes regarding its GI performance. Several parameters seem particularly relevant. The land use types are associated with ecological functions of landscape elements and can be used as an approximation of their capacity to provide habitat services. The hemeroby status of a landscape element can be used to evaluate the semi-natural or natural character of a GI feature. Habitat quality is one of the crucial factors that determines the presence and abundance of species (Mortelliti et al. 2010). Connectivity, which, besides naturalness, is another key aspect of GI, will be assessed on the basis of a GIS analysis and the presence of connectivity features. The capacity of landscape elements to provide ES will be used as an indicator for the third aspect of GI, the provision of ES. The assessment of ES will be based on observations in the field and using indicators derived from expert knowledge. The standard mapping catalogue (Wrbka et al. 2015) was slightly adjusted to the methodological approach of the thesis.

2.1. Collection of the data

Mapping of the landscape structure

At first, the landscape within the defined areas were recorded and specific parameters were assessed in June 2017. A comprehensive mapping including patches, corridors and the matrix is the basis for the subsequent mapping of specific landscape elements of interest under a certain research question. The recorded landscape elements were localized and sketched on orthophotos (scale of 1:2.000 m) that were previously downloaded from GIS Burgenland[19]. The data was stored in a Microsoft Access database (version Microsoft Office 365 ProPlus).

The following list shows the parameters that were recorded for each mapped landscape element:

- characteristics of patches: normal/ complex patch, in case of a corridor patch: indicating line or areal shape
- type of land-use
- hemerobic status[20]
- natural and anthropogenic disturbance of the landscape
- resources: dry/ wet conditions
- resources: nutrient-rich/ nutrient-poor conditions
- capacity for regeneration after disturbances
- introduced biotic and abiotic structures
- change of persistent land units[21]
- multifunctionality[22]

Specifications were given for some groups of landscape elements. For instance, a minimal mapping unit, below which hedges were not recorded, of 15 m in length was defined for hedgerows.

The assessment of the hemeroby was based on the strength and periodicity of the human interventions on landscape elements, which determines nature’s capacity to adapt to the induced changes (Wrbka et al. 2015).

<u>Mapping of Green Infrastructure features</u>
In a second step, only landscape elements, which were selected as relevant GI features, were assessed in September 2017. The selection of landscape elements that qualify as GI features was based on the main criteria proposed in the GI definition by the European Commission: good levels of naturalness, connectivity and the provision of a wide range of ES.

Emphasizing the half-open character of the Rechnitzer Weingebirge landscape, extensive meadows were selected as valuable GI features. Extensive meadows in the Rechnitzer Weingebirge are local hotspots of biodiversity, they provide valuable habitat in the landscape matrix and provide regulation and information services. Furthermore, some of these meadows are protected under the Habitats Directive, thus efforts to connect patches in the Rechnitzer

[19] https://geodaten.bgld.gv.at/de/home.html
[20] The original parameter hemeroby status was later adapted to the concept of “naturalness” which is mostly used in the context of GI context. For explanation, see D.1.3.
[21] This parameter indicates the intensity of changes that land units that remained from former times underwent. The reference point is the preindustrial agriculture (Wrbka et al. 2015).
[22] The parameter “multifunctionality” was introduced as a test to quickly assess the multifunctional character of the landscape. For further explanations see D.1.3.

Weingebirge should focus on these meadows. Hedges and field brushes, remnants of former land use structures, are the most valuable elements within the landscape for the conservation of biodiversity. Specifically hedges rich in flowers, preferably with native species, can provide a wide range of ES with special relevance to the conservation of insects and bees (European Academies Science Advisory Council & Deutsche Akademie der Naturforscher Leopoldina 2015). Landscape elements, on which human cultivation practices create and maintain habitat structures, are important patches in the landscape matrix. Hence, orchard meadows were selected as important GI features, because they in particular increase the multifunctional character of the landscape by contributing to the provision services of the landscape. Forest features that are partially interspersed in the landscape section at the Green Belt provide various services and habitat for forest species, thereby functionally connecting the Rechnitzer Weingebirge with the Green Belt. Forest features were only partially included in the analyses (area percentages of functional groups of GI features and connectivity analysis). The following list shows all landscape elements that were selected for the mapping of GI features[23]:

- Extensive meadows[24]
- Field margins rich in perennial plants
- Linear structures (dry-stone walls and clearance cairns)
- Hedgerows of trees
- Hedgerows of shrubs
- Field brushes
- Orchard meadows young
- Orchard meadows old

The following parameters were recorded for each landscape element:

- biotope type
- morphological characteristics
- structural elements
- characteristics indicating the provision of ES (value-giving characteristics)
- present/ potential threats
- present/ potential management measures

Extensively managed vineyards and vineyards with a medium-intensive management were not selected as GI features, because continuous disturbance and use of spray chemicals reduce their value as habitats. Furthermore, fallows were not considered due to their small number, although they are important landscape elements with low land-use intensity. Trees have a high level of naturalness, but, as single and not connected element, were not specifically analysed.

[23] For a more detailed description of the selection criteria, see the appendices (I.3).
[24] The classification of large extensive meadows was based on the predominant type of vegetation. Particular species were listed in the form sheet.

Furthermore, due to data incompleteness, about 10 % of GI features were not included in the calculation.

2.2. Adaptation of mapping parameters to the Green Infrastructure approach

Naturalness of Green Infrastructure features

For this thesis, the recorded parameter “hemeroby” was transformed into the parameter “naturalness”. The definition of GI itself describes a GI as a network of semi-natural and natural areas, thus defining the level of naturalness of GI elements seems crucial. The decision to use the term naturalness is supported by the fact that the term has a wider range of applications in an international context compared to hemeroby, which is mainly used in the field of conservation in Central Europe. Slightly different approaches characterize both concepts: whereas hemeroby “an integrative measure for the impact of all human interventions on ecosystems” (Sukopp et al. 1990, cited after Machado 2004, p. 98) focuses on the degree of human transformation of the landscape, naturalness describes how natural an ecosystem is, based on the landscape conditions and natural processes (Machado 2004). Machado provides an index system to assess the naturalness of ecosystems for practical applications and suitable for rapid assessments (which become more and more necessary due to limiting factors of time and financing in conservation related management). The index can be applied to large or small ecosystems and allows the user to assign their own labels to the index values in order to reflect cultural differences. Parameters that define each state, are for example, the presence of biotic and artificial elements or the level of fragmentation (Machado 2004). To adapt the seven levels of the hemeroby scale to the ten levels of naturalness, various levels were analysed qualitatively and levels with high congruence were assigned to one another. In the hemeroby-scale there is an important qualitative leap from “euhemerob” to “mesohemerob”: whereas landscape elements of the level “mesohemerob” still reflect pristine natural conditions of a biotope, the level “euhemerob” is used for biotopes that replace other biotopes that would occur naturally in the absence of anthropogenic influences. The identification of the level of hemeroby is based on the present vegetation of the biotope with the potentially natural vegetation as target state (Stein 2011).

The following table shows how the levels of hemeroby were assigned to their respective level of naturalness. The colours indicate the levels of the hemeroby and naturalness scale that were assigned in order to transfer the hemeroby status of a landscape elements to a level of naturalness. Besides, the different of scaling order of both concepts are indicated.

Table 4: Comparison of the two concepts "hemeroby" and "naturalness".

Levels of hemeroby (terminology according to Blume & Sukopp 1976)	Conceptual approach: degree of the human intervention	Levels of naturalness (terminology according to Machado 2004)	Conceptual approach: naturalness of the ecosystem
[1] Ahemerob	Low	[10] Natural virgin system	High
	↓	[9] Natural system	↓
[2] Oligohemerob		[8] Sub-natural system	
		[7] Quasi-natural system	
[3] Mesohemerob	High	[6] Semi-natural system	low
		[5] Cultural self-maintained system	
[4] Euhemerob (beta)		[4] Cultural assisted system	
[5] Euhemerob (alpha)		[3] Highly intervened system	
		[2] Semi-transformed system	
[6] Polyhemerob		[1] Transformed system	
[7] Metahemerob		[0] Artificial system	

<u>The multifunctional character of Green Infrastructure</u>

To represent the multifunctional character of GI that is mentioned in the definition of GI by the European Commission the parameter "multifunctionality" was introduced as a complement to the original set of mapping parameters. The initial idea: to design a parameter for a quick assessment of the provision capacity of a landscape element, (for instance by counting obvious ES) was changed during the mapping procedure. Based on the idea that ES and multifunctionality refer to one another but are not identical the parameter "multifunctionality" should introduce the dominant function that the landscape element has within the context of the surrounding landscape. The basic idea was, in combination with more detailed investigations, to gain insights about how balanced different landscape functions are represented. Nevertheless, is seems useful to roughly indicate the number of provided ES to underpin the capacity of the landscape element to provide services.

In the following table, six categories of GI functions are indicated, that were developed to describe the functional GI aspect of types of land use in the Rechnitzer Weingebirge.

Table 5: Six different categories and assigned landscape elements of the parameter “multifunctionality”.

No.	Category	Landscape elements
1	Biodiversity-rich patch	- Extensive meadows with naturalness level 4 or 5 - Medium intensive meadows (naturalness level 4) - Natural mixed oak and hornbeam-oak forests
2	Structural landscape elements (with connecting function)	- Hedgerows of trees - Hedgerows of shrubs - Field brushes - Dry-stone walls - Field margins rich in perennial plants - Regulated hill country streams
3	Special cultural value	- Old deciduous trees - Old coniferous trees - Special natural landscape elements
4	Land use: extensive	- Old/young orchard meadows (naturalness level 4) - Extensive vineyards (naturalness level 4) - Old fallow lands with tall herbs - Young fallow lands (naturalness level 4)
5	Land use: intensive	- Old/young orchard meadows (naturalness level 2 or 3) - Extensive vineyards and meadows (naturalness level3) - Medium intensive grain fields - Intensive meadows and vineyards - Medium intensive meadows and vineyards (naturalness level 3) - Young tree meadows (naturalness level 3) - Young fallow lands (naturalness level 3) - Young fruit tree rows and -avenues - Young coniferous tree-plantations
6	Housing and infrastructure	- Detached houses with vegetation - Paved roads - Vegetated roads - Gardens and parks - Punctiform built up elements - Ruderal waysides

Ecosystem services

The parameter that aims at the performance of landscape elements, referring to their capacity to deliver ES, was slightly adapted. To reflect the GI approach of the research question, ES especially relevant in cultural landscapes were added with a focus on hedges and flowering rich meadows, e.g. noise and sight mitigation. Provisioning services were excluded instead to emphasize the relevance of habitat services for a local GI network in order to maintain healthy ecosystems (Rodriguez et al. 2006, Liquete et al. 2015). To highlight the capacity of ecosystems to provide ES, especially ones of direct use like provision services, can considerably facilitate conservation efforts by raising the awareness for the importance of healthy ecosystems. Nevertheless, reducing ecosystems to their usefulness for humans neglects the intrinsic value of nature and the importance of undisturbed ecological processes on the basis of which all other services can be provided. The Rechnitzer Weingebirge, as a cultural landscape, has productivity, from a human point of view, in its basis anyways, so the provision of ES in relation to human resource demands is presumed. “Pollination”, “Regulation of pests”, “Environmental education”, “Sight and noise protection” and “Presence of medical plants”[25] were added (European Academies Science Advisory Council & Deutsche Akademie der Naturforscher Leopoldina 2015). “Relevance for hunting” was removed from the value list. Furthermore, with reference to the GI concept, the fact that habitat services were prioritized in the mapping process reflects the current discussion[26]; that biodiversity baselines must be identified and ensured so biodiversity conservation is not watered down by multiple interests attempting to use limited space efficiently.

2.3. Used materials

To support a detailed and coherent mapping process, all recorded landscape elements were categorized according to a previously defined mapping catalogue. The vegetation was classified by relevant literature.

- To record the parameters for all landscape elements within the investigation areas the document “Kartieranleitung Landschaftsstruktur” (T. Wrbka, K. Zmelik, J. Peterseil, F.M. Grünweis 2015) was used. The document was slightly adapted to the research question by introducing the parameter “functionality” (for form sheets, see appendices).
- The type of the recorded landscape elements was assessed with the “Biotoptypenkatalog: “Kartierung der Offenlandhabitate im BP Wr.Wald” (Staudinger & Wrbka 2014). Forest features, which are not included in the catalogue, were classified according to the “Biotoptypenkatalog der Steiermark” (Amt der Steiermärkischen Landesregierung 2008).
- Types of grasslands were classified with the „Schlüssel zum Bestimmen der Wiesen- und Trockenrasentypen im Wiener Wald“ (Willner 2011).
- Plant species were identified based on the “Exkursionsflora für Österreich, Lichtenstein und Südtirol” (Fischer et al. 2008).
- For the parameter “nutrient availability” indicators developed by Ellenberg gave orientation (Ellenberg 1993).

[25] This ES was categorized as a ‘information service’ and not a ‘provision service’. Medical plants were interpreted as a source of information and knowledge for medical use.
[26] Studies indicate that to ensure the contribution of the GI network to biodiversity conservation, focus must lie on biodiversity correlated ES, mainly regulating services. According to the European GI strategy GI and delivered ES should benefit people, so most tangible services, mainly provisioning services, are assessed predominantly. There is a general lack in the assessment of cultural ES. Moreover, the human role in the production of ES is not reflected in most studies (Salomaa et al. 2017; Ruoso et al. 2015). In order to support GI’s potential to contribute to biodiversity conservation, scientific basis for an understanding of “biodiversity being prerequisite for ecosystem service production” (Salomaa et al. 2017) must be established.

3. Classification of Green Infrastructure features into functional groups

A network of local GI comprises a variety of different GI features. For the analysis of the functional value of the GI features, the mapped GI features were categorized into three functional groups, apart from a thematic grouping that can help to reduce the complexity of different functionalities in a GI network, thus larger sample size could be generated for statistical analyses. The categorization into one of the functional groups was based on the defined land use type of the GI feature. Representing the specific landscape structures of the GI site Rechnitzer Weingebirge, all GI features were classified as one of the following three functional groups: a) habitat features (comprising open habitat features and forest features), b) connectivity features or c) extensive use features. Open habitat features are the main patches that provide habitat for species that are adapted to conditions in the cultural landscape, thus their protection is crucial to maintain the local biodiversity. Forest species furthermore find niches and habitat structures in forest features that connect the cultural landscape with the Green Belt. The mix of open GI features and such with closed vegetation provides diverse habitat structures and different niches, allowing species with different needs to thrive. Connectivity features form crucial links within the landscape, especially when human dominated lands form large parts of the matrix. Besides, they can function as areas of refuge and as stepping stones for species, thereby enabling processes of species dispersal. Areas of extensive land use do not only offer provisioning services to humans but can also function as habitat patches with further possible impacts on the quality of the landscape. Unlike the project MaGICLandscapes, in this thesis, the term ”GI feature” is used to stress the functional character of a landscape element in a local context, whereas “GI elements” refers to GI areas in the context of a large-scale GI network.

In the following table, the landscape elements that were defined as important features of GI in the Rechnitzer Weingebirge, were functionally grouped into three categories: 1) habitat features, 2) connectivity features and 3) extensive use features. The habitat features were further split into open habitat features and forested features.

Table 6: Classification catalogue of GI features that are assigned to the three functional groups of GI.

Functional groups of different Green Infrastructure features		Green Infrastructure features	Number of biotope type[27]
Habitat features	Open land	Extensive meadows (partly protected under the FFH Directive as habitat type 6510 (Low land hay meadows [Alopecurus pratensis, Sanguisorba officinalis]) and 6210 (Semi-natural dry grasslands and scrubland facies on calcareous substrates [Festuco-Brometalia] [* important orchid sites]) (European Commission DG Environment 2013)	54, 55, 56 (in specific cases[28]), 74, 75
	Forested[29]	(Semi-) Natural mixed oak and hornbeam-oak forests	1000
Connectivity features		Field brushes	102, 103
		Hedgerows of shrubs	91
		Hedgerows of trees	95
		Dry-stacked stone walls	113
Extensive use features[30]		Orchard meadows young	79
		Orchard meadows old	104
		Field margins rich in perennial plants	82, 84

[27] The numbers for the recorded biotope types were taken from the mapping catalogue.
[28] Meadows with less than five characteristic plant species were classified as species-poor and were not selected as GI features.
[29] Landscape elements were defined as forest features if the mapping threshold for field copses of 5.000 m² was exceeded (Amt der Steiermärkischen Landesregierung 2008).
[30] Extensive meadows were not part of this group, because extensive meadows have the primary function to provide habitat services.

4. Functional assessment of Green Infrastructure features

The recorded data was analysed with the help of ArcGIS (*version* 10.4) and RStudio (*version* 3.4.4). After digitalizing the mapped landscape elements (Projected Coordinate System: MGI_Austria_GK_M34), all information was transferred into an Access database and, together with all relevant ArcGIS shapefiles, tables and layers, stored as Personal Geodatabase.

In this thesis, the functional value of GI features is measured by three key aspects: the level of naturalness, connectivity between defined GI features and provided ES. The methodological approach follows the GI functionality assessment proposed by the project MaGICLandscapes. In the project, assessment methodologies combine landscape structures and ES as a basis of the assessment of GI functionality. The assessment follows three-staged key factors: 1) the classification of elements of GI (regarding broader habitat types), 2) the naturalness of these elements and 3) the functionality of these elements in terms of ES. In step 1, landscape elements are classified into classes, types and furthermore into regional subtypes for the project regions (Csaplovics 2018). In this thesis, the present landscape elements were spatially delineated and classified based on different types of land use. Afterwards, the naturalness distributions of GI features were compared between all area that were investigation. A connectivity index was calculated for open habitat features like extensive meadows and for forest features/ hedges/ field brushes for each area. The provision of ES was assessed for each GI feature and subsequently grouped into functional groups of ES. Lastly, these groups were used for a comparison between the areas. Finally, a combined factor of all key aspects is calculated for the present GI features.

4.1. Abundance

As a first step in analysis, the distribution of different landscape parameters is visualized with ArcGIS in the form of thematic maps. Furthermore, GI relevant landscape elements are localized by different GI feature groups. To underpin the optical interpretation of the landscape area percentages of different land-use types are calculated and results depicted as bar charts with the help of the ggplot2-package (H. Wickham. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York, 2009).

4.2. Naturalness

The naturalness of GI features was analysed separately for each functional group in order to compare the results for the four areas in more detail. Forest features were not included in the analysis, because they only occurred in two of the four areas. In several studies, the naturalness of landscape elements was multiplied by the area that was covered by the element ("area weighting"). This approach guarantees the spatial coherence of landscape elements of different size and the assignment of proper functionality values to each of them (Kuttner et al. 2013), as the capacity to provide function depends on the size of a landscape element. This approach was used in this thesis to analyse the capacity of GI features to provide ES in reference to the features’ size.

The Wilcoxon Rank Sum Test was chosen as a suitable test for a pairwise comparison of the distributions of the naturalness of GI features. The test does not require normally distributed data, is suitable for small sample sizes (minimum sample size of 30 elements) and for ranked data. With this nonparametric test, the naturalness distributions of GI features were compared pairwise between all areas (GB_upper - GB_lower; GB_upper - R_upper and so on). The null hypothesis is that the distributions of two different samples are the same. The alternative is that the distributions differ (by some kind of location shift) (Wild 1997; StackExchange). The p-value indicates whether the null hypothesis is rejected or accepted. A standard confidence interval of 0.05 was used.

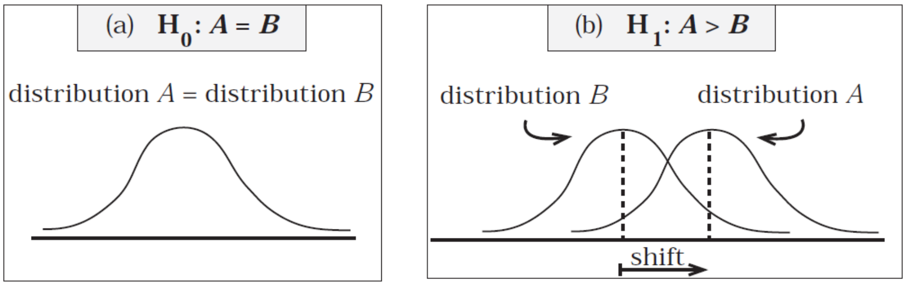


Figure 9: Illustration of the null hypothesis and the alternative for the Wilcoxon Rank Sum Test (Wild 1997).

The results of the test are presented as stacked bars. The bars contain the area percentages of all GI features of each naturalness level. Dissimilarity and similarity of the distributions are indicated with lowercase letters on top of each bar. Similar distributions are indicated by identical lowercase letters on top of bars, whereas dissimilarity is indicated by different lowercase letters.

4.3. Connectivity

Connectivity was measured in terms of landscape structure in this thesis. For an assessment of functional connectivity, reliable data on species distribution would be necessary. Connectivity of defined GI features was used as a parameter for the connectivity in the four areas. A connectivity analysis was performed in ArcGIS with the function “Average Nearest Neighbor” (Spatial Analyst Tools). At first, connectivity was assessed for all semi-natural or cultural assisted landscape elements that were defined as GI features. This criterion is based on the idea that GI features with high levels of naturalness can better provide habitat services to highly-specialized species, whereas landscape elements with low levels of naturalness mainly support populations of generalist species. In a second step, a connectivity analysis was performed specifically for 1) GI features formed by trees and shrubs including forest features, hedges and field brushes and 2) open habitat features. This differentiation accounts for the fact that species that live in landscapes with a closed vegetation cover have different habitat needs compared to species of open landscapes.

The Average Nearest Neighbor tool computes a value, the Average Nearest Neighbour Ratio, which is the average distance between each feature's centroid and the centroid of its nearest neighbor. Reference for the interpretation of the value is a hypothetical random. An index under 1 indicates clustering of input features whereas an index over 1 indicates dispersion of input features. The equations underlying the calculations assume that landscape elements are free to locate anywhere in the research area, which means, that, for instance, no barriers influence the location of landscape elements (Esri). The index is to be understood as an approximation to the actual connectivity of features in a landscape, as the location of features is likely to be influenced by the surrounding landscape. However, the index indicates closeness or distance between features and therefore implies accessibility of these features for target species. Nevertheless, further measures of connectivity should be included to a realistic evaluation of the structural connectivity of the landscape.

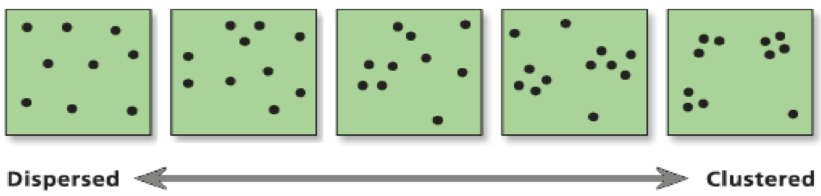


Figure 10: Illustration of a clustering or a dispersion of input features (Esri).

4.4. Provision of ecosystem services

Regulation functions provide the pre-conditions for all other functions: they describe "essential ecological processes and life support systems through biogeochemical cycles and other biospheric processes" (de Groot 2006, p. 177). Natural ecosystems provide habitat functions that conserve the biological and genetic diversity as well as evolutionary processes. The capacity of ecosystems to provide services that are related to habitat functions varies for different species groups and can be estimated in terms of the ecosystems general carrying capacity and the specific spatial needs of a species group (minimum critical ecosystem size). From a human perspective, natural ecosystems enable processes that contribute to human health, like reflection, spiritual enrichment and recreation, referred to as information functions. The carrier functions include providing space and resources like soil, water and air that are needed to support human activities like the cultivation of land. These functions usually trigger profound changes in ecosystems and their capacity to sustainably provide these functions in a long term. As production functions all direct services of value for anthropogenically processes are understood, for instance the production of biomass (e.g. as food), raw materials (fiber, timber, etc.), energy and genetic material (de Groot 2006).

De Groot refers to these ecological services of natural and semi-natural ecosystems and landscapes as "ecosystem functions" and their associated goods and services, implying an ecological, socio-cultural but also economic value of the services (de Groot 2006). A Common International Classification of Ecosystem Services (CICES) was developed in a European Program and differentiates four categories of ES ("provisioning services", "regulation services", "maintenance services" and "cultural services") (Haines-Young & Potschin; European Academies Science Advisory Council & Deutsche Akademie der Naturforscher Leopoldina 2015). For this thesis, the classification of de Groot is used in order to classify different services because the habitat function of landscapes is stressed. Landscape elements that contribute to the ecosystems and landscapes capacity to provide habitat services are especially important in GI, as the goal is to protect the local biodiversity and therefore habitats of high ecological quality are necessary.

During the mapping, the provided ES were recorded in order to assess the functional value of the GI features and to detect differences in the capacity of the four areas to provide biodiversity-related functions. The recorded ES were grouped into habitat services, regulation services and information services. Production functions were not assessed based on two main arguments: on the one hand, current discussions about the GI value of landscapes revealed that focusing on production functions of a landscape can waster down the value of landscape as habitat for wildlife due to a focus on the direct human use value of the landscape (see B.3.2.). Besides, the Rechnitzer Weingebirge fundamentally benefits humans as a cultural landscape, so that the presence of a wide range of production services can be hypothetically assumed.

In a first step, all ES that were provided by a GI features and that belonged to the same category of ES were summed in order to quantify the provided ES. To display the results, the number of provided ES in each category was calculated in the form of percentages. As an alternative, the areas of the GI features that provided different ES of the same category were summed and subsequently transformed into percentages. For instance, if a GI feature provided three ES of the same category, the area of the feature was multiplied with three, in order to display the features importance to the provision of different ES. The calculated percentages were finally presented in bar charts comparing all areas. The difference between both calculation methods is that in the first approach the provided ES were calculated disregarding their size. The second approach stresses large GI features; the larger the area of the GI feature the stronger to weighting of the ES that are provided by this feature. The area of GI features is especially relevant for their capacity to provide habitat and regulation services, whereas a calculation based on the counting of single ES equally weights features of different size, thereby stressing the importance of small GI features for the capacity of the landscape to provide ES. Assigning ES to more than one category of ES was avoided in order to avoid double counting of ES.

Table 7: Categories of ecosystem and landscape functions (classification according to de Groot) and the ES that were assigned to each category.

Groups of landscape functions	Provided ecosystem services
Habitat functions/ services	Patch size Enhancing connectivity Retreat function High species diversity Structural diversity Presence of rare/ threatened animal or plant species or plant communities Rare/ threatened biotope type in the mapping area Natural or artificial relief worthy of protection Population of old trees worthy of protection Scientific importance Stepping stone biotope
Regulation functions/ services	Soil protection Protection against soil washdown Protection against wind erosion Protection against immissions Regulation of the micro climate Pollination Regulation of pests
Information functions/ services	Characteristic biotope type in the mapping area Characteristic and beautiful natural scenery Suitability for recreation Cultural-historical importance Traditional land use type worthy of protection Scientific importance Environmental education Protection of medical plants Sight and noise protection

5. Evaluation tool: index of Green Infrastructure performance

To put the research results into practice, a tool was designed that can help to evaluate the performance of GI features in an area and furthermore allows an easy comparison between different areas. In index of GI performance can facilitate conservation efforts int that it can highlight GI features of high value but also GI features that need improvement. The index is based on the indicators of GI performance that were used for the functional assessment of GI features and thus grounds on the definition of GI that is used in the EU GI Strategy. The Nearest Neighbor Ratio that was computed in the former connectivity analysis is not an adequate indicator that can be used for the index of GI performance, because the ratio refers to the level of connectivity within an area including all present GI features. The presence or absence of the ES “networking function” was used to evaluate the contribution of a single GI feature to the landscape’s connectivity instead. In addition, the number of structures (e.g. shrub layer; tree layer) was added as another indicator. The index should be designed in a way that is can be adapted to the local priorities by the local experts. Therefore, a simple grading system was designed to assign points to GI features according to their performance.

The index was calculated for each GI feature that was recorded in the four areas. The indicators naturalness, number of structures, the networking function and the provided ES equally contribute to a high GI performance, therefore they were equivalently weighted in the calculation. The naturalness is the main indicator for botanical richness. The richness of structures like plant stems is specifically relevant for the diversity of insects, they provide e.g. nesting holes (Stiftung für Mensch und Umwelt). The higher the level of naturalness, the more points were added to the total value of a GI feature and each structure equals one point. If the GI feature provided the ES “networking function”, five points were added; no points were added in the opposite case. For the provision of ES, one point was added for each recorded ES. The value that was based on the number of ES instead of the area weighted values were used in order to emphasize the importance of GI features of each size. A point system was chosen to measure the results instead of a scaling system (for example from 0 – 1). The main reason was that the absolute values would have need to be transformed, for instance into percentages, to compare the results. Like that, results become less accurate. In addition, a point system is easy to grasp and to apply in a practical context, which is the main idea of the index.

The following table summarizes the calculation scheme of the GI index.

Table 8: Calculation scheme of the index of GI performance.

Key factors of Green Infrastructure	Indicators		Point system					
Naturalness	1) Level of naturalness of a GI feature	2) Number of structural elements per GI feature	*Level of naturalness (N)*	semi-natural	cultural assissted	highly inter-vened	trans-formed	
			Points	5	4	3	2	
			Number of structures (S)	8	…	3	2	1
			Points	8	…	3	2	1
Connectivity	Presence or absence of the ES "networking function"		*Connectivity (C)*	yes	no			
			Points	5	0			
Provision of ecosystem services	Number of provided ES per GI feature		*Ecosystem services (E)*	15	…	3	2	1
			Points	15	…	3	2	1
Index of GI performance	Sum of points of all indicators		GI index = $\sum N+S+C+E$					

GI features contributed to the connectivity or the naturalness of the areas to a varying degree. It is important to state that GI features does not need to fulfil all three key factors to be valuable for the local GI network. A hedge might be an important GI feature due to its richness in native species and attached flowering stripes even though it does not connect specific landscape elements. Adding the points (additive index) instead of multiplying them prevents a value of “0” in case one of the indicators is not fulfilled (Maier 2010). Still, GI features that strongly contributed at all indicators and with high points reached most points and were thereby identified as especially valuable features that should be protected. A map that includes the results of the GI index helps to locally direct management measures in order to protect especially valuable GI features and to enhance the quality of features of a lower value. Areas where GI features with low values are clustered can be identified and actions to increase their performance can be initiated. Single GI features that reach high values can work as positive examples and model features that incentivize the implementation of similar GI features in other areas.

E | RESULTS

1. Landscape structures and functions in the Rechnitzer Weingebirge

1.1. Disturbance

The following map visualizes the anthropogenic disturbances that were recorded for landscape elements in the four areas that were investigated. The different disturbance grades (indicated with a graded colour scale from green for a week disturbance regime to red for a strong disturbance regime) imply strength and periodicity of the deprivation of biomass and ploughing. More concrete, the grades indicate 1) episodic disturbance, sometimes with a strong deprivation of biomass, 2) regular disturbance with strong deprivation of biomass but without ploughing, 3) regular disturbance in short intervals partially with non-periodic ploughing, 4) strong and regular disturbance in short intervals partially with a total deprivation of the existing biomass and with periodic ploughing (Wrbka et al. 2015).

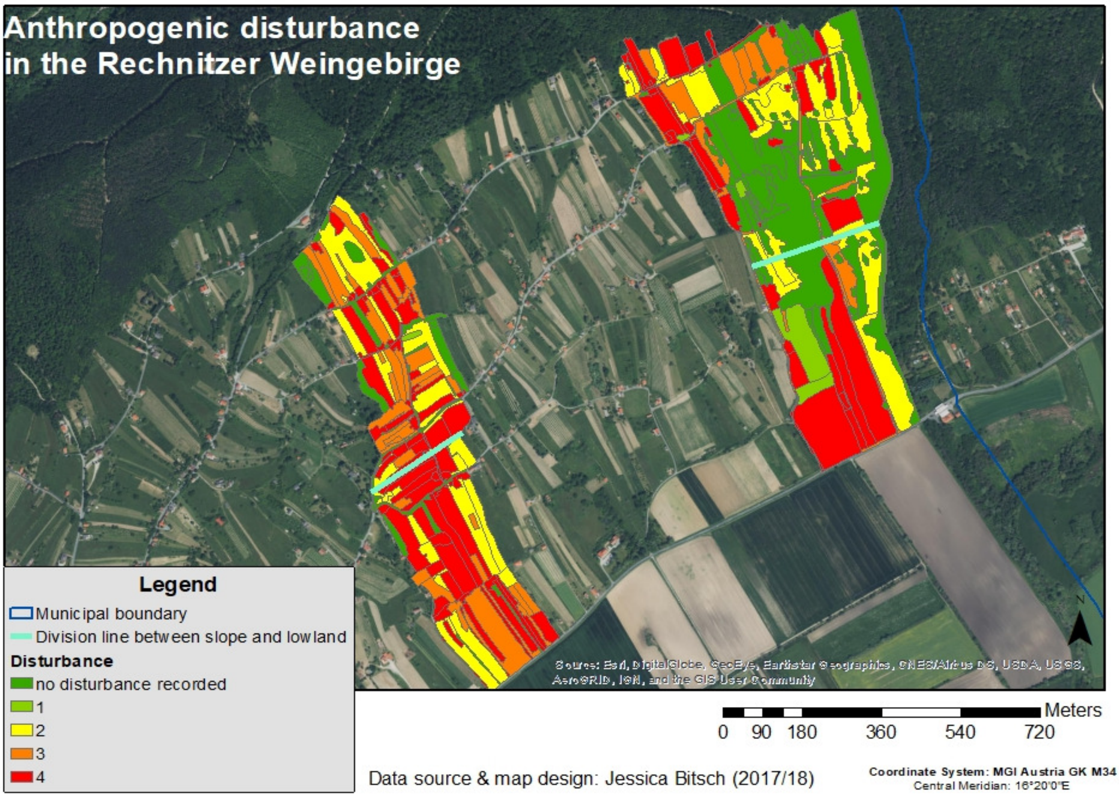


Figure 11: Degree of anthropogenic disturbance of landscape elements in the four areas GB_lower/upper and R_lower/upper.

Which landscape elements were affected by anthropogenic disturbances in GB_lower/upper and R_lower/upper? (figure 12)

The map shows that GB_upper and GB_lower were buffered by a long strip of undisturbed forest at the Green Belt border. The forest was structurally connected to large features (partially small patches of forest) in GB_upper and GB_lower, which were equally spared of anthropogenic disturbances. High disturbance rates for GB_lower were found on large fields close to the municipal road. A few heavily disturbed features were also present in GB_upper and mainly stretched along the western side of the area farther from the Green Belt. Especially in GB_upper, large features with no or low disturbances were dominant. Most of the features with high disturbances were clustered.

In contrast, R_lower and R_upper were interspersed by highly disturbed features. The landscape structure was formed by features in the form of small strips. Due to the shape of the feature they are more likely to be affected by other landscape features. In R_upper a small amount of minimally disturbed features was present, whereas barely any such features were found in R_lower.

Generally, undisturbed features covered a considerably larger area in GB_upper and GB_lower; these features were moreover often connected structurally. A high structural connectivity was due to the existence of small forested areas close to the Green Belt. R_lower and R_upper were strongly affected by anthropogenic disturbances and moreover, the few minimally disturbed features that existed were located a considerable distance from one other and thereby harder to access by animals. These findings hint towards the importance of GI features to increase the permeability and general quality of the landscape matrix in R_lower and R_upper.

1.2. Green Infrastructure features in vicinity and in distance from the Green Belt

The stacked bar chart shows all GI features that were recorded in the landscape sections GB and R. GI features are indicated on the x-axis, the covered area is printed on the y-axis.

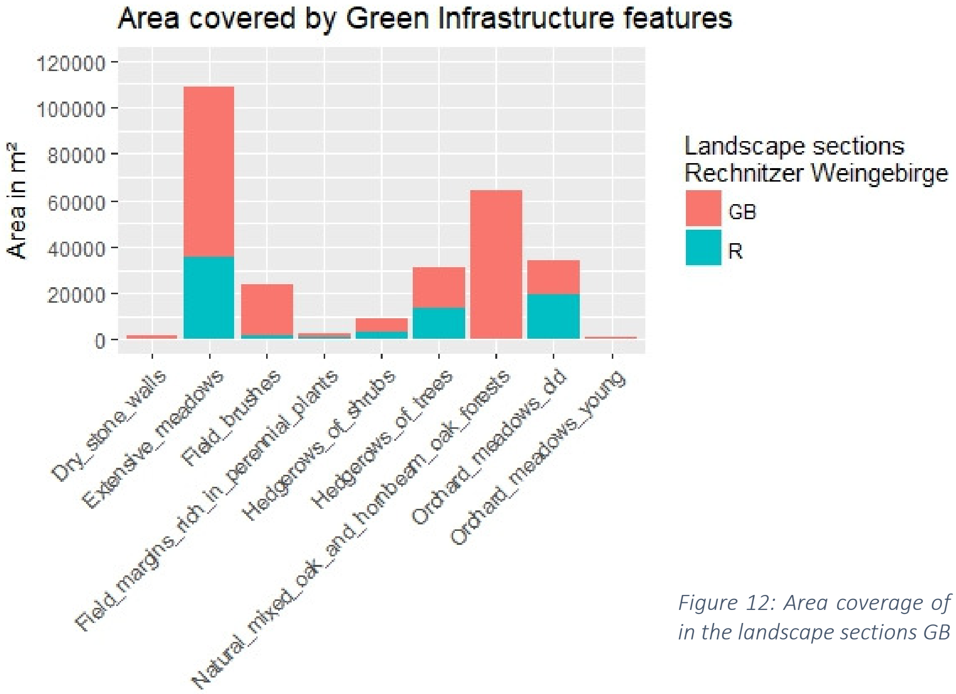


Figure 12: Area coverage of GI features in the landscape sections GB and R.

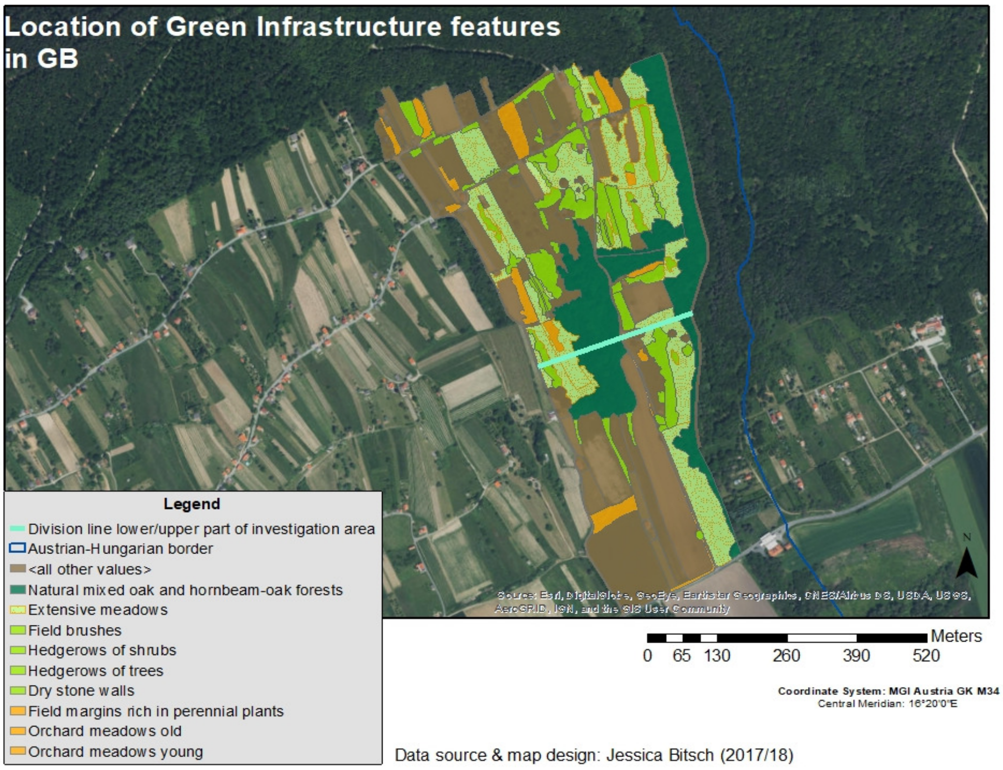
How much area did the Green Infrastructure features cover in the landscape sections GB and R? (figure 13)

The bar chart clearly depicts the differences concerning the areas that were covered by different GI features in GB (GB_upper and GB_lower) and R (R_upper and R_lower). For one thing, some of the recorded GI features, like dry-stacked stone walls, in general are small features, whereas others, for instance forested areas, tend to be large. In general, the area of GI features in GB was significantly larger compared to the area in R. Extensive meadows were the dominant GI feature in GB (73.500 m²) and in R (35.472 m²). The second largest area in GB was covered by natural mixed oak and hornbeam oak forests (64.022 m²). No forested features existed in R. Another obvious difference between GB and R was the abundance of field brushes: they covered 22.704 m² in GB and, a significantly smaller area, 1.426 m² in R. In contrast, hedgerows of trees covered a similar area in both landscape sections: 17.997 m² in GB and 13,170 m² in R. The area covered by old orchard meadows in R (19.024 m²) even exceeded the one in GB (15.085 m²). Hedgerows of shrubs covered small areas in both landscape sections as well: 5.553 m² in GB and 3.473 m² in R. Dry-stacked stone walls, field margins rich in perennial plants and young orchard meadows only covered very small parts of GB and R (each under 1.000 m² except for field margins rich in perennial plants with 1.246 m² in GB).

2. Quantitative analysis of Green Infrastructure features

2.1. Density and localisation

The maps show the location of GI features in GB_lower/upper and R_lower/upper. The three functional groups of GI are indicated with specific colour (see legend). The landscape elements that were not GI features (<all other values>) form the landscape matrix.



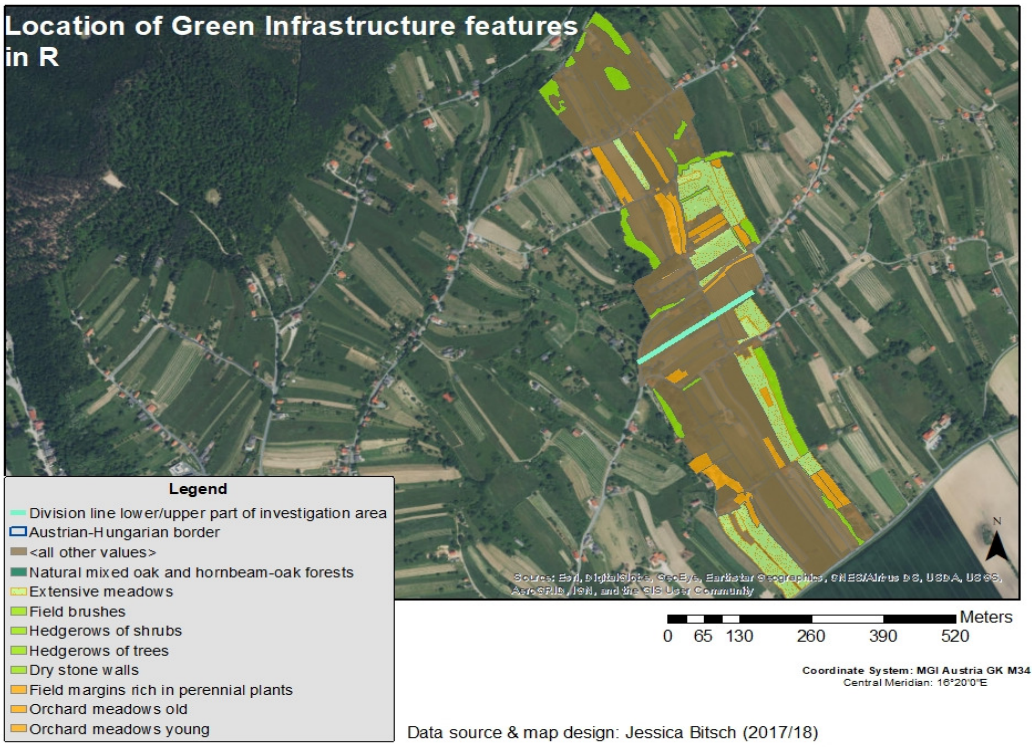


Figure 13: GI features in all areas, displayed according to the three functional groups of GI.

How rich in Green Infrastructure features were GB_lower/upper and R_lower/upper? Where were the Green Infrastructure features of the three functional groups located in the areas? (figure 14)

The map visually underlines the differences in the abundance and size of GI features in all areas that were investigated. It furthermore shows if the GI features were clustered or dispersed in the areas and where they were exactly located.

GB_upper was especially rich in habitat features (extensive meadows and natural forests). In general, the highest number of GI features could be found in this area. Forest features stretched into the cultural landscape from the Green Belt and formed a network with field brushes, hedgerows of trees and hedgerows of shrubs. An especially large number of open habitat features were found clustered close to the Green Belt. In R_lower and R_upper, extensive meadows were clustered together and only present in specific sections of the areas. A high number of connectivity features was found in GB_upper. Moreover, the features were equally distributed across the whole area. In GB_lower, connectivity features were only found close to the division line; the area close to the municipal road was without connectivity features, that are important for species to be able to cross disturbed features in this area. The connectivity features in GB_lower were mainly located close to larger habitat features, which is positive, because the connectivity features can buffer habitats against the intensively used landscape matrix. In R_upper, connectivity features were found interspersed all over the area and were often not attached to habitat or extensive use features. The ability of species to use these GI features as stepping stones will depend on their level of mobility and the intensity and frequency of disturbances in the landscape matrix between these features. In R_lower, only a few connectivity features were found. Extensive use features were similarly abundant in all areas, except for GB_lower, where only two features were found.

Generally, GI features seemed best connected in GB_upper. Dry-stacked stone walls were found in all four areas. The difference between them was that they mainly occurred as clearance cairns in the interior of hedges (they are signs of old land use practices) in GB_upper and GB_lower, whereas in R_lower and R_upper they mainly functioned as garden walls. The map reveals that most of the GI features in both areas in GB tended to be larger compared to the areas in R, with the effect, that edges of landscape elements were less abundant than cores in areas in GB. In addition, one especially large extensive meadow, one of the meadows managed by Franz Ulber, existed in GB_lower. Extensive meadows in GB_upper in parts were structurally connected. In R_upper and R_lower, GI features, like most landscape elements in these areas in general, were very slim and above that, they were interspersed in the landscape matrix. This led to a higher distance between GI features, although most of the extensive meadows were clumped in one edge of the area.

2.2. Richness in different functional groups of Green Infrastructure

The four bar charts below show the area that is covered by the different functional groups of GI for each of the four areas that were investigated. In addition, the area that was covered by the landscape matrix is presented. Different colours were assigned to the functional groups for a better visualization of the results. The percentages on the y-axis refer to the surface area of the respective area.

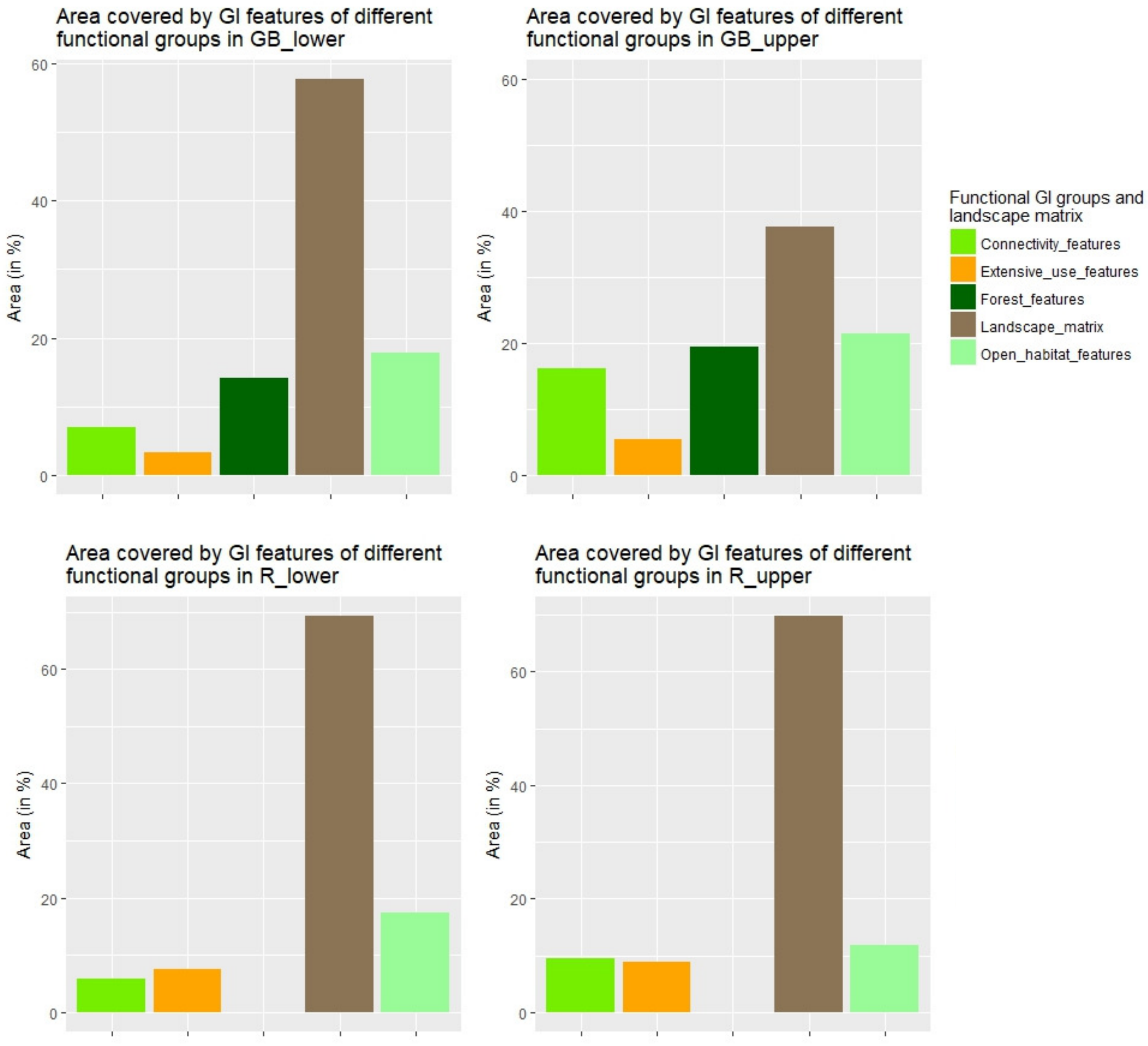


Figure 14: Area coverage of the three functional groups of GI and of the landscape matrix.

Which functional groups of Green Infrastructure predominated in GB_lower/upper and R_lower/upper? (figure 15)

The areas were compared using percentages instead of absolute area, to have more easily comparable results.

The bar charts visualize at first glance, that the landscape matrix (all features that were not defined as GI features) covered the largest parts of all areas that were investigated (GB_lower: 58 %[31], GB_upper: 38 %, R_lower: 69 %, R_upper: 70 %). In GB_upper, however, GI features covered 62 % of the area. 16 % of connectivity features, 19 % of forest features and 21 % of open habitat features respectively were distributed in GB_upper. Extensive use features covered the smallest area with 5 %. In GB_lower, a similar distribution was found. The only difference was that the connectivity features only covered 7 % of the area. Likewise, forest features and open habitat features covered slightly smaller areas at 14 % and 18 % respectively. Extensive use features covered the smallest area at 3 %. Both in R_lower and R_upper the landscape matrix clearly outweigthed the GI features. Open habitats covered 18 % of the area in R_lower and 12 % of R_upper. Forest features did not exist in these areas at all. R_lower was slightly richer in open habitat features at 17 % compared to 11 % in R_upper. The connectivity features and extensive use features covered a similar area: 5 % connectivity features and 8 % extensive use features in R_lower and 9 % connectivity features and 8 % extensive use features in R_upper.

As a general pattern, small areas of forest and open habitats were the most dominant GI features in GB_upper and GB_lower. Furthermore, connectivity features covered only a slightly smaller area compared to the habitat features in GB_upper. Extensive use features were the least dominant functional group of GI features. In R_lower and R_upper, in contrast, open habitat features, connectivity features and extensive use features covered significantly smaller areas. The only exception were extensive use features, that had a higher share of area. R_lower and R_upper had very similar functional groups of GI features with the only exception being open habitat features. They roughly covered 6 % more of the area in R_lower than in R_upper.

[31] All values in the results chapter are rounded.

2.3. Predominant Green Infrastructure features

The following bar charts present the area percentages of GI features in GB_lower/upper and R_lower/upper. GI features are indicated with different colours. The percentages that are indicated on the y-axis refer to the area that all GI features cover in the respective area.

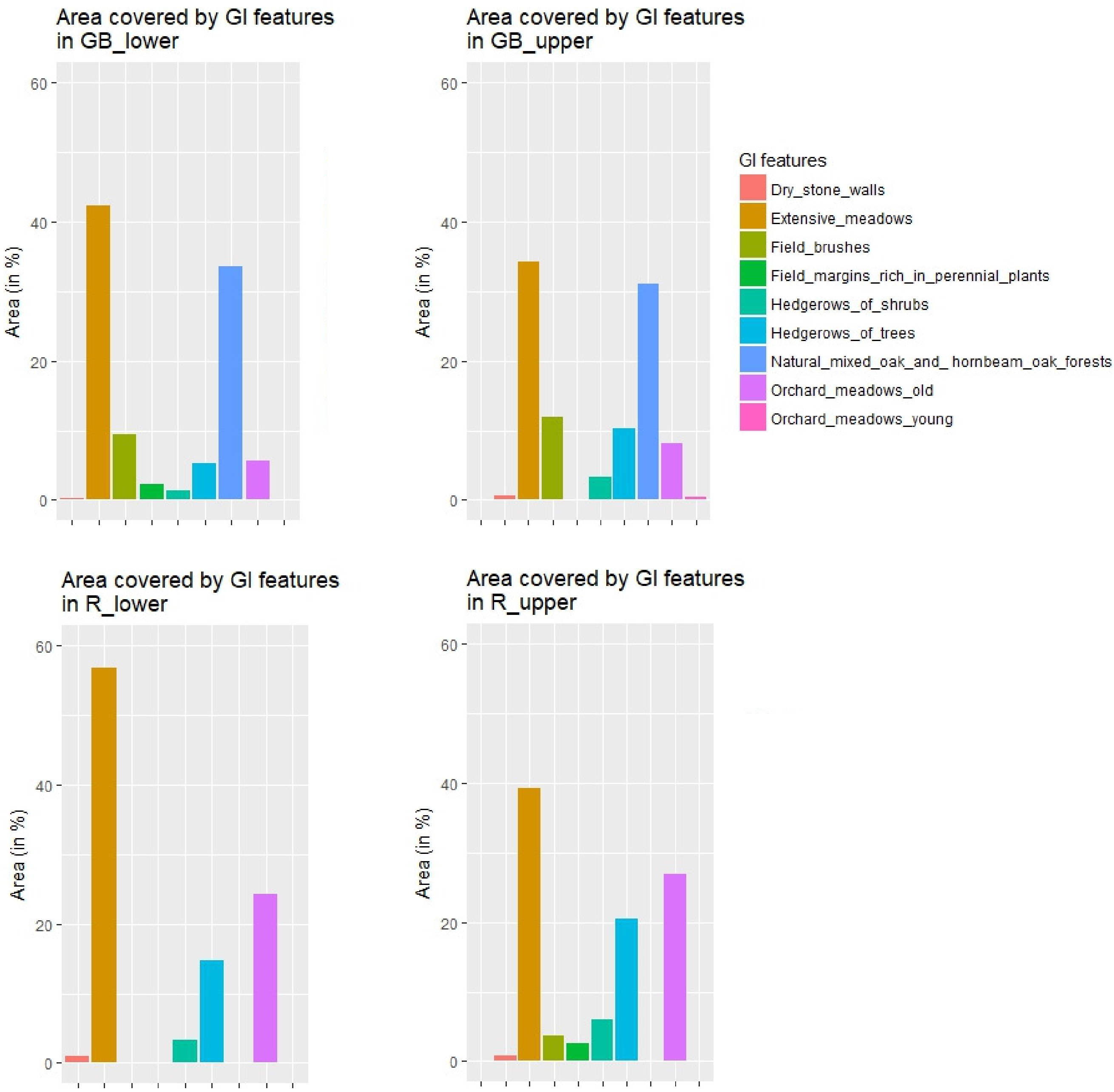


Figure 15: Area coverage of GI features in all areas.

How large were the areas that were covered by the different Green Infrastructure features in GB_upper/lower and R_upper/lower? (figure 16)

The area percentages presented in the figures 18-21 do not refer to the total area of the areas that were investigated, but to the area that was covered by the entirety of all GI features.

Extensive meadows had the highest share of area in all four areas that were investigated. The highest values were found in R_lower with 56 %. Extensive meadows covered smaller areas in GB_upper and R_upper at 42 % and 39 %. The lowest values were found in GB_upper, where extensive meadows represented only 34 % of the total area that was covered by habitat features. Natural mixed oak forests covered 34 % in GB_lower and 31 % in GB_upper, but neither existed in R_lower nor in R_upper. Old orchard meadows covered the second largest area after extensive meadows in R_lower with 24 % and likewise in R_upper with 27 %. In contrast, this GI feature was notably less present in GB_lower and GB_upper with 6 % and with 8 %. Young orchard meadows only occurred in GB_upper and R_upper; they covered very small areas under 2 % (the low value could not be displayed in the bar chart in the case of R_upper). Field margins rich in perennial plants were only present in the areas GB_lower and R_upper and had very small shares of area (roughly 3 %). Field brushes covered 12 % in GB_upper and 9 % in GB_lower; they were less present in R_upper (4 %) and were not found in R_lower at all. Hedgerows of trees had a high share of area in R_lower at 15 % and in R_upper at 21 %. They represented a smaller area of the area covered by GI features in GB_upper and GB_lower at 11 % and 5 %. Hedgerows of shrubs covered a smaller area compared to the hedgerows of trees in all areas (3 % in GB_upper, 1 % in GB_lower, 6 % in R_upper and 3 % in R_lower). Dry-stacked stone walls occurred in all areas but covered less than 1 % due to their generally small size.

3. Assessment of the functional value of Green Infrastructure features

3.1. Naturalness of features

3.1.1. Habitat features

The maps 23 and 24 show the level of naturalness of habitat features in all areas. The different levels are indicated on a graded colour scheme (naturalness: dark green=high; purple=low).

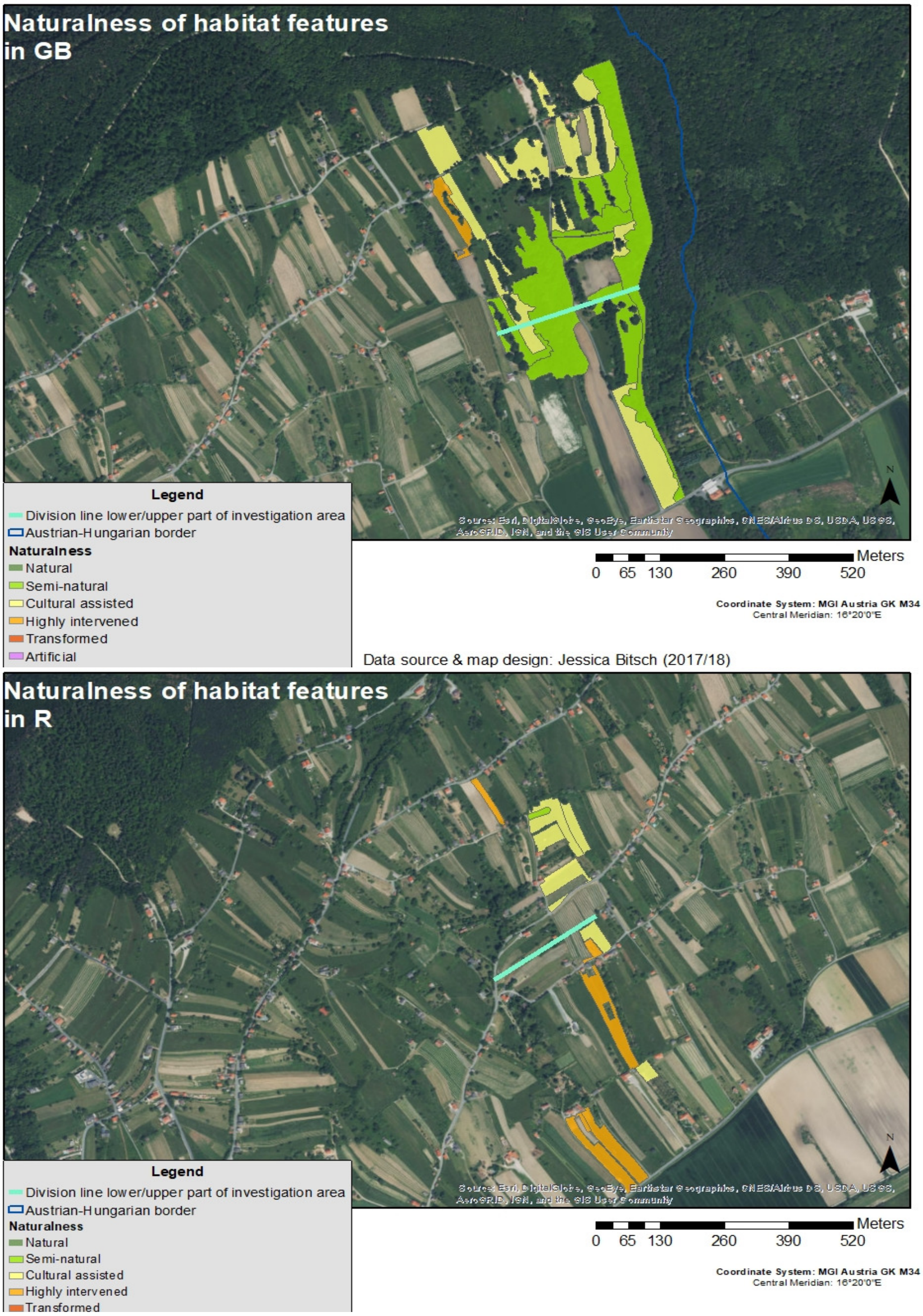


Figure 16: Levels of naturalness of habitat features in all areas.

Which levels of naturalness did the habitat features (open and forested) in GB_lower/ upper and R_lower/upper have? (figure 17)

The naturalness of habitat features was highest in GB_upper. Semi-natural forest features were the most dominant GI feature with regards to their size. Besides the high naturalness of forested areas, several semi-natural extensive meadows were found in GB_upper. Their especially high level of naturalness was due to patches with rocky underground on which with typical vegetation of dry grasslands could establish and provide habitat for highly specialised species. Besides, most extensive meadows were of a “cultural assisted” the level of naturalness, indicating that their type of management allows for a richness in structural elements and different niches for species. The only (negative) exception was one meadow, that faced the side towards the centre of the cultural landscape, that was classified “highly intervened”. GB_lower was astonishingly poor in open habitat features: the only two semi-natural meadows (one of them quite large) that were recorded were close to the upper part of GB. Furthermore, one especially large cultural assisted meadow (managed by Franz Ulber) were found at the municipal road. Besides, semi-natural, forested areas occurred in GB_lower; they stretched into the area from GB_upper. Only one small semi-natural extensive meadow was recorded in R_upper. As a general tendency, habitat features in R_upper were mostly classified as cultural assisted. In R_lower, most of the present open habitat features were highly intervened.

Did the distributions of naturalness of open habitat features[32] differ significantly between the areas? (figure 18)

The following stacked bar chart summarizes the key findings on the naturalness of open habitat features in all four areas that were investigated. The chart compares the distributions of the different levels of naturalness that were assigned to all recorded features in the form of percentages. The percentages are based on the summed share of area of all GI features of the same level of naturalness. The lowercase letters on top of each bar indicated similarity or dissimilarity of the respective area with the distributions of the three other areas, based on the results of the Wilcoxon Rank Sum Test.

The distribution with the highest percentage of semi-natural open habitat features was the one of GB_lower. In this area, semi-natural features covered 43 % of the total area covered by open habitat features. Semi-natural features positively contribute to the capacity of a landscape to provide habitat for different species. In GB_upper, semi-natural features represented 22 % of the total area covered by open habitat features. In R_upper, only a small percentage of semi-natural

[32] Forest features were not included into the pairwise comparison of naturalness distributions, because forest features do not exist in R_upper and R_lower.

features occurred at 3 %, whereas in R_lower no semi-natural features existed at all. Cultural assisted features had a slightly larger share of area than the semi-natural features in GB_lower at 57 %. In contrast, GB_upper was clearly dominated by cultural assisted features at 70 %. R_upper was the area where cultural assisted features had the highest share of area at 87 %. In R_lower, only 16 % of the total area that was covered by open habitat features were cultural assisted. Highly intervened open habitat features were most abundance in R_lower; they covered 82 %. Open habitat features of the lowest level of naturalness represented 11 % of the area covered by features of all levels in R_upper and 6 % in GB_upper. No highly intervened features were recorded in GB_lower.

The distributions of different levels of naturalness were significantly similar between the areas GB_lower, GB_upper and R_upper. Moreover, the distributions of R_upper and R_lower expressed a significant similarity. In R_lower, a notably larger area was covered by highly intervened features in comparison to the other areas. The similarity with the distribution in R_upper might be due to a certain percentage of highly intervened features and a comparably small percentage of semi-natural features. Thus, the landscape quality in the four areas concerning the level of naturalness of the present open habitat features was similarly high in GB_lower, GB_upper and R_upper, and significantly lower in R_lower.

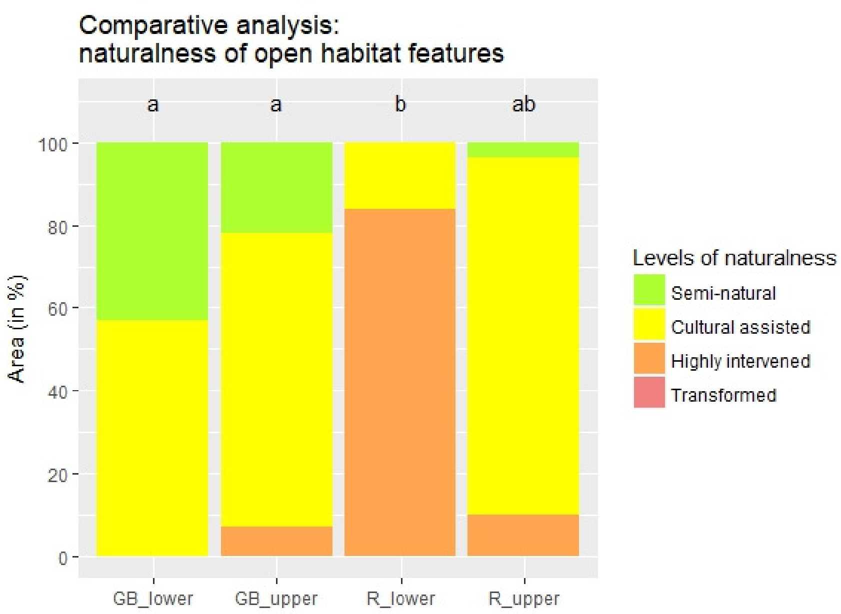
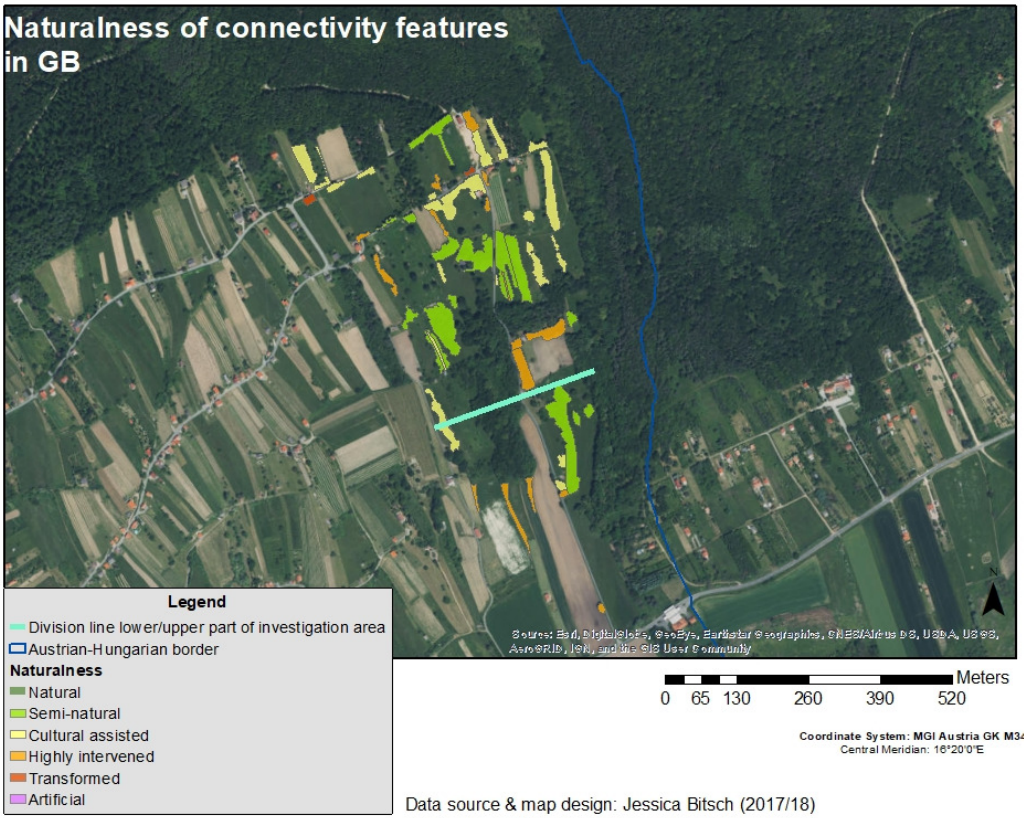


Figure 17: Dis/similar area coverages of the levels of naturalness of open habitat features in all areas.

3.1.2. Connectivity features

The following maps show the levels of naturalness of all connectivity features that were recorded in GB_lower/upper and R_lower/upper.



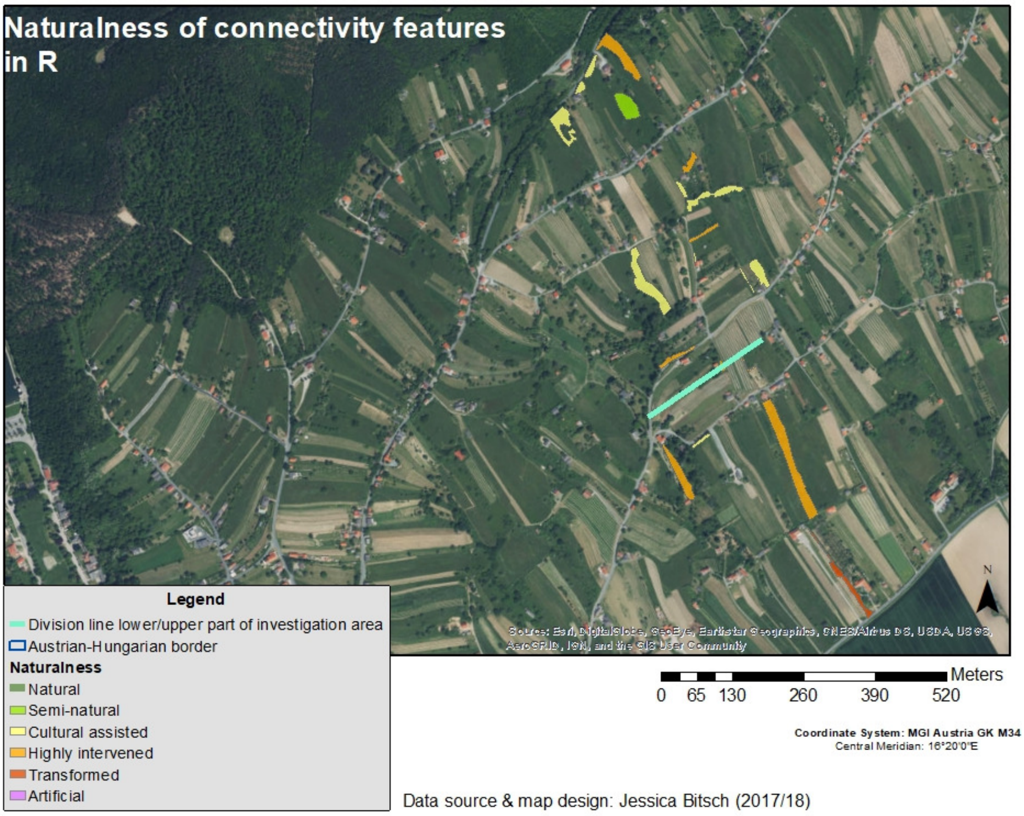


Figure 18: Levels of naturalness of connectivity features in all areas.

Which levels of naturalness did the connectivity features in GB_lower/upper and R_lower/upper have? (figure 19)

The ArcGIS maps clearly visualize that GB_upper is significantly richer in connectivity features compared to the other areas. This finding clearly matches with the hypothesis that the Green Belt and forests to the North of the area increased the amount of field brushes and hedgerows in the surrounding landscapes. Connectivity features in GB_upper were of especially high naturalness, roughly half of them were semi-natural. GB_lower and R_lower were clearly poorer in connectivity features, hinting towards a more intense use of the landscape. A generally lower number of the habitat features in GB_lower and R_lower increases the importance of connectivity features for species to cross the anyways disturbed landscape matrix and to connect the habitat patches with each other. In R_upper, mainly cultural assisted and highly intervened connectivity features were recorded.

In general, to classify hedgerows as cultural features the presence of dry and warm conditions at the edges of the hedges would have been needed. The different layers of vegetation favour the occurrence of different species, thereby increasing the biodiversity of the hedge.

Did the distributions of naturalness of connectivity features differ significantly between the areas? (figure 20)

Figure 27 shows that the distributions of GB_lower and GB_upper are to a large extent dominated by semi-natural features; they nearly covered 60 % of the area covered by connectivity features of all levels of naturalness in GB_lower and 43 % in GB_upper. Even though GB_lower had very few connectivity features, one large semi-natural connectivity feature strongly influenced the distribution. In R_upper, 12 % of the area covered by connectivity features were semi-natural. R_lower was the only area where no semi-natural features existed. Cultural assisted features dominated the distribution of the naturalness of connectivity features in R_upper at 59 %. In GB_upper, the cultural assisted features covered a similar area like semi-natural features at 38 %. In contrast, cultural assisted features only covered a small percentage of area in GB_lower at 19 % and in R_lower at 2 %. Highly intervened features had an obvious maximum of nearly 80 % in the distribution of R_lower, indicating a generally high level of intensification compared to the other areas. Besides, they represented a similar share of area in the other areas: 24 % in GB_lower, 18 % in GB_upper and 29 % in R_upper. In contrast to the open habitat features, whose levels of naturalness ranged from semi-natural to highly intervened, transformed connectivity features existed in two of the areas. 18 % of the total area that was covered by connectivity features in R_lower were transformed, e.g. due to a dominance of non-native species; thereby their functional value as GI features was reduced significantly. Furthermore, about 1 % of the features in GB_upper was transformed as well, but this small amount was compensated by the high percentage of features of a higher level of naturalness.

As a consequence, the distribution of naturalness of connectivity features in R_lower was significantly dissimilar to the other three areas, which, by contrast, all had similar distributions. In contrast to habitat features, the level of naturalness of connectivity features is not the essential criterion, because most species use these features only temporarily. Therefore, connectivity features do not need to sustain species populations and in addition, a smaller size does not necessarily lead to a decrease in the capacity of features to function as connecting elements. Furthermore, the natural quality of hedgerows and field brushes can easily be enhanced with a focused management.

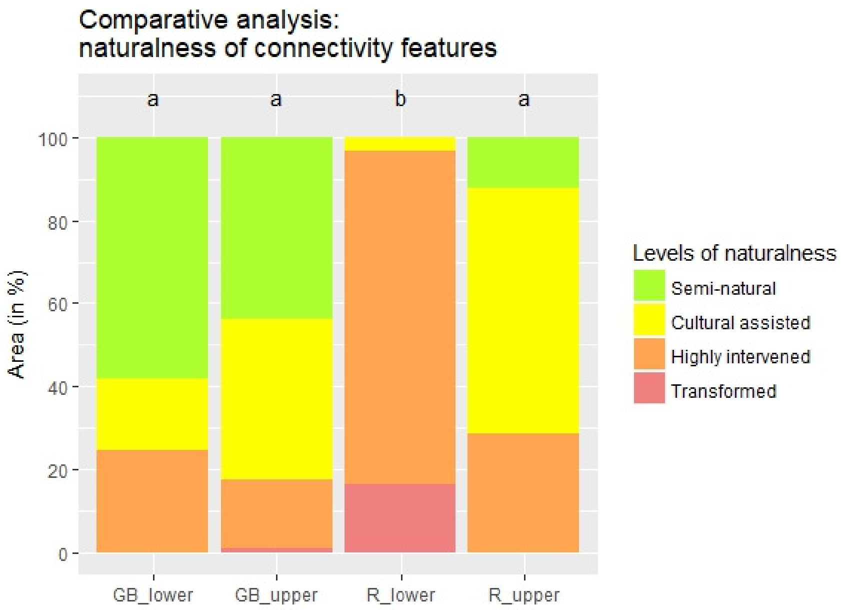
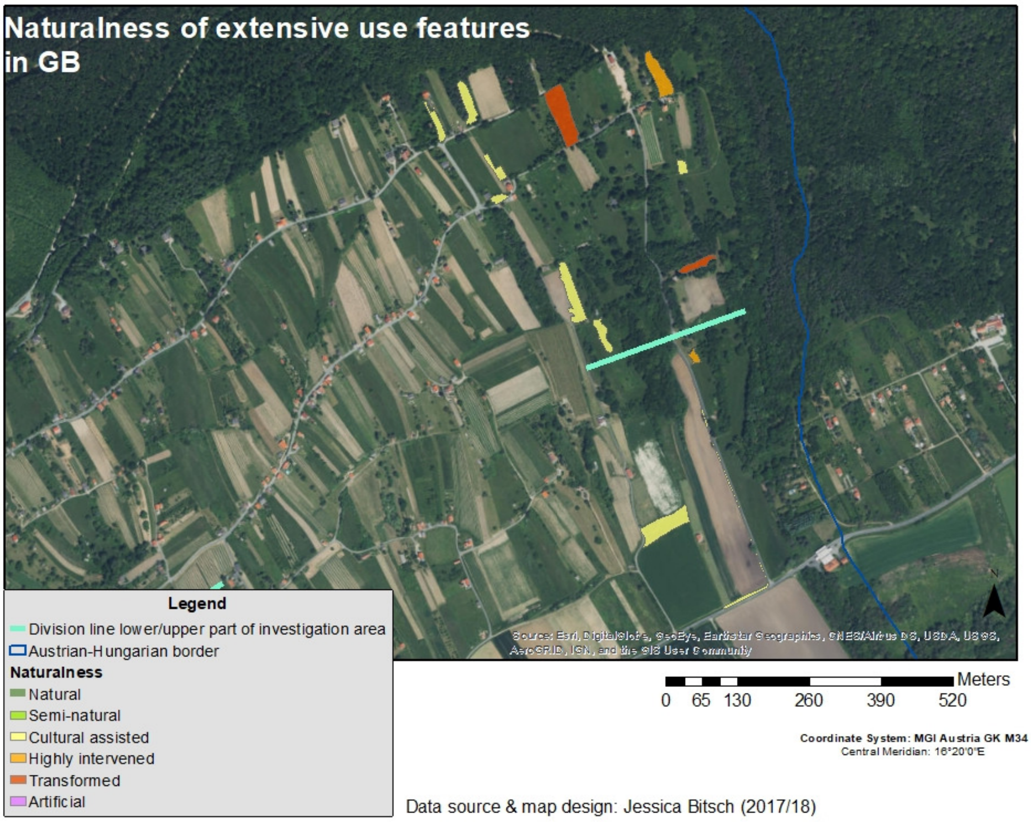


Figure 19: Dis/similar area coverages of the levels of naturalness of connectivity features in all areas.

3.1.3. Extensive use features

Figures 29 and 30 show the levels of naturalness of all extensive use features that were recorded in GB_lower/upper and R_lower/upper



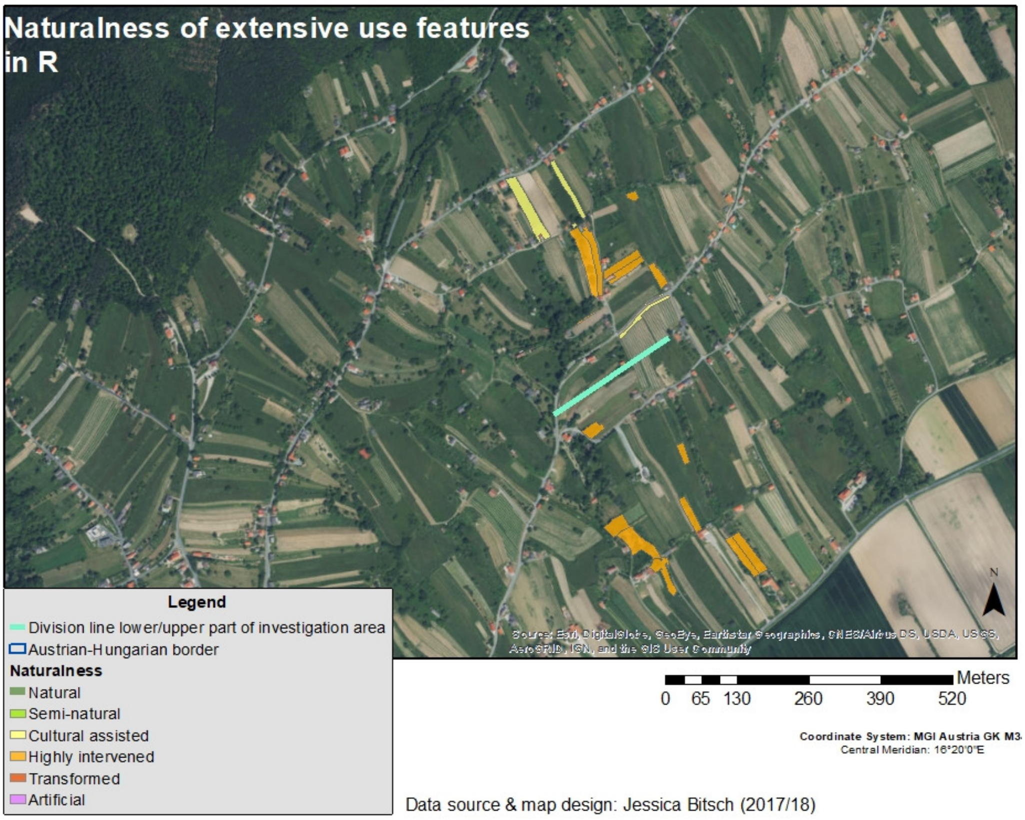


Figure 20: Levels of naturalness of extensive use features in all areas.

Which levels of naturalness did the extensive use features in GB_lower/upper and R_lower/upper have? (figure 21)

Of all functional groups, the extensive use features were least natural, because the human exploitation of natural resources (even though in an extensive way) are the priority. Orchard meadows nevertheless have a high value for the local species by offering habitat-like structures, especially a half-open landscape pattern with a variety of niches. Field margins that are rich in perennial plants were recorded close to extensive meadows, where a conservation-oriented management takes place. No features with a semi-natural level of naturalness were recorded in the category “extensive use features”, because these features are often characterized by a regular disturbance and the influence of, for instance, spraying agents. Only two cultural assisted features and one highly intervened feature were recorded for GB_lower, which is, in general, characterizes by large landscape elements and a homogenous landscape pattern. GB_upper was richest in cultural assisted features but contained highly intervened and even transformed features as well. In R_upper, a similar number of cultural assisted and highly intervened features existed, whereas R_lower was exclusively dominated by highly intervened features.

Did the distributions of naturalness of extensive use features differ significantly between the areas? (figure 22)

As well as for the functional groups “open habitat features” and “connectivity features”, the distributions of naturalness of extensive use features of GB_lower, GB_upper and R_upper were similar, whereas the distribution of R_lower significantly differed from the other areas. In the case of extensive use features, R_lower still had a similar distribution with GB_upper, hinting towards a lower level of naturalness of most extensive use features in GB_upper compared to the ones in GB_lower and R_upper. Cultural assisted features represented 90 % of the area covered by extensive use features of all levels of naturalness in GB_lower. They only represented half of this area in GB_upper and R_upper, respectively 40 and 50 %. All extensive use features in R_lower were highly intervened. They covered nearly 60 % in R_upper, but only 8 % in GB_lower and 16 % in GB_upper. GB_upper was the only area with transformed extensive use features at 30 %. A management that enhances the natural quality of extensive use features is especially desirable for GB_upper and R_lower, but also for R_upper.

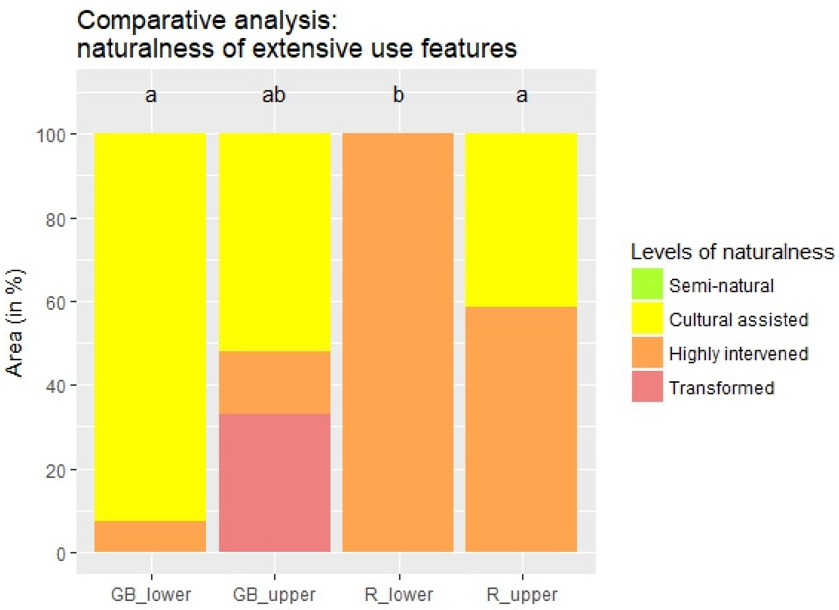


Figure 21: Dis/similar area coverages of the levels of naturalness of extensive use features in all areas.

3.1.4. All Green Infrastructure features

The following map shows the level of naturalness of all GI features in GB_lower/upper and R_lower/upper.

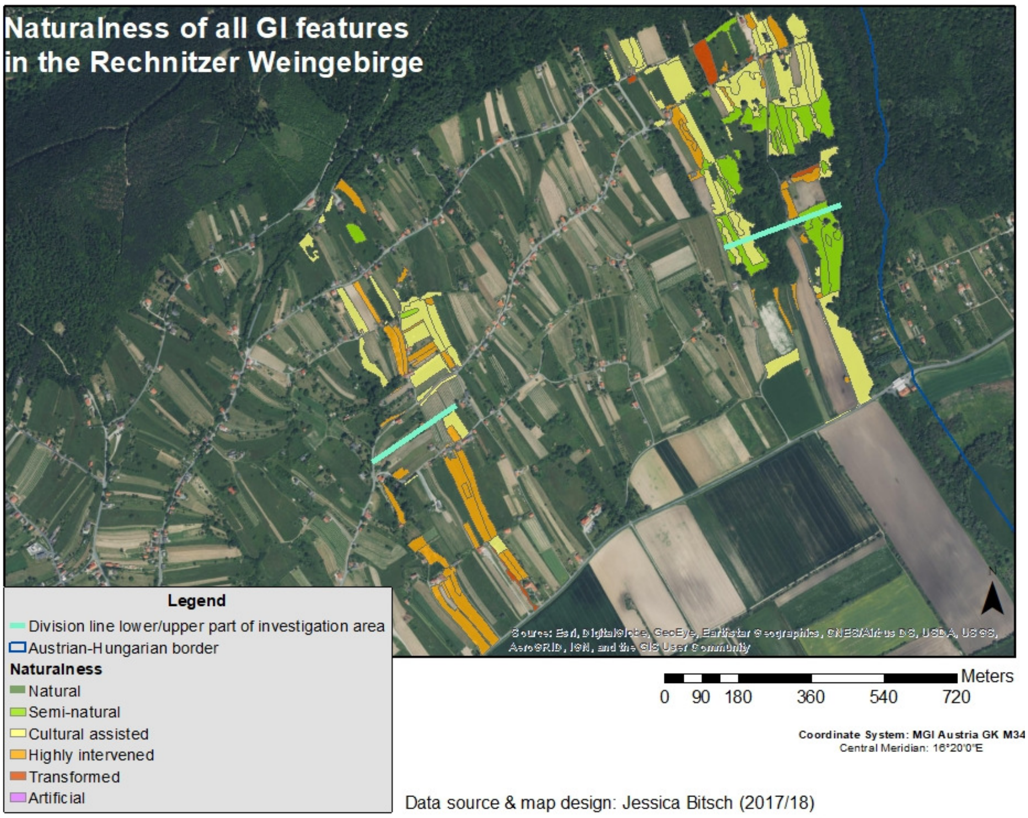


Figure 22: Levels of naturalness of all GI features in all areas.

Which levels of naturalness did all Green Infrastructure features in GB_lower/upper and R_ lower/upper have? (figure 23)

Taking all functional groups of GI into consideration, a similar pattern was noticed with regards to the naturalness of GI features, compared to the pattern when only one of the functional groups was focused. GB_upper was characterized by the largest number of semi-natural GI features, mainly because of the large number of habitat features which were mainly semi-natural. GB_upper is furhtermore characterized by a large number of cultural asissted features. However, together with R_lower, transformed features were recorded as well. Compared to GB_upper, GB_lower was significantly poorer in GI features, even though the GI features that existed were especially large. What became obvious was that not many small features were interspersed into the landscape matrix, emphasizig the importance of a conservation management of the existing habitat features. Both in R_upper and R_lower small and long GI features were dominant; in R_upper levels of naturalness of features ranged from semi-natural to highly intervened whereas in the case of R_lower nearly excluseively highly intervened features were present. These findings seem to support the hypothesis that GI features should be of a especially high natural quality in

GB_upper and GB_lower. However, features bordering the Green Belt would favourably have a higher level of naturalness in order to facilitate the dispersal of species from the corridor into the cultural landscape. The low natural quality of single transformed GI features is compensated by the general high abudnace and quality of GI features, whereas especially in R_lower and GB_lower measures to improve the quality of the landcape for species should be taken.

Were the distributions of naturalness of Green Infrastructure features significantly different between the areas? (figure 24)

Comparing the distributions of naturalness of all GI features between the four areas revealed an even more clear ranking of the areas. GB_lower and GB_upper were characterized by the highest percentages of semi-natural features at 28 % and 25 %. In R_upper, semi-natural features existed to a smaller extent of 5 % of the total area that was covered by GI features of all levels of naturalness. In R_lower, no semi-natural features contributed to the distribution. Cultural assisted features had similar shares of area in GB_lower, GB_upper and R_upper at 70 %, 60 % and 65 %. R_lower had the smallest percentage of cultural assisted features with 10 %. GI features of the lower levels of naturalness “highly intervened” and “transformed” were found in all areas, but with a clear maximum in R_lower with a percentage of 88 % for the highly intervened features. The area where highly intervened features covered the second largest area after R_lower was R_upper, where these features covered 30 %. In GB_lower and GB_upper, features that are highly intervened only represented 4 % and 8 % of the area covered by features of all levels of naturalness. Besides, transformed features had the same share of area of 3 % in GB_upper and R_lower.

Comparing the distributions of naturalness of GI features (all functional groups included) revealed a clear pattern of similarity and dissimilarity. The naturalness of GI features in GB_lower was significantly similar to the naturalness of such features in GB_upper but also to features in R_upper. However, GB_upper and R_upper did not have similar distributions of naturalness, even though the percentages gave a different impression; R_upper, with a quite small percentage of semi-natural features but a considerable percentage of highly intervened features seemed closer to the naturalness pattern of GI features in GB_upper. They were of slightly lower natural quality than features in GB_lower; therefore, similarity between GB_upper and R_upper was to be detected more likely. The distribution of naturalness of R_lower significantly differed from all other areas, being characterized by notably less natural GI features.

In general, GB_lower appeared to area where GI features had the highest natural quality, nearly only cultural assisted and semi-natural features existed. A factor that probably had a strong impact on the distribution were two large extensive meadows that are managed by Franz Ulber.

A large number of extensive meadows and connectivity features with a high natural quality in GB_upper have a strong positive impact on the ecological quality of this area. Whereas R_upper probably profited from the forests at the Northern border, R_lower was more exposed to a higher degree of agricultural intensification and was therefore mainly dominated by GI features of a low natural quality.

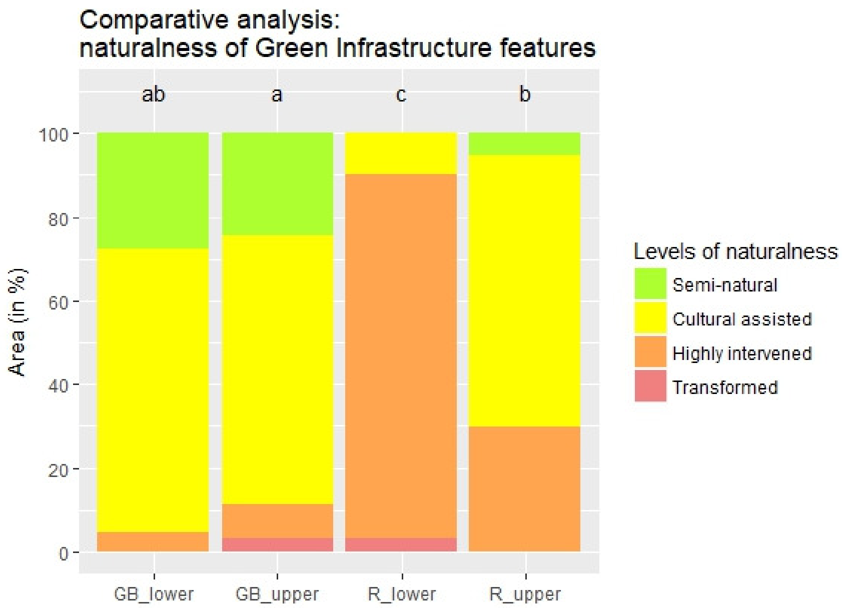


Figure 23: Dis/similar area coverages of the levels of naturalness of all GI features in all areas.

3.2. Connectivity between features

Table 9 demonstrates the results of the connectivity analysis, performed for 1) all semi-natural and cultural assisted GI features, 2) semi-natural and cultural assisted features that were dominated by forest, hedgerows and field shrubs and 3) semi-natural and cultural assisted features, that in contrast were characterized by an open landscape character (extensive meadows and orchard meadows).

Table 9: Results of the Average Nearest Neighbor analyses in ArcGIS for three subgroups input features.

Input features	GB_lower	GB_upper	R_lower	R_upper
1) NNRatio for all semi-natural and cultural assisted GI features	1,023622	1,019313	3,299269	1,247513
Observed mean distance between input features	35,71 m	31,44 m	206,36 m	41,08 m
2) NNRatio for semi-natural and cultural assisted features with a high vegetation cover (hedgerows of trees and shrubs, field brushes)	1,284695	1,131088	Only 1 feature was recorded, no connectivity analysis was performed	1,530391
Observed mean distance between input features	43,79 m	42,75 m	-	75,98 m
3) NNRatio for semi-natural and cultural assisted open features (extensive meadows and meadow orchards)	1,245404	1,114636	35,474152	1,4184
Observed mean distance between input features	59,81 m	51,30 m	314,609 m	39,03 m

How high was the structural connectivity between Green Infrastructure features in the areas? (table 9)

The results of the Average Nearest Neighbor Analysis showed a general tendency for the three subsamples of GI features for which a connectivity analysis was performed; GI features were most clustered in GB_upper, followed by slightly higher NNRatios for GB_lower. R_upper had the third lowest NNRatio. R_lower were outstanding due to a notably higher NNRatio, that indicated complete dispersion of GI features.

When connectivity between all semi-natural and cultural assisted GI features was assessed, the lowest mean distances between the input features was found due to the largest number of features that were included. In GB_upper, a mean distance of 31 m between GI features and a NNRatio of 1,02 indicated a well-connected network of GI features. GI features in GB_lower and R_upper were similarly well connected, indicated by small mean distances and low NNRatios at 36 m (mean distance)/1,02 (NNRatio) for GB_lower and 41 m (mean distance)/1,25 (NNRatio) for R_upper. The extremely high mean distance between GI features and the high NNRatio in R_lower pointed towards a significantly lower permeability of the landscape for species. The mean distance between features in GB_lower and GB_upper was slightly bigger with roughly 43 m in both areas in the subgroup of GI features with a high vegetation cover. The mean distance between such features nearly doubled to 76 m in the case of R_upper. In R_lower, the number of recorded features was to small in order to calculate a NNRatio and consequently a mean distance. The results indicate that no network of hedgerows and field brushes exist in R_lower, whereas in R_upper the NNRatio of 1,53 indicates dispersal of GI features but a functional network of GI features can still be assumed. In the subgroup of GI features with an open landscape structure again GB_upper and GB_lower expressed similarly low NNRatios and mean distances between GI features (NNRatio: 1,25 in GB_lower and 1,11 in GB_upper, mean distance: 59,81 m in GB_lower and 51,30 m in GB_upper). What was striking is that the mean distance between features was lowest in R_upper with 39 m, although the NNRatio was higher compared to the ones of GB_lower and GB_upper. This might be explained with a clustering of the few extensive meadows and orchard meadows in the centre of the area, resulting in a small mean distance. The network did not encompass the entire area (compare figures 24 and 30 in E.3.3.1.). R_lower had the highest NNRatio and mean distance between GI features. A realistic estimation of the connectivity of GI features is important in order to assess the ecological quality and connectedness of a landscape in regard to its permeability and the presence of undisturbed areas. Habitats of a high quality, a main indicator for species richness, are supported by GI features that facilitate species dispersal between sinks and sources, thereby maintaining viable meta populations. Based on the ArcGIS analysis, NNRatios over 1 were calculated for all areas. This indicated the dispersion of GI features in all subgroups. Even though, the NNRatios cannot be compared directly between the areas because the area size was not identical. Besides, the number of input features per area considerably differed. The p-values for most results were over 0.05, so that the null hypothesis[33] (which was that GI features were randomly dispersed into the landscape without being connected structurally) could not be rejected in most cases. The null-hypothesis could only be rejected for GB_upper, probably due to the significantly larger number of input features. Thus, results were only significant in the case of GB_upper. Even though the results of the test suggest a low degree of structural connectivity between GI features in the four areas, the functional connectivity is often more meaningful since more realistic to describe important ecological processes (Esri). The test computed in ArcGIS can be read as an assessment of the structural connectedness of input features based on a hypothetical reference distribution. The test cannot make statements about the actual ability of species to reach these features. Whether GI feature are connected functionally depends on factors like the species mobility, disturbances in the landscape matrix, similarity of landscape matrix and GI features or the existence of stepping stones. Thus, the NNRatio alone has limited informative value concerning the functional connections that exist within the Rechnitzer Weingebirge.

Observations in the field

Even though the results of the Average Nearest Neighbor Analysis indicated the dispersion of GI features in all four areas, the observations in the field showed a different situation. The high quality of GI features but other landscape elements as well maintained a good quality of the landscape that sustained species and ES especially in GB_upper and GB_lower. Compared to other agricultural used areas, the areas are especially rich in hedgerows and field brushes. Small structures were also abundant in R_upper. For R_lower, the results of the test seem adequate, as very few connectivity features and general structural landscape elements were present. Besides, the landscape structure itself was small-structured in the Rechnitzer Weingebirge, so that distances between patches seemed small enough that landscape elements were accessible for species. Only the absence of grazing animals, like in most landscapes, hinders effective and continuous seed dispersal of plants.

[33] The null hypothesis for the all Pattern Analysis Tools including the Average Nearest Neighbor is Complete Spatial Randomness "CSR" (Esri).

3.3. Provision of ecosystem services in the areas

The following bar chart show the percentages for each category of ES which were provided by GI features in the four areas GB_lower/upper and R_lower/upper. Figure 25 presents the results that are based on an area weighting of ES. For this purpose, the area of the GI feature was multiplied with the number of ES that were provided by the respective feature for each ES category. Figure 26 in contrast displays the results derived from a simple counting of the number of provided ES for each GI feature.

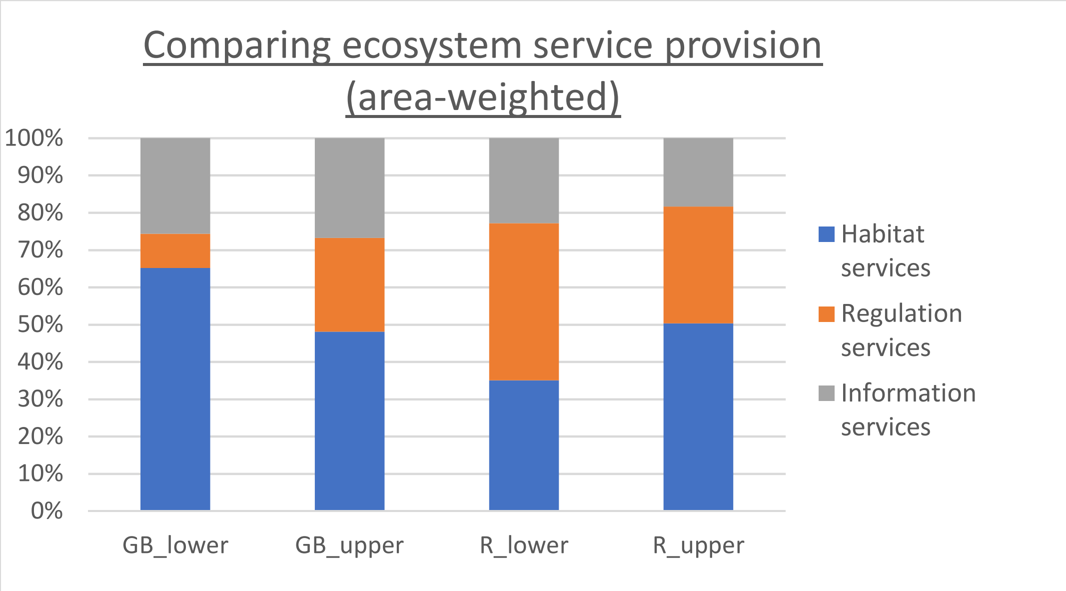


Figure 24: Percentages of ES categories provided by GI features based on an area weighting of services.

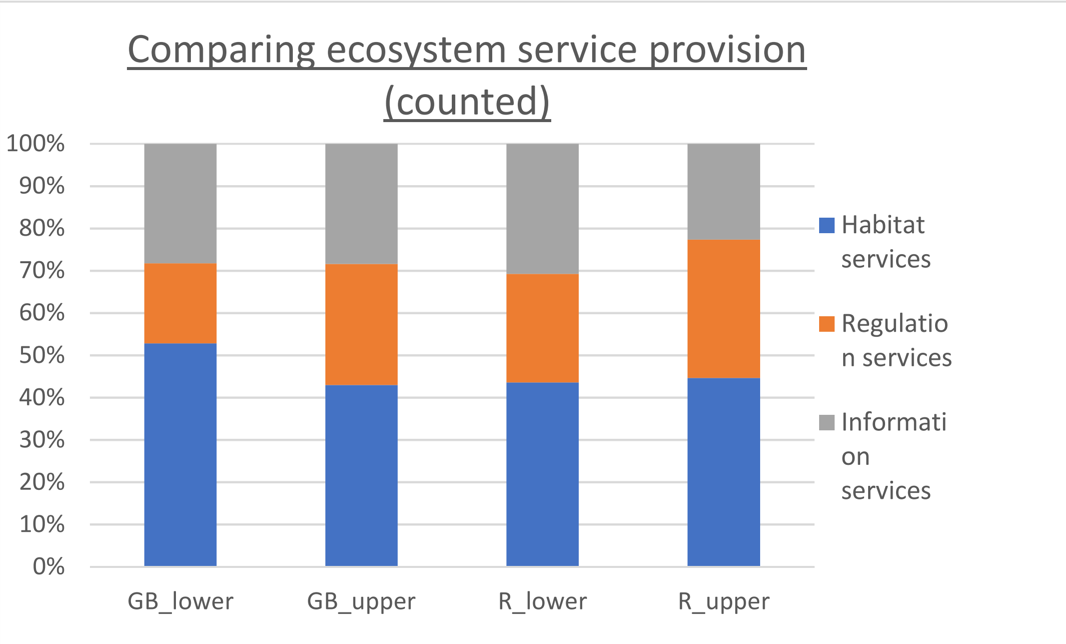


Figure 25: Percentages of ES categories provided by GI features based on the counting of services.

Which ecosystem services were provided by the Green Infrastructure features in GB_lower/upper and R_lower/upper? (figures 25-26)

The bar charts compare the ES clustered in three categories between the four areas that were investigated. Figure 25 shows the results based on the summed area of the GI features that provided ES, whereas figure 26 illustrates the results got from a simple counting of the number of ES that were provided by each GI feature. In the first calculation method, ES that were provided by small GI features are less reflected in the distribution of percentages because they did not have a strong impact during the calculations. This approach reflects the importance of area size of landscape elements especially for the capacity to provide habitat services and regulation services (Freemark & Merriam 1986; Kremen et al. 2004). The second calculation method equally emphasizes small and large GI feature, thereby stresses the importance of the variety of different features and the positive impact of small features to the overall ecological quality of the landscape.

In general, the percentages of habitat services, regulation services and information services were similarly distributed in all areas. At first glance, the results are more similar for the counting-based method, whereas the area weighted calculation showed some differences in the distribution of ES percentages in the areas. GB_lower was the area where habitat services had the highest percentage (area weighted: 65 %, counting-based: 52 %). Large extensive meadows that are managed by Franz Ulber probably significantly contributed to this result. Whereas counting the ES resulted in very similar percentages of habitat services for GB_upper, R_lower and R_upper (slightly over 440 %), taking the area size of GI features into consideration led to a significant lower percentage of habitat services in R_lower (35 %) compared to GB_upper and R_upper at roughly 50 %. Regulation services were equality distributed between all areas as well, based on the counting of ES (GB_lower: 19 %, GB_upper: 29 %, R_lower: 26 %, R_upper: 33 %). An area weighting of the ES dramatically increased the percentage of regulation services in R_lower to 42 %. In contrast, percentages in GB_lower strongly decrease to 9 %. Percentages for GB_upper and R_upper were comparably constant at 25 % and 31 %. These findings astonished because they contradicted with the hypothesis that GI features in R_lower are of a lower ecological quality. The findings let assume that a similar percentage of GI features provided habitat and regulation services in each of the four areas. Moreover, the GI features that provided habitat services in GB_lower were either especially large or provided multiple ES of this category, whereas this is the same for the regulation services in R_lower. In the case of information services, no significant differences were found, neither in the area weighted nor in the counting-based method. Information services generally ranged from 31 % to 18 %. Counting the information services resulted in a roughly 30 % share of the distribution for GB_lower, GB_upper and R_lower and a slightly lower percentage of 23 % in R_upper. Area weighting slightly highlighted the capacity of

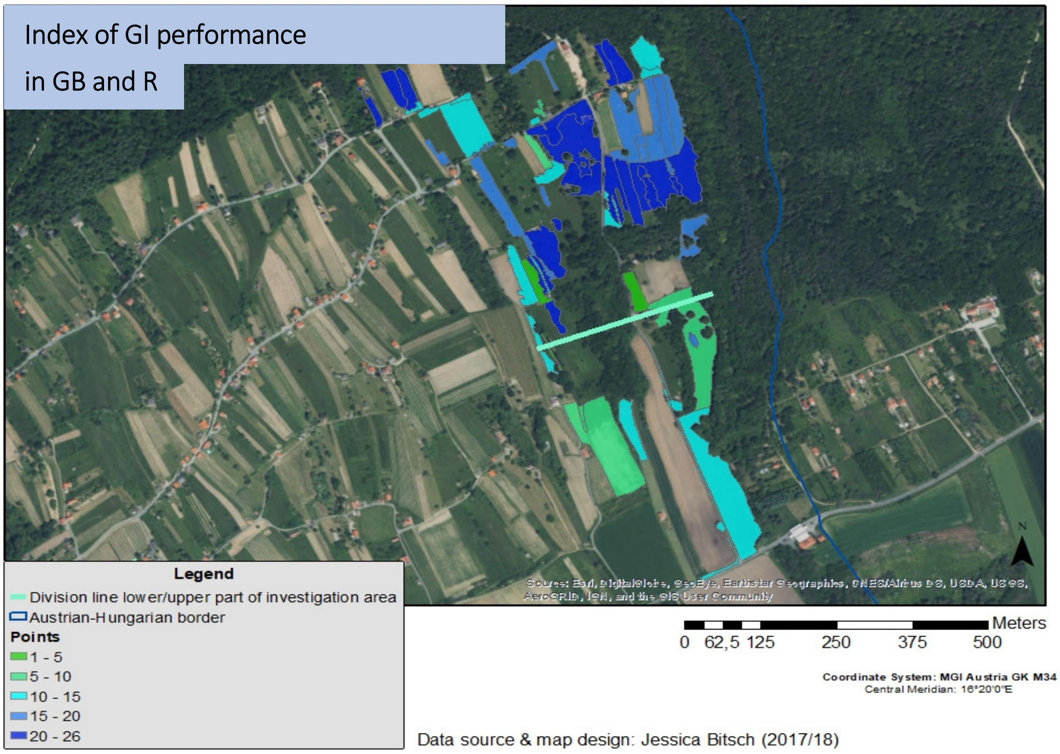
GI features in GB_upper and GB_lower to provide information services at 27 % and 26 %. R_upper reached the lowest percentage with 18 %.

For a correct interpretation of the results it is important to state that the calculated percentages displayed the share of area of ES categories in reference to the total surface coverage of the providing GI features and not to the area of the four areas that were investigated. In summary, GI features equally provided information services in all areas, whereas differences were found for habitat and regulation services (especially when the GI features area was taken into account). Habitat services were provided the most by GI features, which clearly underlines the GI features quality and capacity to provide valuable habitat which is a main precursor to conserve the local biodiversity. GB_lower reached the best results. Regulation services were provided to a similar degree by all areas as well. The percentage considerably increased for R_lower when ES were area weighted, probably due to the generally few GI features in the area and the particularly large size of single GI features that specifically provided regulation services. The fact that habitat services had the lowest percentage in R_lower matched with the hypothesis that extensive meadows of a high quality were almost completely absent in the area. It was striking that, in contrast to the hypotheses, GB_upper did not stand out with the highest percentages of habitat and regulation services, even though GI features with a high level of naturalness were assumed in this area. Still, the large number of GI features in GB_upper might explain why a homogenous distribution of ES were found, because small differences were easily equalized.

From a more general perspective, the results could show that the Rechnitzer Weingebirge is an especially small-structured cultural landscape that sustains a large number of semi-natural and cultural assisted landscape features. Such features have a specifically high capacity to provide habitat and regulation services, even in areas of a lower ecological quality. Regulation services often open appear together with habitat services but were likewise provided by GI features in areas with lower percentages of habitat features, probably due to the presence of small features that still provided these services regardless of their size.

3.4. Combined value of Green Infrastructure performance of features

The two following maps show the specific performance of GI features (referring to the level of naturalness, the number of structures, the connectivity function and the provision of ES) in all areas. The number of points that was assigned to each feature is indicated with a graded colour scheme; dark blue indicating high numbers of points and apple green indicating low numbers of points.



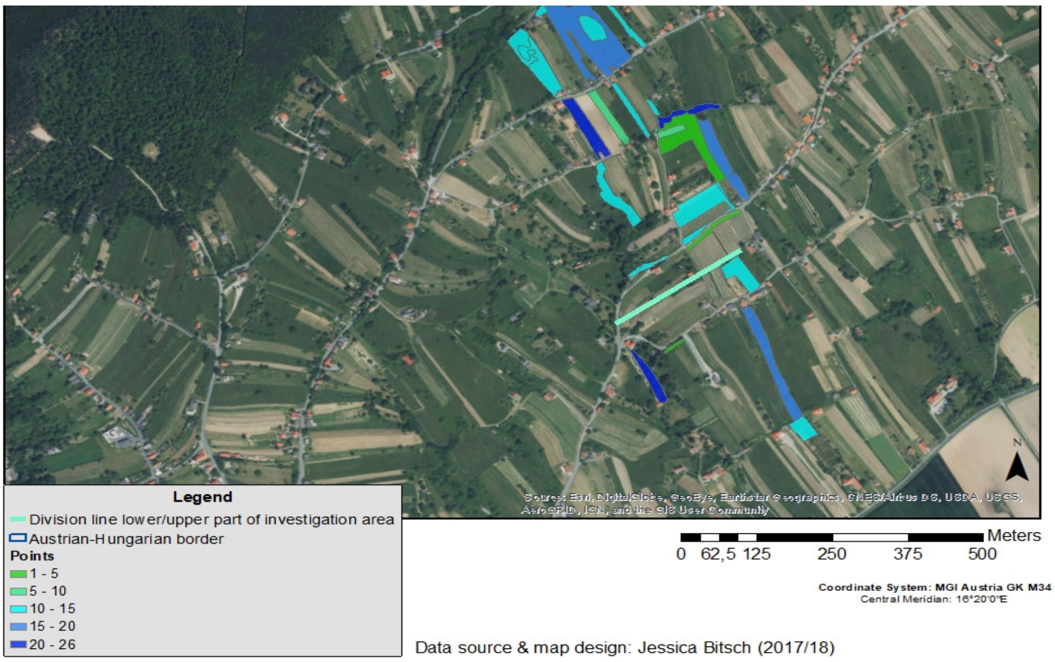


Figure 26: Index of the GI performance of GI features.

Green Infrastructure features with a high performance were found in which areas? (figure 27)

Some of the GI features did have an especially high functional value for the GI site Rechnitzer Weingebirge due to a high performance with regard to their naturalness, contribution to the connectivity in the area and provision of ES. The maps visualize that GB_upper was richest in GI features with a high combined performance. Especially the GI features in vicinity to the Green Belt proved to reach high points (15 - 26 points). In GB_lower, especially large GI features were found, even though their performance mainly ranked from 5 to 15 points. The large meadows at the Green Belt border are managed by Franz Ulber and were especially important for the GI performance in this section of the cultural landscape. R_upper showed a large range of GI features of different quality, ranging from the highest (20 – 26 points) to the lowest category (1 - 5 points). The GI features in the area with the smallest number of features, R_lower, likewise showed a wide range of performance. One GI feature even reached a very high number of points.

A high number of points indicated a strong contribution of one of the GI key factors. All three key factors are important for the performance of the Rechnitzer Weingebirge as a GI site. However, GI features can have different functional values by mainly supporting one or two of the key factors and still have a high value for the GI performance of the entire cultural landscape. The naturalness of a GI feature mainly improved its own capacity to be a habitat for species and, subsequently, to provide ES. The provision of the "networking function" that was used to measure the contribution of a single GI feature to the connectedness of the landscape mainly contributed to the connectivity between GI features in a specific section of the cultural landscape. By providing multiple ES, a GI feature did not only provide ecological services to the local wildlife, but it directly benefited the local agriculture and the landscapes quality for nature-based recreation. Furthermore, natural and semi-natural features are crucial to maintain healthy ecosystems and thereby biodiversity and human well-being.

F | DISCUSSION AND CONCLUSIONS

1. Summary of the key findings

The goal of this thesis was to show that cultural landscapes are precious elements of a GI network and how different GI features perform with regards to the key factors of GI; the naturalness, the connectivity and the provision of ES. The research results revealed a different performance of functional groups of GI features in four areas of the cultural landscape Rechnitzer Weingebirge. A high number of habitat features in areas at the Green Belt (GB_lower/upper) and their high level of naturalness suggested that the areas were positively impacted by the Green Belt. Moreover, semi-natural and cultural assisted GI features showed the highest degree of connectivity in these areas. On the other hand, extensive use features were of a comparably low level of naturalness and only covered small percentages of the areas. Even though the quality of the landscape in GB_lower and GB_upper is very high in general, it can be reasonable to enhance the quality of orchard meadows (extensive use features) as a type of land use that provides habitat and provisioning services at the same time. Such features of a high natural quality can maintain species and thereby complement the increase the overall number of habitats. Thus, the hypothesis that areas at the Green Belt are of higher quality compared to those in R could be verified for some aspects. However, the differences were not as clear as expected, probably due to the fact that the Rechnitzer Weingebirge in general is characterised by a less intensive land use compared to similar areas. Only R_lower had a significantly low performance compared to the other areas. Extensive meadows that are managed by Franz Ulber especially had an impact in GB_lower, where they covered a large area. The expertise of the local stakeholders is a key factor to conserve biodiverse meadows that still exist in the cultural landscape and that are important natural capital in the region.

Even though qualitative differences were clear in the case of the level of naturalness of GI features and the degree of connectivity in the areas, no meaningful differences were found relative to the GI features' provision of habitat, regulation and information services. Habitat services were the most dominant category in all areas with a maximum at GB_lower. The similar share of area of the habitat services in all areas seems to contradict the findings that significantly more GI features existed in GB_lower and GB_upper and also in R_upper. The fact that percentages were used instead of absolute values for the comparison of the provided services could explain these findings. The percentages referred to the total amount of services provided in one area, but the number of features that provided the ES significantly differed between areas.

Furthermore, the method to assess different ES was too rough for a detailed investigation of the GI features' capacity to provide ES. In addition, the high ecological quality of the entire landscape in the Rechnitzer Weingebirge, mainly the richness in small structures and areas of extensive land use, contributes to a good performance of landscape elements in general; thus, they are all crucial in order to conserve the local biodiversity.

2. Green Infrastructure performance of areas at the Green Belt and in farther distance

A closer look on the results revealed that the scope of differences varied between **functional groups of GI features**. In GB_upper, GI features had a higher share of area compared to the **landscape matrix**; habitat features covered more than 40 % of the area. GB_lower was similarly rich in habitat features, but GI features (especially extensive meadows and orchard meadows) had a slightly lower degree of connectivity, probably due to a quite low number in connectivity features and that were furthermore farer away from each other. Both R_upper and R_lower were especially dominated by the landscape matrix. No forested areas existed at all in these areas. R_lower was especially poor in connectivity and open habitat features. Surprisingly, connectivity features in R_lower had the same share of area compared to GB_upper. This was probably due to numerous hedgerows in R_lower that cover quite a large area. A reversed pattern was found for the extensive use features, that were predominant in R_lower and R_upper, probably due to the higher degree of intensification in this section of the cultural landscape and the location close to Rechnitz. Out of all GI features, extensive meadows were the feature the most abundant in all areas.

A similar pattern for all three functional groups and the combined group of all GI features was found when the **levels of naturalness** of features were assessed. The following common pattern was recognized: GB_lower > GB_upper > R_upper > R_lower. Only in the case of extensive use features R_upper had better results in comparison to GB_upper. In general, the results revealed that more areas were significantly similar with regard to the naturalness distributions of GI features when a single functional group (open habitat features, connectivity features and extensive use features) was considered as if all GI features were included in the test; more distributions were dissimilar in that case. The distribution of GB_lower, GB_upper and R_upper were significantly similar in all cases. R_lower, where the GI features were of especially low naturalness shared a similar distribution with R_upper when distribution of open habitat features were compared. The same applied to the distributions of R_lower and GB_upper in the case of extensive use features. These findings indicated that extensive meadows in R_upper were of comparably low natural quality and management should target an increase in the level of naturalness of these features. The same applies to extensive use features in GB_upper. The connectivity features in R_lower were of a significantly lower level of naturalness highlighting the urgency to increase the number and the quality of connectivity features, especially hedgerows and field brushes in R_lower. At this place It needs to be stated that evaluation of the evaluation of the natural quality of areas based on the naturalness distributions of GI features involved personal judgement; for instance, a high percentage of semi-natural and cultural assisted features in GB_upper was rated higher, even though transformed features occurred as well, compared to R_upper were mainly cultural assisted GI features existed. All GI features combined, only the distributions of GB_lower and GB_upper were significantly similar. Furthermore, a similarity was found for the distributions of GB_lower and R_upper. This finding seems to be counter intuitive based on the visual impression of the stacked bar chart, which shows that GB_lower and R_upper had similar naturalness distributions but GB_upper and R_upper did not. A possible explanation is that, even though low levels of naturalness had a larger percentage in GB_upper, which therefore should be similar to R_upper, the small number of GI features in GB_lower and R_upper affected the results. Again, the level of naturalness of GI features in R_lower were significantly lower compared to the other area.

Based on the comparison of the naturalness of GI features, no significant differences were found between GI features between GB_upper, GB_lower and R_upper. Only the distribution of naturalness of R_lower was significantly different in that that lower levels of naturalness were predominating. Though, in the case of open habitat features and extensive use features, the distribution of R_lower was significantly similar with GB_lower in one case and with R_upper in another case.

The research results are summarized in the tables on the following two pages and main conclusions for the management are drawn. All area percentages covered by Gi features and functional groups are indicated for each area. Furthermore, the four areas are ranked with regard to their degree of naturalness and the connectivity (e.g. GB_upper reached the second-best result for the naturalness of “connectivity features”).

Table 10: Summary of results for GB_lower/upper.

	GB_upper	GB_lower
Predominating functional groups of GI	38 % landscape matrix 22 % open habitat features 19 % forest features 16 % connectivity features 5 % extensive use features	57 % landscape matrix 18 % open habitat features 14 % forest features 7 % connectivity features 3% extensive use features
Predominating GI features	34 % extensive meadows 31 % natural mixed oak and mixed hornbeam forests 12 % field brushes	42 % extensive meadows 33 % natural mixed oak and mixed hornbeam forests 9 % field brushes
Green Infrastructure performance		
Naturalness	All GI features: 2 Open habitat features: 2 Connectivity features: 2 Extensive use features: 3	All GI features: 1 Open habitat features: 1 Connectivity features: 1 Extensive use features: 1
Connectivity	Between all cultural assisted and semi-natural GI features: 1 Between open habitat features: 1 Between GI features with closed vegetation: 1	Between all cultural assisted and semi-natural GI features: 2 Between open habitat features: 2 Between GI features with closed vegetation: 2
Provision of ES	Habitat services > regulation services > information services	Habitat services > regulation services > information services
Index of GI performance	Highest: 26 Lowest: 3 Average: 17,08 (total number of GI features: 50)	Highest value: 16 Lowest value: 4 Average: 10,70 (total number of GI features: 10)

GB_upper was especially rich in habitat features and therefore the landscape had the highest capacity to provide habitat especially for specialized species. Where the Green Belt borders the cultural landscapes disturbances should be minimized in order to enable species' flow between the forest and the half-open landscape. Many different niches characterized this area. Besides, biodiverse extensive meadows, forests and a network of hedges and field brushes covered large parts of the area. GB_lower was characterized by some very large managed extensive meadows but was quite poor in connectivity features. Such features would be especially important in that area as buffers for habitats against impacts from adjacent intensively used fields and as areas of refuge, because surrounding fields showed high disturbance rates. Hotspots of habitats within the landscape matrix require a specific management that is furthermore adjusted to the surrounding landscape setting, whereas extensive use structures and connectivity features can be managed in the same way in that the number of structures and a natural vegetation is increased.

Table 11: Summary of results for R_lower/upper.

	R_upper	R_lower
Predominating functional groups of GI	70 % landscape matrix 12 % open habitat features 9 % connectivity features 8 % extensive use features	69 % landscape matrix 18 % open habitat features 17 % connectivity features 8 % extensive use features
Predominating GI features	39 % extensive meadows 27 % old orchard meadows 21 % hedgerows of trees	56 % extensive meadows 24 % old orchard meadows 15 % hedgerows of trees
Green Infrastructure performance		
Naturalness	All GI features: 4 Open habitat features: 4 Connectivity features: 4 Extensive use features: 4	All GI features: 3 Open habitat features: 3 Connectivity features: 3 Extensive use features: 2
Connectivity	Between all cultural assisted and semi-natural GI features: 3 Between open habitat features: 3 Between GI features with closed vegetation: 3	Between all cultural assisted and semi-natural GI features: 4 Between open habitat features: 4 Between GI features with closed vegetation: 4
Provision of ES	Habitat services > regulation services > information services	Habitat services > regulation services > information services
Combined value of GI performance	Highest value: 23 Lowest value: 4 Average: 13,68 (total number of GI features: 22)	Highest value: 21 Lowest value: 5 Average: 13,50 (total number of GI features: 6)

R_lower and R_upper were significantly poorer in GI features especially compared to GB_upper but also compared to GB_lower. Especially the low number in open habitat features, which predominantly were of low levels of naturalness accounted for the low capacity of R_lower and R_upper to maintain species rich habitat. That is way existing extensive use features like orchard meadows were of special importance, because orchard meadows with a natural undergrowth still provided crucial habitats in the areas, that were characterized by quite strong disturbance regimes. However, the lower quality of the landscape for species probably only allowed generalist species to find adequate habitats. An increase in GI features would be especially necessary in R_lower, where highly intervened or even transformed landscape features predominated, in order to increase the areas GI performance.

R_lower and R_upper represent the classical cultural landscape, that is mainly characterized by human activities but still maintains some semi-natural, biodiverse landscape features. In contrast, especially GB_upper but also GB_lower are positive examples for a high quality of landscape features and the overall landscape structure in a cultural landscape. A strong positive impact of the Green Belt probably is the main driving factor in combination with a management of local experts that prioritize the conservation of species rich meadows instead of a cultivation of the land. These meadows and a network of hedgerows and field brushes probably leads to an overall increase of the landscapes capacity to provide multiple ES. Even though extensive meadows had a high quality in the area, efforts to increase their connectivity should be taken nevertheless to counteract a fragmentation of these meadows (Lazowski 2014). As a conclusion, the Rechnitzer Weingebirge profits from its location at the Green Belt, but vice versa, increases the connectivity of the corridor's forests with landscape features within the cultural landscape, thereby increasing the chances for species flow between the corridor and the surrounding landscape. The Rechnitzer Weingebirge can be considered a network of linked GI features (Kuttner et al. 2013).

3. Reflection on the research methods

The **assessment of the GI performance** of areas in the cultural landscape Rechnitzer Weingebirge was mainly based on the GI features and their functional value for the GI performance of the site. To assess the GI performance of an area for a GI network further information are needed. Especially the connectivity of the site with other sites in the region (gap-analysis in the network) can be crucial but was not feasible due to time limitations. Furthermore, the interactions of GI features and the landscape matrix could have given a comprehensive insight into the capacity of the landscape to provide ecological functions (Wrbka et al. 2003). Some improvements could be useful concerning the three key factors of the functional assessment. Due to reasons that were mentioned in chapter D provisioning services were not recorded during the research process in order to focus on ES with stronger connection to conservation. By **excluding provision services** from the mapping, it was not possible to quantify the relationship between these services and other services for which data were collected. Another method to emphasize conservation related services would have been to stronger weight those services and the capacity of the landscape to provide services would have been depicted in a comprehensive way. Besides, the results could be enriched by including the demand side and perception of ES via stakeholder interviews and possible trade-offs identified (Liquete et al. 2015; Kalóczkai 2015). Social-scientific methods in the form of expert interviews and a stronger focus on the stakeholder side of ES provision was methodologically not included into the research process, although important for a practical implementation of GI related actions in the field (Kalóczkai 2015). The high percentages of habitat services nevertheless can be biased because a selection criterion for GI features was that they are expected to provide a variety of habitat services, thereby as subjective preselection was taken. Furthermore, the used method does not allow a fine differentiation between the provided ES between the investigation areas because grouping of ES equals out specific differences. The method is more suitable to compare cultural landscape with semi-natural landscape elements with landscapes where landscape elements of high quality where removed due to higher levels of intensification.

The classification of functional groups of GI features served the purpose to cluster a large amount of GI features into meaningful groups to bundle results with the side effect to increase the sample size, thereby enhancing the statistical significance of the results. It must be clear that a classification, even though derived by considerations on GI principles - always contains subjective estimations and furthermore reduces the real complexity. For instance, GI features fulfil a variety of functions, e.g. hedges are connectivity features but also provide habitat and therefore do not exclusively fit into one of the three functional groups. The classification scheme was based on a prioritization of functions according to the main management goals that are important for conserving the quality of the Rechnitzer Weingebirge landscape. Focus was given to open habitat features as hotspots of the local biodiversity. Hedges, that are widely disappearing from intensively used agricultural landscapes are crucial linking elements within a landscape. Therefore they were classified as connectivity features, but they provide habitat services at the same time.

Another aspect of the research was to test whether the applied methods are suitable for practice and useful for practitioners who want to assess the performance of GI features in a specific area. Therefore, tools must be easy to apply, science-based and yet sound. Generally, the natural status and ES are relatively easy to assess based on a mapping catalogue. Of course, the catalogue cannot provide an in-depth assessment especially for complex interactions between ES. Nevertheless, it can be a helpful tool for a rapid assessment, which can be the basis for a dedicated research. Some of the parameters of the standard catalogue for a landscape mapping revealed to be of special interest for the GI assessment. For the functional assessment of GI features, land use types and biotope types, the naturalness of features, the number of structural elements and the provided ES were especially relevant. The parameter “functionality” that was developed during the research to depict the GI functionality of landscape elements could not be used for the assessment of the GI performance in the end. Figure 27 exemplary shows the results of the assessment of “multifunctionality” in landscape section GB. Six categories of the main GI functionalities are indicated with different colours.

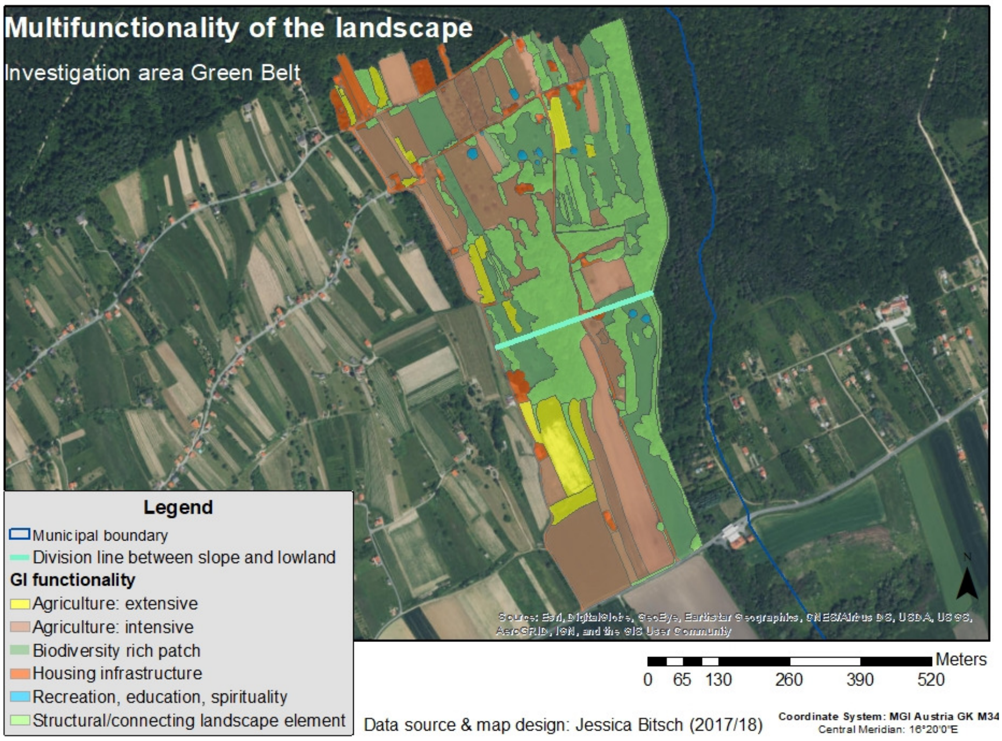


Figure 27: GI features according to their "multifunctionality" for landscape section GB.

In order to have a higher explanatory power, the parameter needs to be designed as rapid assessment tool to quantify the provision of ES, for instance by roughly estimating their number on grouped scale (< 3, 4 - 7, 8 - 11, > 11).

From the perspective of biology, the research results could be strongly enriched by collecting data on species abundance and richness as well as on metapopulations. Suitable measures to track species dispersal processes can give important hints towards the **functional connectivity** of the landscape. Assessing landscape elements exclusively already gives the basis for further specie analysis, but alone only represents structural connectivity which is only one factor influencing the connectivity of important elements in an ecological network (Liquete et al. 2015). It is a general challenge in the field of conservation research that the landscape configuration does not follow similar pattern in different areas, thereby sample size can considerably differ most notably. The number of GI features often different between the areas and moreover in same cases were too small to gain **statistical valid results**. However, the fact alone that the abundance of GI features in the areas notably varied was a valuable finding. Besides, the **comparability of results of the four areas that were investigated** was impeded by the differences on the size of the areas (GB_upper was especially large). Thus, percentages were used to compare results despite of different area size as well as number of GI features. Although some explanatory power of the results might be lost by transforming absolute values into percentages, the results nevertheless showed clear differences, for instance in the area coverage of GI features of a different level of naturalness.

Furthermore, to be able to identify a statistically valid correlation between the influence of the Green Belt on the quality of GI features in the surrounding areas more sites need to be included in the research, which was not feasible due to limitations in the course of a master thesis. In addition, to clearly evaluate a gradient in the degree of naturalness from the Green Belt towards Rechnitz a third landscape section closer to Rechnitzer would increase the explanatory power of the research.

Gaining insights into the specific performance of the cultural landscape Rechnitzer Weingebirge is an important basis to understand and assess landscape features in similar regions, even though results are too specific to be transferred one-to-one. The combined GI value is an approach to incorporate all relevant key factors for the functional assessment of GI into one measurement tool. The idea is that local experts can tailor the value to the local priorities by weighting specific ES individually for example. In this thesis, the points for the GI features where given without weighting the area with the effect that small and large GI features are considered as important features of the local network. This can also be changed in a different context. All three key factors were considered equally into the point system, stressing the fact that GI features are multifunctional elements that contribute various functions to the local GI network. can be valuable parts of a GI network due to different reasons. The fact that GI features can collect points even if they only provide ES and have a low level of naturalness accounts for the idea that not all GI features must fulfil all key factors. The GI network, consisting of GI features which contribute different functions, should have good values of naturalness and provide a variety of ES. Further it can be questioned whether the presence of the ES “networking function” is a suitable indicator to describe the connectedness of a single feature with other features. The existence of other similar features in a distance that appears reachable for target species should also be taken into consideration. The combined GI value represents an adjustable “expert tool” that helps local experts to scientifically evaluate the quality of GI features.

It was mentioned by the Naturschutzbund that the mapping and identification of possible connectivity elements in the transition zone from the northern part of the cultural landscape to the forests at the foot of the Geschriebenstein could be a worthwhile field for research. Nutrient-poor grasslands and extensively managed vineyards could be important areas that can be protected in order to increase the connectivity within the Rechnitzer Weingebirge. Generally, most meadows of high quality are already protected and under conservation management so that a future purchase of more areas does not seem necessary. Is appears positive that the area around the Rechnitzer Weingebirge is spared of strong construction activities. Another interesting field of research is the connectivity to the Hungarian side. A common conservation bureau and a motivated mayor in the Hungarian neighbouring municipality are positive conditions for a future cooperation. could be a contact point for common activities in this direction.

4. What does the results mean in practice?

The Rechnitzer Weingebirge is characterized by a mosaic-like landscape pattern that consists of a variety of land uses. The specific ecological and climatic conditions, its vicinity to the Green Belt and extensive cultivation practices that prevailed for many decades are the main driving factors for the conservation of a diverse landscape structure, natural and semi-natural landscape features and biodiverse habitat patches. The Rechnitzer Weingebirge on the one hand is a buffer zone for pristine lands against impacts of intensive land use practices and urbanisation. On the other hand, the Green Belt, maintains free space for natural processes and thereby positively influences the quality of the areas close by. Thus, the cultural landscape Rechnitzer Weingebirge supports an important goal of the GI strategy: to maintain natural and semi-natural areas of high quality in close distance to core zones of GI like the Green Belt to increase their connectivity with the surrounding landscape.

In the Rechnitzer Weingebirge, nature conservation and extensive agriculture are combined. Local stakeholders are actively involved in the management of the area. Besides, the site is part of a broader Natura 2000 area and therefore is part of a comprehensive management. Combined with a large quantity of natural and semi-natural landscape features that provide multiple services and increase the connectivity within the landscape the site fulfils main factors that determine the GI performance of a site (Liquete et al. 2015). The management of the Rechnitzer Weingebirge should address the conservation of its multifunctional character and the diverse landscape structures that are especially ich for a cultural landscape. In order to create a local GI network, it is worthwhile to assess and increase, if necessary, the connectivity of the Rechnitzer Weingebirge with further GI sites in the region.

The location of the Rechnitzer Weingebirge at the Green Belt is a specific characteristic of the study area. Even though the landscape as well as land use conditions are very site-specific, the research results can give interesting insights into the functional value of different settings, represented by the four different areas that were investigated, that are characterized by a different richness in and quality of GI features. A “modular system” of single segments of a cultural landscape with specific configurations and assets of GI features could be used to transfer positive examples of a study area to similar areas. Furthermore, the combined index of GI performance facilitates the comparison of GI features in different cultural landscapes with regard to their performance. The combined GI value, based on the three key factors of GI, is a practical support tool to identify GI features of special importance and could also point out characteristics of GI features that are special examples of high value. Especially the test area GB_upper can function as a positive example for other cultural landscapes at the Green Belt. It shows how connectivity between the Green Belt and adjacent half-open landscapes can be established and which GI features of different levels of naturalness can support the landscapes’ capacity to provide multiple ES.

A strong involvement of local exports can notably increase the efforts in providing valuable research results that can be transferred to similar sites. Thus, a GI network is not only a network of natural and semi-natural areas and landscape features but is also connects people and projects with one another.

“The key then is to downplay centrism and focus instead on the kinds of interactions that might occur across a variety of boundaries between regions, levels, hierarchies, organisations, NGOs, departments, etc. It must be considered of great importance to turn target groups and land users into active co-producers in the social process of creating and protecting ecological networks”(Jongman et al. 2004).

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I | FIGURES AND TABLES

FIGURES

TABLES

J | APPENDICES

1. Form sheets of the mapping of the landscape structure and the GI features
2. Results table of the Wilcoxon Rank Sum Test

All GI features		
Area A	Area B	p-value
GB_upper	GB_lower	0.8775
GB_upper	R_upper	0.001823
GB_upper	R_lower	0.000001754
GB_lower	R_upper	0.07258
GB_lower	R_lower	0.00007556
R_upper	R_lower	0.000349

Connectivity features		
Area A	Area B	p-value
GB_upper	GB_lower	0.7069
GB_upper	R_upper	0.2139
GB_upper	R_lower	0.008675
GB_lower	R_upper	0.6633
GB_lower	R_lower	0.04302
R_upper	R_lower	0.01881

Open habitat features		
Area A	Area B	p-value
GB_upper	GB_lower	0.2832
GB_upper	R_upper	0.5015
GB_upper	R_lower	0.002751
GB_lower	R_upper	0.2456
GB_lower	R_lower	0.01128
R_upper	R_lower	0.09052

Extensive use features		
Area A	Area B	p-value
GB_upper	GB_lower	1
GB_upper	R_upper	0.5738
GB_upper	R_lower	0.0553
GB_lower	R_upper	0.5874
GB_lower	R_lower	0.02248
R_upper	R_lower	0.02981

p-value < 0.05	H0 rejected --> the distributions are significantly different
p-value > 0.05	H0 not rejected --> the distributions are significantly similar

3. Calculation scheme of the provision of ecosystem services

<u>Percentages based on a counting of ES for each GI feature</u>

	Habitat services	Regulation services	Information services	Total
GB_lower	28	10	15	**53**
Percentage	52.83	18.87	28.30	100.00
GB_upper	180	120	119	**419**
Percentage	42.96	28.64	28.40	100.00
R_lower	17	10	12	**39**
Percentage	43.59	25.64	30.77	100.00
R_upper	71	52	36	**159**
Percentage	44.65	32.70	22.64	100.00

Percentages based on an area weighting of ES for each GI feature

	Habitat services	Regulation services	Information services	Total
GB_lower	104069.97	14718.06	41000.89	**159788.92**
Percentage	65.13	9.21	25.66	100
GB_upper	383549.41	200459.21	213524.00	**797532.63**
Percentage	48.09	25.13	26.77	100
R_lower	27255.17	32803.45	17785.54	**77844.16**
Percentage	35.01	42.14	22.85	100
R_upper	141993.83	88345.63	51699.79	**282039.24**
Percentage	50.35	31.32	18.33	100

4. Species list of plant species on meadows at the Green Belt (according to Josef Weinzettl, botanist and member of the Naturschutzbund in the region since many years)

- Allium lusitanicum (Berg-Lauch)
- Anacamptis morio (Klein-Hundswurz, Klein-Knabenkraut)
- Anthericum ramosum (Rispen-Graslilie)
- Campanula bononiensis (Filz-Glockenblume)
- Campanula glomerata (Knäuel-Glockenblume)
- Centaurea stoebe (Rispen-Flockenblume)
- Cervaria rivini (Hirschwurz)
- Chamaecytisus ratisbonensis (Regensburger Zwerggeißklee)
- Dictamnus albus (Diptam)
- Drymocallis rupestris (Gewöhnliches Steinfingerkraut)
- Euphorbia angulata (Kanten-Wolfsmilch)
- Filipendula vulgaris (Klein-Mädesüß)
- Galatella linosyris (Goldschopf-Steppenaster)
- Helianthemum nummularium subsp. obscurum (Trübgrünes Sonnenröschen)
- Inula hirta (Rauhaar-Alant)
- Inula salicina (Weidenblatt-Alant)
- Iris variegata (Bunt-Schwertlilie)
- Linaria genistifolia (Ginster-Leinkraut)
- Muscari comosum (Schopf-Traubenhyazinthe)
- Neotinea ustulata var. aestivalis (Sommer-Brand-Keuschständel)
- Odontites luteus (Gelb-Zahntrost)
- Ononis spinosa (Dorn-Hauhechel)
- Ophrys apifera (Bienen-Ragwurz)
- Orchis pallens (Bleich-Knabenkraut)
- Ornithogalum kochii (Schmalblatt-Milchstern)
- Potentilla recta (Hoch-Fingerkraut)
- Prunella laciniata (Weiß-Brunelle)
- Pulsatilla grandis (Große Küchenschelle)
- Pulsatilla pratensis subsp. nigricans (Schwarze Wiesen-Küchenschelle)
- Rumex thyrsiflorus (Rispen-Sauerampfer)
- Saxifraga bulbifera (Zwiebel-Steinbrech)
- Scabiosa ochroleuca (Gelb-Skabiose)
- Thalictrum minus (Klein-Wiesenraute)
- Trifolium alpestre (Hügel-Klee)
- Trifolium montanum (Berg-Klee)