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„Green Infrastructure along bicycle routes: a benefit for cycling tourism and nature conservation"

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Abstract

In this study I demonstrate a method of evaluating a landscape on a regional scale, based on multiple factors and considering multiple perspectives. In the study area of Western Weinviertel I assessed the Green Infrastructure along four bicycle routes applying newly developed formulas to compute three overall values for each sampling circle. The 'Natural Value' describes the perspective of nature conservation, the 'Cycling Tourism Value' represents the extent of experience of nature for cycling tourists and to calculate the 'Land Use Value' I adopted the perspective of intensive land use. I analysed how the three overall values correspond, to determine correlations and conflicts between them.

I aim to provide a scientific background for enhancing both, nature conservation and the experience of nature for cycling tourists. To create a nature themed bicycle route as an upgrade to an existing bicycle route, I propose an investment in existing Green Infrastructure.

I applied a stratified sampling design to represent the spectrum of possible landscape sections in the study area and created three different strata, one of them with four sub-strata. The selection criteria were based on the 'Central European Habitat Map' and on the presence or absence of special features, that are especially interesting for the study, like nature protection areas, natural monuments, Kellergassen and Points of Interest.

On site I mapped the sampling circles, conducted and a landscape structure survey and collected additional data for focus habitats and the bicycle route itself. I processed data from 2567 polygons in 70 sampling circles and calculated rescaled values for 28 landscape variables per sampling circle, which I used as criteria to compute the three overall values. Different criteria that contribute to the particular perception were used in each of the formulas and the yielded values were rescaled to range from 0 to 1. The overall values are comparative and enabled analyses within the spectrum of landscape sections in the study area.

The newly developed formulas proved their effective operation. Furthermore the robustness of the method could be confirmed.

The strong positive correlation between the 'Natural Value' and the 'Cycling Tourism Value' and their strong negative correlation to the 'Land Use Value' was very distinct. The conflict between nature conservation and intensive land use was obvious. However, valuable areas for nature conservation provide also a high level of experience of nature for cycling tourists and in turn the latter has only little negative impact on the 'Natural Value'. Therefore an enhancement of Green Infrastructure for both nature conservation and the experience of nature for cycling tourists is possible as these perspectives are highly correlating and little conflicts are to be expected. The intensive land use will have to recede suitably to implement that.

In another analysis I compared the results to the strata. The sampling circles that were selected based on the favoured habitat classes from the 'Central European Habitat Map', showed a clear trend according to the overall values.

Additionally I developed the separately computed value ’Suitability for Multifunctional Development, SMD’. It is based on expert knowledge and represents the suitability of the sampling circle for development that benefits both, nature conservation and the experience of nature for cycling tourists. The results of ’SMD’ were highly corresponding to the pattern of the three overall values which makes it a promising approach and efficient tool.

The demonstrated methods performed well. They also could be transferred to other study areas and even to other research questions, but would have to be adapted. As they are in an early stage of development, further analyses and refinement of the formulas are recommended.

Keywords

bicycle route, bike trail, cycle path, landscape, multifunctionality, nature conservation, Green Infrastructure, cycling tourism, land use, values

Zusammenfassung

In dieser Studie demonstriere ich eine Methode für Landschaftsbewertung auf regionaler Ebene, welche auf mehreren Faktoren basiert und verschiedene Perspektiven berücksichtigt. Im Untersuchungsgebiet Westliches Weinviertel bewertete ich die Grüne Infrastruktur entlang von vier Fahrradrouten. Mithilfe neu entwickelter Formeln wurden drei Gesamtwerte pro Probekreis berechnet. Der "Natural Value" beschreibt die Perspektive des Naturschutzes, der "Cycling Tourism Value" repräsentiert das Maß des Naturerlebnisses für Radtouristen und um den "Land Use Value" zu berechnen habe ich den Blickwinkel der intensiven Landwirtschaft eingenommen. Zusammenhänge zwischen den drei Gesamtwerten wurden analysiert um Übereinstimmungen und Konflikte zwischen ihnen zu ermitteln.

Das Ziel der Studie ist, einen wissenschaftlichen Hintergrund zu liefern, damit gleichzeitig der naturschutzfachlichen Zustand des Gebiets und das Naturerlebnis für Radfahrer verbessert weren kann. Um einen Natur-Themenradweg als Aufwertung zu einem existierenden Radweg zu kreieren schlage ich eine Investition in existierende Grüne Infrastruktur vor.

Ich wandte ein stratifiziertes Stichprobenverfahren an, um das Spektrum der möglichen Landschaftsausschnitte im Untersuchungsgebiet zu repräsentieren und generierte drei verschiedene Straten, davon eines mit vier Sub-Straten. Die Auswahlkriterien basierten auf der 'Central European Habitat Map' sowie auf der An- oder Abwesenheit von Besonderheiten mit hoher Bedeutung für die Studie, wie Naturschutzgebieten, Naturdenkmälern, Kellergassen und anderen touristisch interessanten Orten.

Vor Ort führte ich eine Kartierung des Probekreises und eine Landschaftsstrukturerhebung durch und erhob zusätzliche Daten für Fokusbiotope und den Fahrradweg selbst. Daten von 2567 Polygonen in 70 Probekreisen wurden ausgewertet und skalierte Werte von 28 Landschaftsvariablen errechnet. Diese wurden als Kriterien zur Berechnung der Gesamtwerte genutzt. Für jeden der drei Blickwinkel zog ich entsprechende Kriterien zur Berechnung heran und skalierte die errechneten Werte auf eine Bereich zwischen 0 und 1. Diese Gesamtwerte sind vergleichend und ermöglichen Analysen innerhalb der Bandbreite von Landschaftsausschnitten im Untersuchungsgebiet. Die neu entwickelten Formeln bewiesen ihre Wirksamkeit und darüber hinaus konnte die Robustheit der Methode bestätigt werden.

Die starke positive Korrelation zwischen "Natural Value" und "Cycling Tourism Value" und deren starke negative Korrelation zum "Land Use Value" war sehr ausgeprägt. Der Konflikt zwischen Naturschutz und intensiver Landwirtschaft war offensichtlich. Hingegen boten wertvolle Flächen für den Naturschutz auch ein hohes Maß an Naturerlebniswert für Radtouristen und umgekehrt hat Letzteres auch nur einen geringen negativen Einfluss auf den "Natural Value". Daher ist eine Verbesserung der Grünen Infrastruktur für den Naturschutz und zugleich auch für den Naturerlebniswert für Radfahrer möglich. Da diese Blickwinkel stark korrelieren sind kaum Konflikte zu erwarten. Um das umzusetzen muss die intensive Landwirtschaft etwas zurückgenommen werden.

In einer weiteren Analyse wurden die Ergebnisse mit den Straten verglichen. Die Probekreise welche auf den favorisierten Habitatklassen der "Central European Habitat Map" basieren, zeigten den gleichen Trend wie die Gesamtwerte.

Zusätzlich entwickelte ich den separat berechneten Wert "Suitability for Multifunctional Development, SMD", welcher auf Expertenwissen basiert. Es ist ein Wert der die Eignung des Probekreises für Entwicklung zugunsten von Naturschutz und Naturerlebniswert für Radfahrer beschreibt. Die Ergebnisse des "SMD" korrelierten stark mit dem Muster der drei Gesamtwerte. Das macht ihn zu einem vielversprechenden Ansatz und effizienten Werkzeug.

Die demonstrierten Methoden haben sich als erfolgreich erwiesen. Sie könnten auch auf andere Untersuchungsgebiete oder sogar andere Forschungsfragen übertragen werden, müssten dafür aber angepasst werden. Da sie sich noch in einer frühen Entwicklungsstufe befinden, werden nähere Untersuchungen und die Verfeinerung der Formeln empfohlen.

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1 Introduction

1.1 General

This work provides an assessment of different ecosystem services provided by the Green Infrastructure along four bicycle routes in the case study area of Western Weinviertel. I surveyed different aspects of the habitats by mapping and collecting data of over 2500 polygons in 70 sampling circles. Each sampling circle was evaluated with newly developed formulas to compute overall values from three different points of view. The perspective of nature conservation was researched considering a multitude of different factors which were then used to compute the 'Natural Value'. Also the 'Cycling Tourism Value' of the sampling circle and therefore of the route section of the bicycle routes, was determined to find out which areas contribute most to the cyclists experience of nature. Additionally I assessed the landscape from the perspective of land use and computed the 'Land Use Value'. By evaluating each sampling circle from different points of view I could achieve a more holistic assessment of the landscape and its value. By connecting and comparing the data, I assessed the value of the bicycle routes as an element of regional Green Infrastructure and detected correlations and conflicts between three different perspectives. This can be a foundation for developing strategies for both nature friendly and visually appealing bicycle routes.

This study is meant to contribute to plan and implement a nature themed bicycle route as an upgrade to an existing bicycle routes. Although building new grey infrastructure can increase access to nature and the experience of nature for tourists, it is almost always at the expense of Green Infrastructure. With my approach I propose an investment in existing Green Infrastructure to enhance it and make it more valuable for both nature conservation and experiencing nature. In this way stepping stone areas can be created and the tourism value of the bicycle route is increased.

With this study I aim to provide a scientific background for enhancing both, nature conservation and the experience of nature for cycling tourists.

1.2 Research questions

To do so the following research questions were formulated:

The research question:

- What is the contribution of the Green Infrastructure along the bicycle routes to both nature conservation and the experience of nature for cycling tourists and where are possibilities to enhance both?

Sub questions:

- How do nature conservation, experience of nature for cycling tourists and land use correspond?
- Is there a specialisation or a multifunctionality of the ecosystem services of this landscape?

1.3 Background

1.3.1 Strategies for implemented nature conservation

The approach of my study was chosen against the background of the concept of Green Infrastructure. It is described in the EU (European Union) Green Infrastructure Strategy 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. On land, Green Infrastructure is present in rural and urban settings.' (European Commission 2013)

The Natura 2000 network is described by the European Commission as the 'backbone of the EU Green Infrastructure'. The Natura 2000 approach is that people work with nature rather than against it and although it includes strictly protected nature reserves, most of the land remains privately owned. It aims to protect rare species and habitats to ensure their long-term survival. (European Commission 2020) The protected species and habitats are listed in the 'Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora' (EEC 1992), shortly known as 'Habitats Directive' and in the 'Birds Directive' with the official name 'Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds' (European Parliament and the Council of the European Union 2010). The European Protection Area 'Westliches Weinviertel', which is located in the study area, is part of the Natura 2000 network.

Also the European Commission (2020) values Green Infrastructure planning as a successfully tested tool to provide environmental, economic and social benefits through natural solutions. Apart from being the better choice for the environment and biodiversity, it can even be less expensive to build and maintain compared to grey infrastructure.

But the scope of the EU Green Infrastructure Strategy is even broader and it states that human society depends on the benefits provided by nature. It is problematic, that the value of the ecosystem services is not fully appreciated. (European Commission 2013) Green Infrastructure shall become an integral part of spatial planning as it can contribute to grey infrastructure solutions or even offer better alternatives (European Commission 2020). Investing in Green Infrastructure could bring benefits in medium and long-term perspectives and is already recognised as contributing to sustainable growth in Europe (European Commission 2011b). There is usually a high return on Green Infrastructure investments (European Commission 2013).

The implementation of the EU Green Infrastructure Strategy is an important step towards the success of another strategy developed by the EU, the 2020 Biodiversity Strategy which reflects the commitments taken by the EU in 2010, within the international Convention on Biological Diversity (European Commission 2020).

The 2020 Biodiversity Strategy formulates six main targets, several of which are related to the topic of this study. Target 1 aims 'to halt the deterioration in the status of all species and habitats covered by EU nature legislation and achieve a significant and measurable improvement in their status [...]'. The strategy requires in Target 2 that by establishing Green Infrastructure ecosystems and their services have to be maintained and enhanced and at least 15% of degraded ecosystems have to be restored by 2020. Target 3A concerns agriculture, species and habitats that depend on or are affected by agriculture and related ecosystem services. Through biodiversity-related measures conservation of biodiversity and a measurable improvement shall be ensured and sustainable management shall be supported. Furthermore Target 6 states that 'by 2020, the EU has stepped up its contribution to averting global biodiversity loss'. (European Commission 2011a)

The mid-term review of the EU Biodiversity Strategy assessed that local actions delivered positive outcomes, but it stresses the importance of intensifying the implementation of measures across all targets. It warns that further biodiversity loss and the degradation of ecosystem services will significantly affect the capacity of biodiversity to meet human needs in the future. (European Commission 2015) There is a need to develop, preserve and enhance healthy Green Infrastructure and the greater the scale, coherence and connectivity of its network the greater the benefits (European Commission 2020). The patterns of land cover and the degree of fragmentation of natural habitats will also influence the ability of ecological systems to respond to a changing climate (Dale et al. 2000).

The concept of Green Infrastructure describes a holistic approach to preserve and restore a functional network which provides benefits to both nature in general and also to mankind. In this context my work can provide additional data which subsequently can be used to create concepts for further strategies.

1.3.2 Sustainable planning

Especially in a country where natural undisturbed wildlife no longer exists, nature conservation can not be banned to a few last resorts but has to be extended to form a network covering the whole landscape. This is in line with Cassatella (2013) who states, that there is need for integrating the protection of natural resources into ordinary territorial planning.

Dale et al. (2000) provided ecological principles and guidelines for managing the use of land. Decision makers and citizens should include ecological perspectives in choices on how land is used and managed. Most land-management decisions currently have little relation to ecological science, being influenced more strongly by economics, values, traditions, politics, and other factors. Dale et al. (2000) state that scientists have a significant opportunity to help guide that process for the benefit of all creatures and should develop the science that is needed by land managers.

The theory of contemporary sustainable landscape planning was reviewed by Ahern (2005), who described methods and discussed challenges, barriers and strategies to the implementation of sustainable landscape planning. He describes the transdisciplinary model where planning may become even more integrated with research, enabling the multidimensional challenge of sustainability to be understood more rigorously. In this approach many disciplines are involved, and also the public (i.e. stakeholders, elected officials) are similarly involved in planning and decision making. He states that 'the trend towards interdisciplinarity and transdisciplinarity is central to sustainable planning'.

Pena et al. (2010) developed a methodology for creating greenways for walking and cycling through multidisciplinary sustainable landscape planning. They point out the necessity of understanding the natural and cultural interrelationships as a basis for ecological landscape planning to archive landscape sustainability.

In line with these concepts I aim to deliver a scientific background for stakeholders and decision makers to create nature friendly bicycle routes and develop sustainable bicycle tourism projects.

My study was connected to the interreg programme 'MaGICLandscapes - Managing Green Infrastructure in Central European Landscapes' which is shortly described as following: 'MaGICLandscapes aims to provide tools and information to help policy-makers, land managers and communities manage Green Infrastructure in a way that meets local needs and maximises the benefits it provides at the local, regional, national and transnational level. The tools are designed to enable targeted and evidencebased investment that is supported by communities, local, regional and national agencies.' (MaGICLandscapes n.d.)

Nature conservation has to be embedded in the landscape where it has to cope with other users with different needs and demands. With this study I want to contribute in finding solutions that benefit different parties to develop a concept with a realistic chance to be sustainable.

1.3.3 Cycling tourism

Apart from more general planning approaches I could not find any previous research where the specific topic of nature conservation in connection to cycling tourism was analysed in detail. However, many studies indicate, that the preferences of bicycle tourists are related to the aims of nature conservation in the study area.

Ode et al. (2009) found that landscape indicators associated with naturalness are important in the formation of preference. The findings of De Valck et al. (2017) show that cyclists seem to prefer natural, semi-natural and diverse landscapes. They enjoy crossing landscapes that offer a good mix of features. Van Berkel & Verburg (2014) surveyed the appreciation of tourists of cultural ecosystem services in an agricultural landscape and evaluated it conducting a willingness to pay exercise. They found that landscape change due to rewilding is not considered a problem. Ritchie (1998) researched the increasingly important vacation type of bicycle touring and determined, that cycle tourists are primarily motivated by the travel experience of cycling. Therefore for further development he recommends to promote for example nature, environment, scenery or the ability to explore an area, rather than the traditional core products such as attractions or entertainment. Even though day touring cyclists can not be compared exactly to touring cyclists, these aspects seem to apply here too.

Additional information about nature along the bicycle routes could enhance the experience of nature for cycling tourists even more, as Gobster (1999) determined that ecological knowledge changes how people look at nature and also what is considered to be aesthetic. Therefore it could help resolve conflicts between aesthetic and sustainability values.

Those findings indicate, that a nature themed bicycle route would be appealing to cyclists. This could be described as a variant of ecotourism in a cultural landscape as the International Ecotourism Society defines ecotourism as ’responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education’. (TIES 2015)

In this study I focus on the experience of nature for cycling tourists. Related aspects such as Points of Interest and the type of road surface on the path were also considered. But as it would have gone far beyond the scope of this study I did neither take into account touristic infrastructure such as accommodations or restaurants, nor the quality of the signposting on the cycling paths.

1.4 Outline

What might be considered as natural and appealing to bicycle tourists is not necessarily the same as the objective of nature conservation. And on the other hand attractive areas could be overused which leads to pressure and decreasing quality of nature. Therefore the compatibility of the ecological and the touristic point of view had to be determined. Additionally I assessed the perspective of land use as it is a main factor in the study area and had to be considered too. By comparing this three perspectives I assessed correlations and possible conflicts.

First I selected four bicycle routes in the study area Westliches Weinviertel considering aspects such as length of the bicycle route, degree of difficulty, location according to the European Protection Area ’Westliches Weinviertel’ and habitat classes according to the ’CEH’ (’Central European Habitat Map’).

Then I applied a stratified sampling design and selected 70 sampling circles in three different strata for the survey. On site I mapped the sampling circle, conducted a landscape structure survey (Wrbka et al. 2015) and collected additional data for focus habitats and the bicycle route itself.

After data entry and digitalisation I applied a newly developed method which I based on the approach of Pöll et al. (2016) to compute a composite biotope value.
I calculated rescaled values for 28 landscape variables per sampling circle from the mapping and the collected data and used them as criteria to compute three overall values of each sampling circle. Each of the overall values expresses a different point of view and therefore the three formulas use different criteria that contribute to the particular perception. After applying the formulas I rescaled the yielded values to range from 0 to 1 resulting in the overall values 'Natural Value', 'Cycling Tourism Value' and 'Land Use Value'.
The 'Natural Value' describes the perspective of nature conservation and the ecological value of the sampling circle, the 'Cycling Tourism Value' represents the extent of experience of nature for cycling tourists in a sampling circle and to calculate the 'Land Use Value' I adopted the perspective of intensive land use which aims for maximum direct profit.

Additionally I compared the results to the strata and to the separately computed value 'Suitability for Multifunctional Development, SMD'.

2 Materials and methods

2.1 Software, basemaps and spatial data

I used Microsoft Excel 2016 (Microsoft n.d.) for digitising the collected data from my data entry forms and for creating tables and bar charts for the thesis.

I digitised my mappings with ESRI ArcGIS 10.6 ArcMap (ESRI 2017) which I also used for processing all spatial data and creating maps for the thesis.

For the maps I used the basemaps ’Weltweite Grenzen und Orte’ (ESRI n.d. b), ’Weltweite Bilddaten’ (ESRI n.d. a), ’OpenStreetMap’ (OpenStreetMap (and) contributors n.d.) and ’Geoland Basemap Orthofoto’ (Stadt Wien und Österreichische Länder bzw. Ämter der Landesregierung n.d.).

In addition I used the ’Central European Habitat Map’ (Kuttner et al. 2017).

In the study I used spatial data from data.gv.at, namely the administrative boundaries of Austria (BEV - Bundesamt für Eich- und Vermessungswesen 2017), the punctual natural monuments (Amt der NÖ Landesregierung 2017b), the laminar natural monuments (Amt der NÖ Landesregierung 2017a), nature conservation areas (Amt der NÖ Landesregierung 2017c), and from the European Protection Areas the Special Areas of Conservation (SAC) (Amt der NÖ Landesregierung n.d. a) and the Special Protection Areas (SPA) (Amt der NÖ Landesregierung n.d. b).

For calculations, assessment and creating charts I used R (R Core Team 2018), in particular Rstudio (RStudio Team 2016) and the additional packages vegan (Oksanen et al. 2019b), corrgram (Wright 2018), rgl (Adler et al. 2019) and ggplot2 (Wickham 2016).

For writing the thesis I used Microsoft Word 2016 (Microsoft n.d.).

2.2 The study area

2.2.1 Geography and geology

My study area was chosen in accordance to the ’MaGICLandscapes’ case study area ’Eastern Waldviertel & Western Weinviertel’. To get more comparable results for this specific study I focused on Western Weinviertel.

Western Weinviertel is located in Austria in the federal province of Lower Austria. Austria is subdivided in nine states. The state of Lower Austria in the northeast of the country is again subdivided in quarters. Weinviertel - the ’quarter of wine’ - is in the northeast, bordering Waldviertel - the ’quarter of forest’ - in the northwest. There are different definitions of the border to Eastern Waldviertel. **Figure 1** shows the location of the four bicycle routes I chose for my study and the borders of the political district Horn, which is part of Waldviertel, and Hollabrunn, which belongs to Weinviertel. The political boundary does not follow the landscape structure and the geographical classification of natural landscapes, where the border between the two regions is the ridge of the mountain Manhartsberg. Referring to the geographical boundary small parts of the bicycle routes still just cross the border to Waldviertel, but they are primarily located in Weinviertel.

There is no large stream network in the study area. The existing rivers Pulkau, Schmida and Göllersbach are embedded in wide valleys. Pulkau flows into the river Thaya in the north, whereas Schmida and Göllersbach empty into Austria's main river Donau in the south.

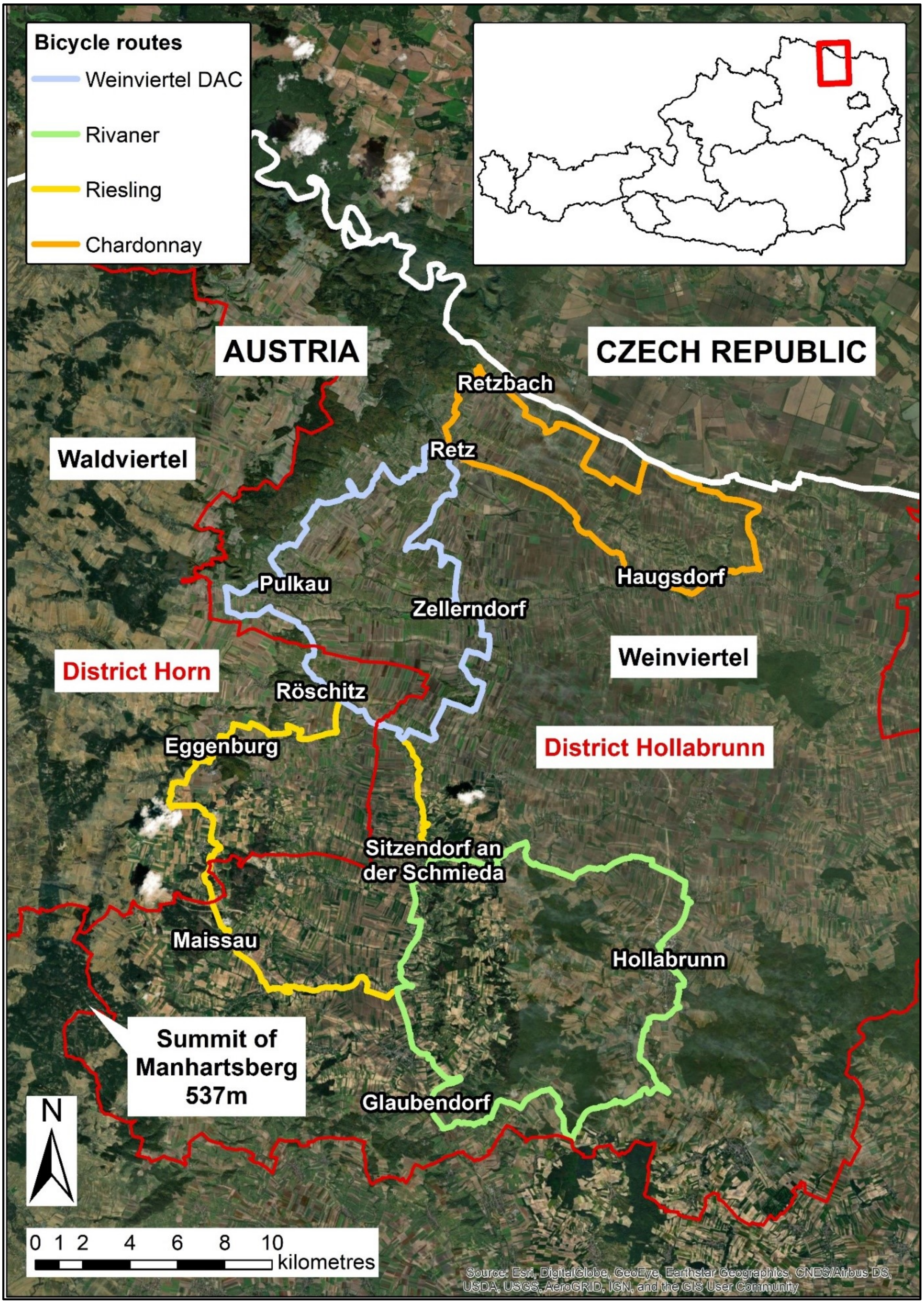

Figure 1: Location of the selected bicycle routes, landscape structure and political districts

The geologic multi-topic map of Austria 1 : 1,000,000 of the 'Geologische Bundesanstalt', the federal institute of geology, shows that the whole study area is part of the Eurasian Plate. Furthermore it is part of the Moravo-Silesian Superunit and the Moldanubian Superunit with the Drosendorf Nappe System ('Bunte Serie') and the Gföhl Nappe System in the study area. Three faults and fault systems cross the surveyed bicycle routes (See **Figure 2**). The geology consists mainly of granite, orthogneiss and paragneiss, covered by the sediments of a sediment basin from the post and middle Eocene (See **Figure 3**). (Geologische Bundesanstalt 2017) The formative sediment in the area is loess, a deposit blown in by wind during glacial periods (Geologische Bundesanstalt n.d.).

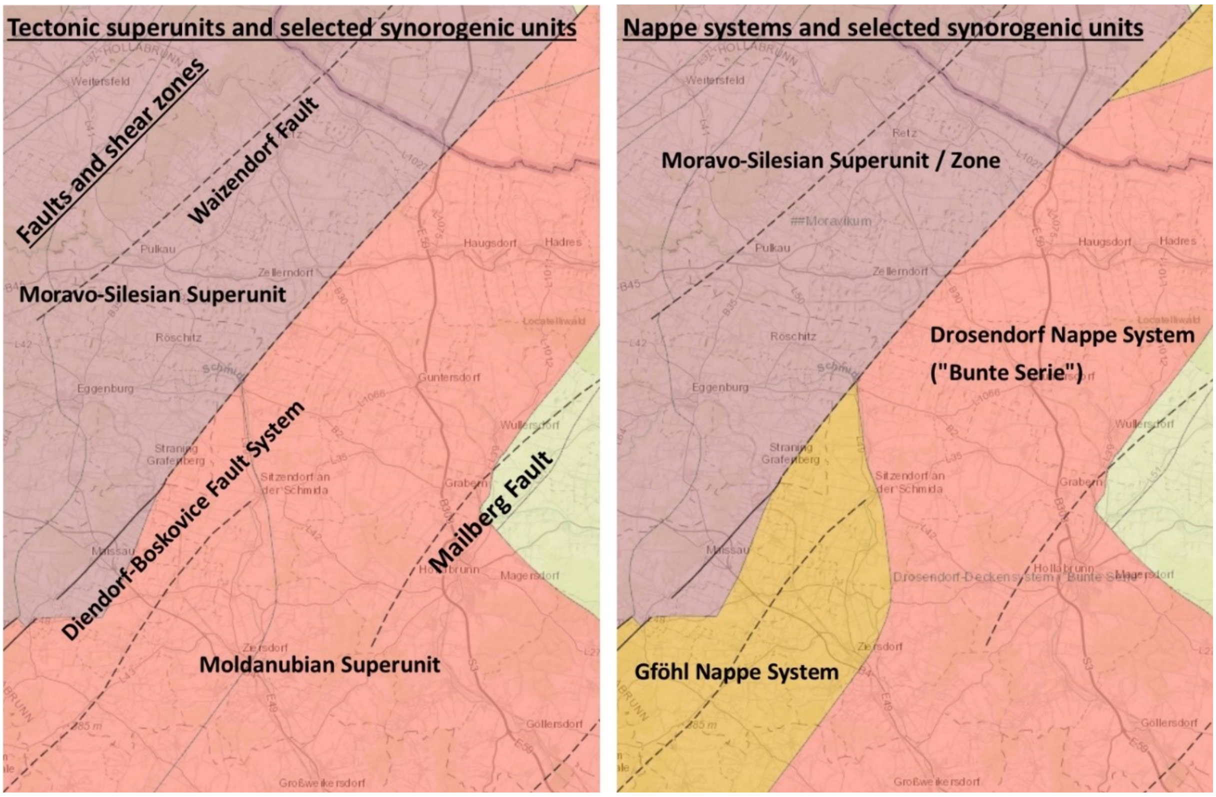

Figure 2: Tectonic, nappe systems and faults of the study area
Adapted from the geologic multi-topic map of Austria (Geologische Bundesanstalt 2017). Section of the study area. Items in the map without label do not touch the surveyed bicycle routes.

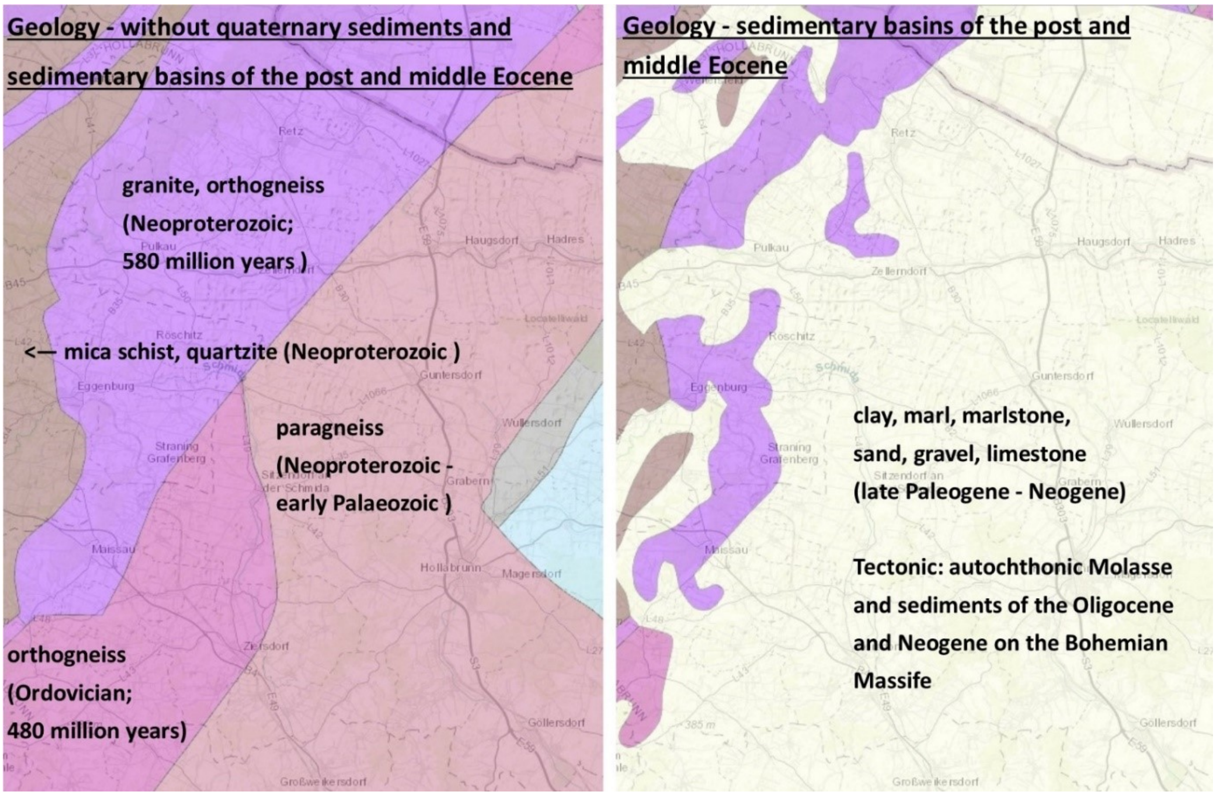

Figure 3: Geology of the study area
Adapted from the geologic multi-topic map of Austria (Geologische Bundesanstalt 2017). Section of the study area. Items in the map without label do not touch the surveyed bicycle routes. The bicycle routes Chardonnay and Weinviertel DAC pass the granite / orthogneiss zone and the paragneiss zone but Weinviertel DAC also touches the orthogneiss zone in the south. The bicycle route Rivaner passes the paragneiss zone and the orthogneiss zone in the south while the bicycle route Riesling passes all four geologic zones. The sediments of the basin cover most of the area and are connected to all four bicycle routes.

2.2.2 Climate and landscape structure

Western Weinviertel is part of the Pannonian climate zone. The ZAMG (Zentralanstalt für Meterologie und Geodynamik - the Austrian research facility for meteorology and geodynamics from the federal ministry) has two permanent measuring facilities for meteorological data in the study area, in Retz and Hollabrunn. The data from the period 1981-2010 is listed in **Table 1**. The mean temperature and hours of sunshine are above Austrian average, while days of frost, snow cover and the amount of precipitation are below average. Especially the very low amount of precipitation with 483 mm and 519 mm per year is distinguishing, as Western Weinviertel is one of the driest regions in Austria.

	Air temperature	Days of frost	Days with snow cover of at least 1cm	Hours of sunshine	Sum of precipitation
Austrian mean	7,3 °C (169 p.m.f.)	123 days (164 p.m.f.)	85 days (143 p.m.f.)	1754 hours (61 p.m.f.)	1013 mm (163 p.m.f.)
Retz	9,5 °C	87 days	no data	1827 hours	483 mm
Hollabrunn	9,2 °C	95 days	43 days	no data	519 mm

Table 1: Adapted from the climate data of the period 1981-2010 from ZAMG (ZAMG n.d.)
All values are the mean per year in the period 1981-2010.
I calculated the Austrian mean from the existing data. In brackets I listed the amount of permanent measuring facilities for meteorological data (p.m.f.) with measured values to this particular measurement.

The undulating landscape is ascending from east to west and is mostly characterised by intensive agriculture. In steeper areas small structured vineyards are combined with patches of arid grassland. In some valleys there are remnants of former large wetlands, on the hilltops there are some remaining arid forests.

2.3 Nature conservation in the study area

2.3.1 General

In ArcMap I applied a buffer of 500 m around the natural reserves and natural monuments, both punctual and laminar. The sampling circles I created on the four surveyed bicycle routes have a radius of 100 m (See 2.7 Sampling design). The buffer area of two natural reserves intersected the sampling circles and were therefore considered in my study. 'Fehhaube-Kogelsteine' with an extent of 70,099 m^2 is located in the municipalities Straning-Grafenberg and Eggenburg in the district Horn and 'Mühlberg' with an extent of 10,094 m^2 in the municipality Sitzendorf/Schmida in the district Hollabrunn. Also the buffer areas of 22 natural monuments intersected with the sampling circles. They are listed in **Table 2**.

Description	Category
1 *Tilia platyphyllos*, 1 *Aesculus hippocastanum*	Grove / tree-lined road
2 *Quercus sp.*	Grove / tree-lined road
Aesculus hippocastanum, *Tilia sp.*	Grove / tree-lined road
Aesculus hippocastanum, *Tilia sp.*	Grove / tree-lined road
Taxus baccata	Single tree
Quercus sp.	Single tree
Quercus sp.	Single tree
Tilia sp.	Single tree
Morus sp.	Single tree
Populus sp.	Single tree
Fagus sylvatica	Single tree
Tilia platyphyllos	Single tree
Tilia cordata	Single tree
Block of granite and surroundings in a radius of 5 meter	Rock formation
Stone 'Hangenstein'	Rock formation
Holy stone or cup marked stone	Rock formation
Rock formation 'Teufelswand'	Rock formation
Artificial cave system 'Schredlkeller'	Cave
Rock formation and plant site 'Fehhaube'	Dry habitats
Plant site	Dry habitats
Plant site *Krascheninnikovia ceratoides*	Dry habitats
Area of dry grassland 'Hollerberg'	Dry habitats

Table 2: Natural monuments pertinent for the study
Adapted from the datasets of natural monuments from data.gv.at (Amt der NÖ Landesregierung 2017b; Amt der NÖ Landesregierung 2017a).

Furthermore the two protected landscapes 'Oberes Pulkautal' and 'Retzer Hügelland' are in the study area but they are without further consideration in the study.

2.3.2 The European Protection Area 'Westliches Weinviertel'

The European Protection Area 'Westliches Weinviertel' is part of the EU Natura 2000 network and was among other things an important parameter in selecting the bicycle routes for the study. It is composed of Special Areas of Conservation (SAC) which are protected according to the 'Habitats Directive' and of Special Protection Areas (SPA) which are protected according to the 'Birds Directive'. Located in the districts Horn and Hollabrunn it is partly in Waldviertel but it is organised as a European Protection Area of the main region Weinviertel. The many smallish SACs are located east of the Manhartsberg range and cover an area of about 2,982 hectare. The SPAs are much larger and more connected and extend into Pulkautal in the north covering about 16,904 hectares. In total the European Protection Area 'Westliches Weinviertel' has an area of 18,099 hectares as some areas are SAC and SPA at once. It is one of the smaller European Protection Areas in Lower Austria but despite its small size it is an important part of the European network of conservation areas. Many habitat types and animal species reach the north-western border of their geographic range here. (Amt der NÖ Landesregierung n.d. c)

The area is part of the continental biogeographic region and of the Pannonian clime and is one of the driest regions in Austria. It ranges from 191 m to 468 m above sea level and is part of the Bohemian Massif with sour, siliceous rocks as well as of cancerous loess areas in the east. (Amt der NÖ Landesregierung n.d. c)

The position of the European Protection Area 'Westliches Weinviertel' and the surveyed bicycle routes is shown in **Figure 4**.

The information given by (Amt der NÖ Landesregierung n.d. c) is not quite up to date. In the Standard Data Form for 'Westliches Weinviertel' (EEA 2018b) 2,994.41 hectares for the SACs are listed. It seems that the area around the stream Retzbach has been added, which can be seen on the Natura 2000 Network Viewer.map of the European Environment Agency (EEA 2018c) but it is not represented in the spatial data available on data.gv.at (Amt der NÖ Landesregierung n.d. a). Therefore this SAC in the northwest of my study area in connection to the bicycle route Chardonnay is not represented in my sampling design, especially as I discovered this fact at the end of my study. But since I considered the SACs and SPAs only in the preselection of the bicycle routes and not in the selection of the sampling circles it would not have changed the sampling design because in any case I chose the bicycle route Chardonnay for the survey.

Also the protected species and habitats listed by (Amt der NÖ Landesregierung n.d. c) do not correspond to the Standard data form (EEA 2018b).

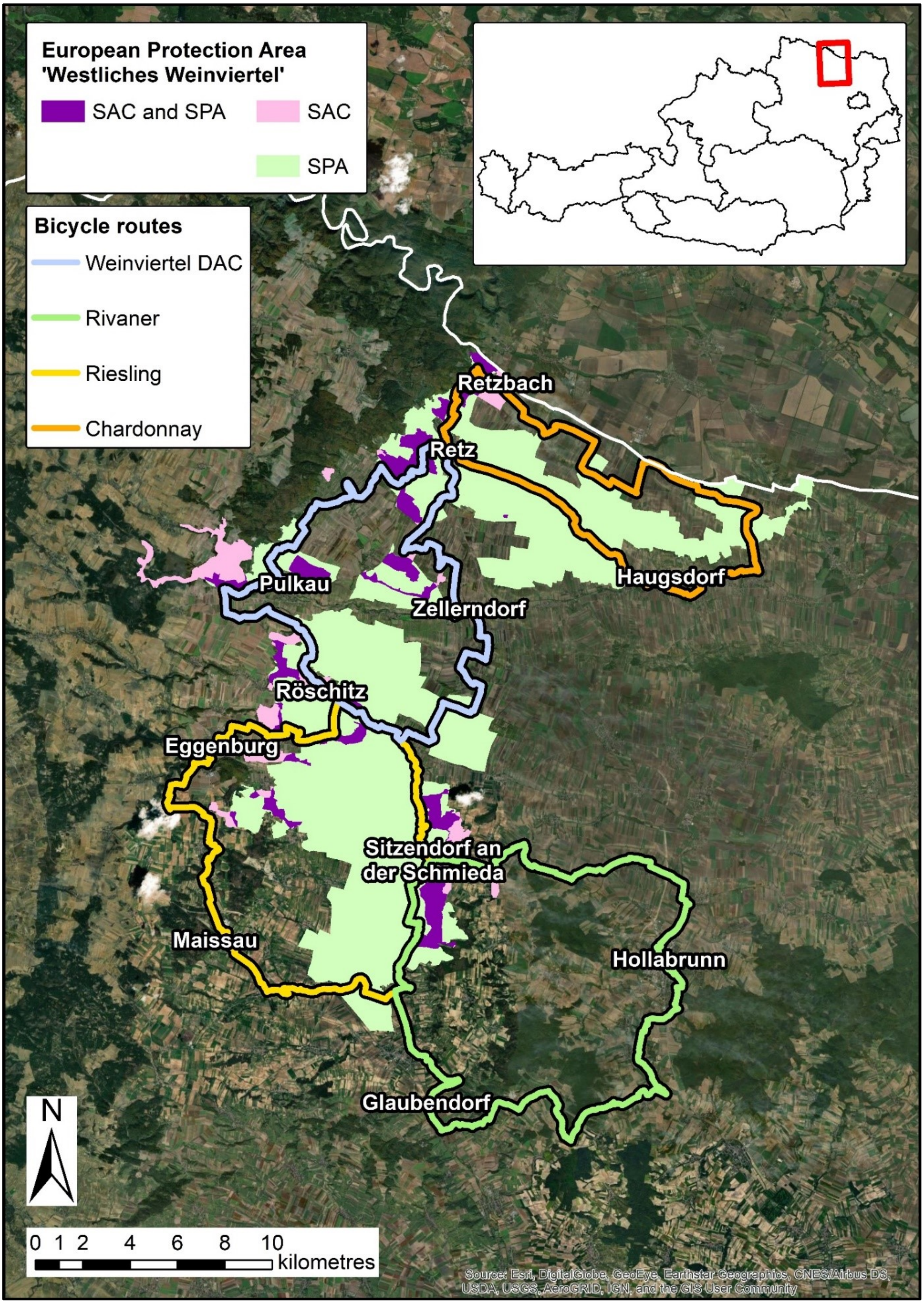

Figure 4: The four selected bicycle routes and the European Protection Area 'Westliches Weinviertel'

21 species listed in Annex II of the 'Habitats Directive' are listed for the European Protection Area 'Westliches Weinviertel' (EEA 2018b) (See **Table 3**). *Spermophilus citellus* and *Lycaena dispar* occur frequently in the European Protection Area 'Westliches Weinviertel' whereas the sites for other species are very localized. The listed amphibians *Bombina bombina*, *Triturus cristatus* and *Triturus dobrogicus* can be found at two small ponds close to Röschitz and Pranhartsberg. *Myotis emarginatus* and *Rhinolophus hipposideros* live at the Kellergasse Obernalb (Amt der NÖ Landesregierung n.d. c).

Group	**Binomial name**
Plant	*Himantoglossum adriaticum*
Plant	*Iris humilis ssp. arenaria*
Plant	*Pulsatilla grandis*
Invertebrate	*Coenagrion ornatum*
Invertebrate	*Euphydryas maturna*
Invertebrate	*Lucanus cervus*
Invertebrate	*Lycaena dispar*
Invertebrate	*Ophiogomphus cecilia*
Invertebrate	*Osmoderma eremita*
Invertebrate	*Phengaris nausithous*
Invertebrate	*Phengaris teleius*
Invertebrate	*Vertigo angustior*
Amphibian	*Bombina bombina*
Amphibian	*Triturus cristatus*
Amphibian	*Triturus dobrogicus*
Mammal	*Barbastella barbastellus*
Mammal	*Mustela eversmanii*
Mammal	*Myotis emarginatus*
Mammal	*Myotis myotis*
Mammal	*Rhinolophus hipposideros*
Mammal	*Spermophilus citellus*

Table 3: Species in the European Protection Area 'Westliches Weinviertel' listed in Annex II of the 'Habitats Directive'.
Adapted from European Environment Agency (EEA 2018b).

There are 54 different bird species in the European Protection Area 'Westliches Weinviertel' referred to in Article 4 of the 'Birds Directive' (EEA 2018a). The SPAs of 'Westliches Weinviertel' cover mainly sweeping open agricultural landscape. This is the perfect habitat for *Otis tarda* whose sub-population here is presumed to be the largest in Lower Austria. Furthermore it is an important habitat for raptors like *Circus pygargus*. In areas of forested steppe and dry grassland with vineyards *Lullula arborea*, *Lanius collurio* and *Sylvia nisoria* can be found, sometimes with high population density (Amt der NÖ Landesregierung n.d. c).

Annex I of the 'Habitats Directive' specifies natural habitat types of community interest whose conservation require the designation of SACs. In the Natura 2000 Standard Data Form for 'Westliches Weinviertel' 16 of those habitat types are listed, 6 of them are priority habitat types (See **Table 4**) (Rat der Europäischen Union 2013; EEA 2018b).
The list includes two habitats which have been additionally added to the original Annex I of the 'Habitats Directive'. These are habitat code 40A0, Subcontinental peri-Pannonic scrub and habitat code 6190, Rupicolous pannonic grasslands (Stipo-Festucetalia pallentis) (Rat der Europäischen Union 2006). **Table 5** shows more details of the assessment of the habitat types present on the site.

Code (* = priority)	**Habitat type**
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation
40A0*	Subcontinental peri-Pannonic scrub
6190	Rupicolous pannonic grasslands (Stipo-Festucetalia pallentis)
6210	Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites)
6240*	Sub-Pannonic steppic grasslands
6250*	Pannonic loess steppic grasslands
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
6510	Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis)
8220	Siliceous rocky slopes with chasmophytic vegetation
8230	Siliceous rock with pioneer vegetation of the Sedo-Scleranthion or of the Sedo albi-Veronicion dillenii
8310	Caves not open to the public
9170	Galio-Carpinetum oak-hornbeam forests
9180*	Tilio-Acerion forests of slopes, screes and ravines
91E0*	Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)
91G0*	Pannonic woods with Quercus petraea and Carpinus betulus

Table 4: Habitats in the European Protection Area 'Westliches Weinviertel' protected according to Annex I of the 'Habitats Directive'.
Adapted from European Environment Agency (EEA 2018b) and Rat der Europäischen Union (2013).

Annex I Habitat types				Site assessment			
Code	**Cover [ha]**	**Cave [number]**	**Data quality**	**Representativity [A|B|C|D]**	**Relative Surface [A|B|C]**	**Conservation [A|B|C]**	**Global [A|B|C]**
3150	0.5	-	M	D	-	-	-
3260	0.5	-	M	D	-	-	-
40A0	0.14	-	G	A	B	A	A
6190	15	-	M	B	C	A	B
6210	125.9	-	M	B	C	B	B
6240	1.9	-	M	C	C	B	C
6250	1.15	-	G	A	B	B	A
6430	0.5	-	M	D	-	-	-
6510	0.6	-	M	C	C	B	C
8220	5.1	-	M	B	C	B	B
8230	1.3	-	M	C	C	B	C
8310	0.1	3	M	B	C	A	C
9170	9.1	-	M	C	C	C	C
9180	18.1	-	M	B	C	C	C
91E0	46.6	-	M	C	C	B	C
91G0	56.4	-	M	C	C	B	C

Table 5: Habitat types present on the site and assessment for them
Adapted from European Environment Agency (EEA 2018b)
Caves: for habitat types 8310, 8330 (caves) enter the number of caves if estimated surface is not available.
Data quality: G = 'Good' (e.g. based on surveys); M = 'Moderate' (e.g. based on partial data with some extrapolation); P = 'Poor' (e.g. rough estimation)
Representativity: = A(a) of Annex III: degree of representativity of the habitat type on the site.
A: excellent representativity; B: good representativity; C: significant representativity; D: non-significant presence
Relative Surface: = A(b) of Annex III: Area of the site covered by the natural habitat type in relation to the total area covered by that natural habitat type within the national territory.
A: 100 ≥ percentage > 15 %; B: 15 ≥ percentage > 2 %; C: 2 ≥ percentage > 0 %
Degree of conservation: = A(c) of Annex III: Degree of conservation of the structure and functions of the natural habitat type, concerned and restoration possibilities.
A: excellent conservation; B: good conservation; C: average or reduced conservation
Global assessment: = A(d) of Annex III: Global assessment of the value of the site for conservation of the natural habitat type concerned.
A: excellent value; B: good value; C: significant value

Grassland is the most important category of habitat types in the European Protection Area 'Westliches Weinviertel'. Except a few lowland hay meadows they are types of dry grassland. At places of very shallow soil siliceous rock with pioneer vegetation of the Sedo-Scleranthion or of the Sedo albi-Veronicion dillenii and Siliceous rocky slopes with chasmophytic vegetation can be found. Semi-natural dry grasslands and scrubland facies on calcareous substrates, Sub-Pannonic steppic grasslands, and Pannonic loess steppic grasslands are mostly scattered small patches placed on hilltops. They are mainly originated from mowing and pasturing. Nowadays they are not used in these ways anymore and are therefore endangered by the encroachment of shrubs. This results in a decrease in the biodiversity of species.

The forest habitats have diverse characteristics. Particularly distinguishing are the Pannonic woods with *Quercus petraea* and *Carpinus betulus* which can be found mainly in the east of the area. Tilio-Acerion forests of slopes, screes and ravines and Galio-Carpinetum oak-hornbeam forests are mostly situated further west. Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* are predominantly alongside streams. (Amt der NÖ Landesregierung n.d. c)

I downloaded the spatial data of the European Protection Area 'Westliches Weinviertel' with all SACs and SPAs in May 2018 from data.gv.at (Amt der NÖ Landesregierung n.d. a; Amt der NÖ Landesregierung n.d. b). For my study I chose four bicycle routes which are connected to the European Protection Area 'Westliches Weinviertel' as it can be assumed that there is pre-existing Green Infrastructure and good possibilities for cycling tourists to experience nature.

2.4 The 'Central European Habitat Map'

Another important basis for the sampling design was the 'Central European Habitat Map' (CEH) (Kuttner et al. 2017) which is freely available for non-commercial scientific use. For this map fine-scale data from various sources in the public domain were harmonized and supplemented by remote mapping and modelling techniques. It covers Austria, Germany (Baden-Wurttemberg, Bavaria), Liechtenstein, Italy (South Tyrol) and Switzerland and shows habitat distribution in 19 habitat classes at a resolution of 25 m. (Kuttner et al. 2015)

I categorized the habitat classes according to the requirements of this study and for the surveyed landscape in 'Agriculture/Forestry', 'Potential' and 'Urban'. I used these categories for the sampling design (See 2.7 Sampling design). The category 'Agriculture/Forestry' comprises habitats of intensive land use. In the study area this includes coniferous forests as they have no natural occurrence in this area and are forest plantations. ’Urban’ comprises all build up areas, roads and railways. ’Potential’ are all habitat classes that might contain ecologically valuable habitats. Of course some of the habitats are not occurring in the study area such as glaciers or alpine grassland. Habitats like dry biotopes or wet biotopes are very likely to consist of ecologically valuable habitats. Whereas broad leaved forests can be remains of naturally occurring forests as well as plantations of the neophyte *Robinia pseudoacacia*. Four of the habitat classes in the category ’Potential’ intersected with the sampling circles I created for the study. These are broad leaved forest, dry biotopes, extensive grasslands and wet biotopes. **Table 6** lists all habitat classes of the ’Central European Habitat Map’ and their assigned categories. **Figure 5** shows the distribution of the habitat classes in the study area.

Category for this study	**Name**	**Habitat class**
Agriculture/Forestry	Arable land	Arable land [ARAB]
Agriculture/Forestry	Coniferous forest	Coniferous forest [CFO]
Agriculture/Forestry	Intensive used grassland	Intensively used grasslands [IGR]
Agriculture/Forestry	Vineyards	Vineyards [VIN]
Potential	Alpine grasslands	Alpine grasslands [ALPGR]
Potential	Broad leaved forest	Broad leaved forest [BLFO]
Potential	Dry biotopes	Dry grasslands [DRY]
Potential	Extensive grasslands	Extensive grasslands [EXTGR]
Potential	Glaciers	Glaciers [GLAC]
Potential	Gravel banks	Gravel banks [GRAVEL]
Potential	Lakes	Lakes [LAKE]
Potential	Major rivers	Major rivers [RIV]
Potential	Orchards	Orchards [ORC]
Potential	Rocks	Rocks [ROCK]
Potential	Shrublands	Shrub lands [SHRUB]
Potential	Wet biotopes	Mires and wet grasslands [WET]
Urban	Build up areas	Built up areas [BUA]
Urban	Major railways	Major railways [RAIL]
Urban	Major roads	Major roads [ROAD]

Table 6: Habitat classes of the ’Central European Habitat Map’ with the categories I assigned for this study

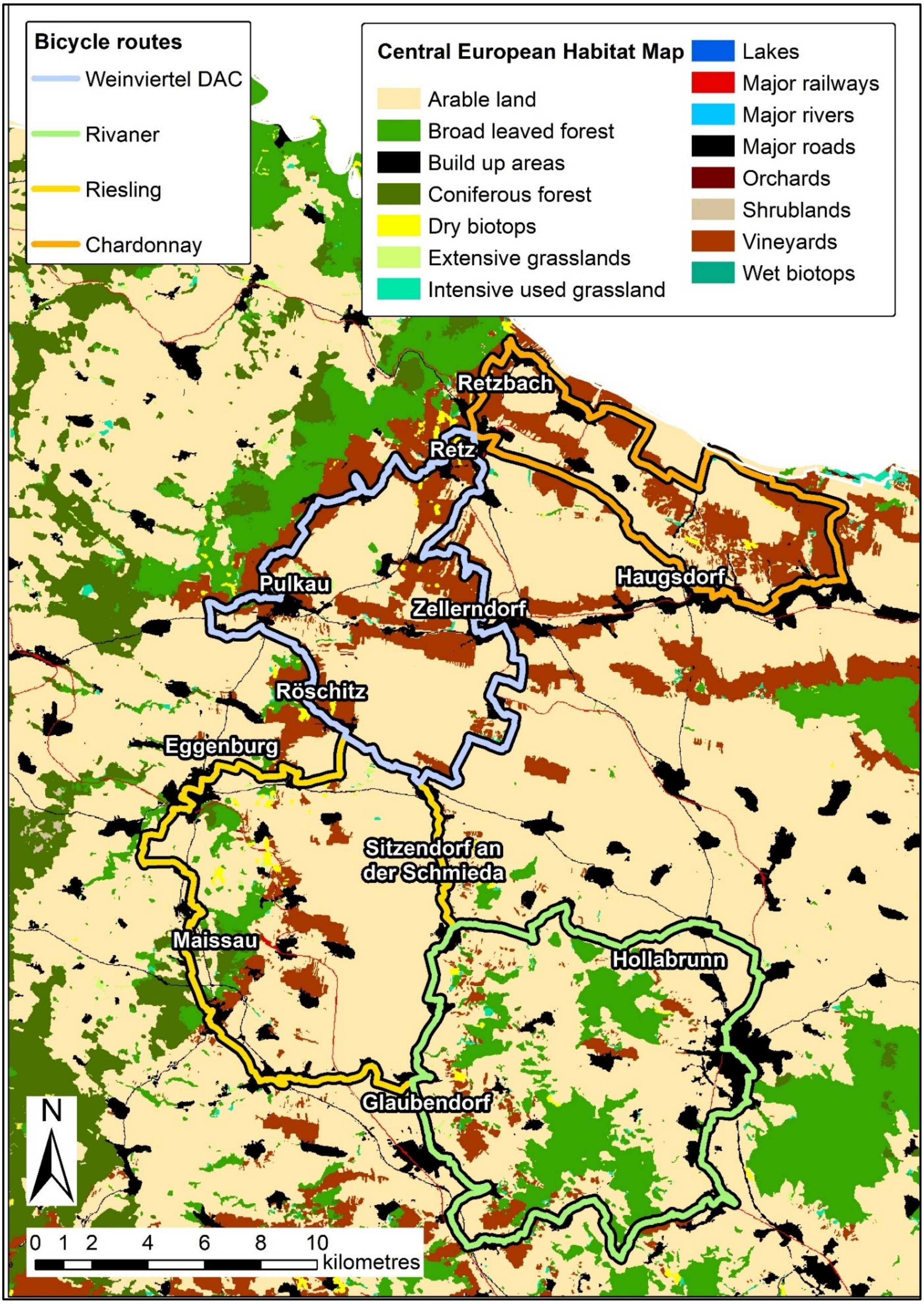

Figure 5: The 'Central European Habitat Map' in the study area, adapted colour scheme
Map created using the 'Central European Habitat Map' (Kuttner et al. 2017)

2.5 Kellergassen and Points of Interest

Kellergassen are alleys of wine cellars. They are very characteristical for the region and are located in between the vineyards. The cellars are directly dug into the soft ground, mostly with a small building on top but sometimes only with an entrance leading directly into the wine cellar. Being of cultural importance the Kellergassen are also interesting structures that provide additional habitats in an agricultural landscape.

I digitised the Kellergassen and Points of Interest (POIs) from the map 'Radkarte Weinviertel' which is the official cycling map of Weinviertel tourism available from weinviertel.at (Weinviertel Tourismus GmbH 2017). In ArcMap I buffered all Kellergassen and POIs with a radius of 500 m and kept only the records that intersected with the sampling circles on the surveyed bicycle routes (See 2.7 Sampling design). Those are 8 Kellergassen and 35 POIs in 7 categories. The POIs consist of 10 rest places, 5 castles, 4 viewpoints, 4 churches, 1 museum, 1 bicycle repair station and 10 other places of interest like exceptional buildings, natural or cultural places.

2.6 Bicycle routes

Cycling is an own branch of tourism in Weinviertel. On the official web page www.weinviertel.at there is a subpage for cycling where next to touristic packages descriptions of bicycle tours can be found. Also the download of PDF-files and geodata of the tours in the data type GPX or KML is possible. Additionally the 'Radkarte Weinviertel', a map of bicycle routes in Weinviertel on a scale of 1 : 80,000, can be ordered (Weinviertel Tourismus GmbH 2017).
'Weinviertel Tourismus GmbH' is the institution behind the web page and is among other things responsible for cycling tourism in Weinviertel. They showed an interest in my thesis and also in collaboration for further projects. Due to their cooperation I could gain a little insight in the concept and management of the bicycle routes and the touristic point of view. Thus I could choose bicycle routes for the study which are also interesting for follow-up projects on the part of cycling tourism.

In Weinviertel a whole network of bicycle routes exists. Some follow the concept of being named after different vine varieties and most of them are called ’Weinradwege’. These can be cycled as a loop and they are all suitable for daytrips. All over Weinviertel they range from 38.28 km with the level of difficulty ’easy’ at ’Welschriesling’ to 81.36 km and the level of difficulty ’difficult’ at ’Zweigelt’.

For this study I surveyed the bicycle routes ‘Chardonnay’, ’Weinviertel DAC’, ‘Riesling’ and ‘Rivaner’. For all spatial information about the bicycle routes on my project, I used the KML-data downloaded from www.weinviertel.at for the bicycle routes Chardonnay (Weinviertel Tourismus GmbH n.d. a), Riesling (Weinviertel Tourismus GmbH n.d. b), Rivaner (Weinviertel Tourismus GmbH n.d. c) and Weinviertel DAC (Weinviertel Tourismus GmbH n.d. d). I adapted the data a little by roughly correcting obviously wrong editing or double routeing.

One more ’Weinradweg’ lied in my study area, which I excluded for several reasons. ’Portugieser’ has the level of difficulty ’difficult’ and although in the meanwhile it´s lengths has been changed from 82.7 km to 75.01 km it is still one of the more ambitious routes and differs from the other four bicycle routes in the study area. Also its share in potentially interesting habitat types according to the ’Central European Habitat Map’ (see 2.4 The ’Central European Habitat Map’) is the lowest amongst them. Above all it has no contact to any SAC and only touches the SPA in the north on a route section of under two kilometres length.

However, ’Chardonnay’, ’Weinviertel DAC’, ’Riesling’ and ’Rivaner’ cover a representative variety of landscape types in the study area and are well positioned according to the European Protection Area ’Westliches Weinviertel’. All four bicycle routes are designed for day trips and have the level of difficulty ’medium’. They have length between 43.5 km and 57.3 km with altitude differences between 396 m and 717 m. Their specifications make them well comparable and are likely to attract a relatively particular and consistent kind of tourists.

The surveyed bicycle routes were built on existing paths, mostly farm tracks and small roads with little traffic. A continuous signposting marks the bicycle routes.

The location of the bicycle routes in the study area was already shown above in **Figure 1**. How they are positioned according to the European Protection Area 'Westliches Weinviertel' is shown in **Figure 4** and for the 'CEH' habitat types in which the bicycle routes are embedded see **Figure 5**. The following four figures show a closeup of the four bicycle routes on the common OpenStreetMap background (OpenStreetMap (and) contributors n.d.) (see **Figure 6**, **Figure 7**, **Figure 8**, **Figure 9**).

During the fieldwork I discovered that the actual routing sometimes does not correspond to the KML-data. Nevertheless I mapped those sampling circles if the bicycle route was still running through it.

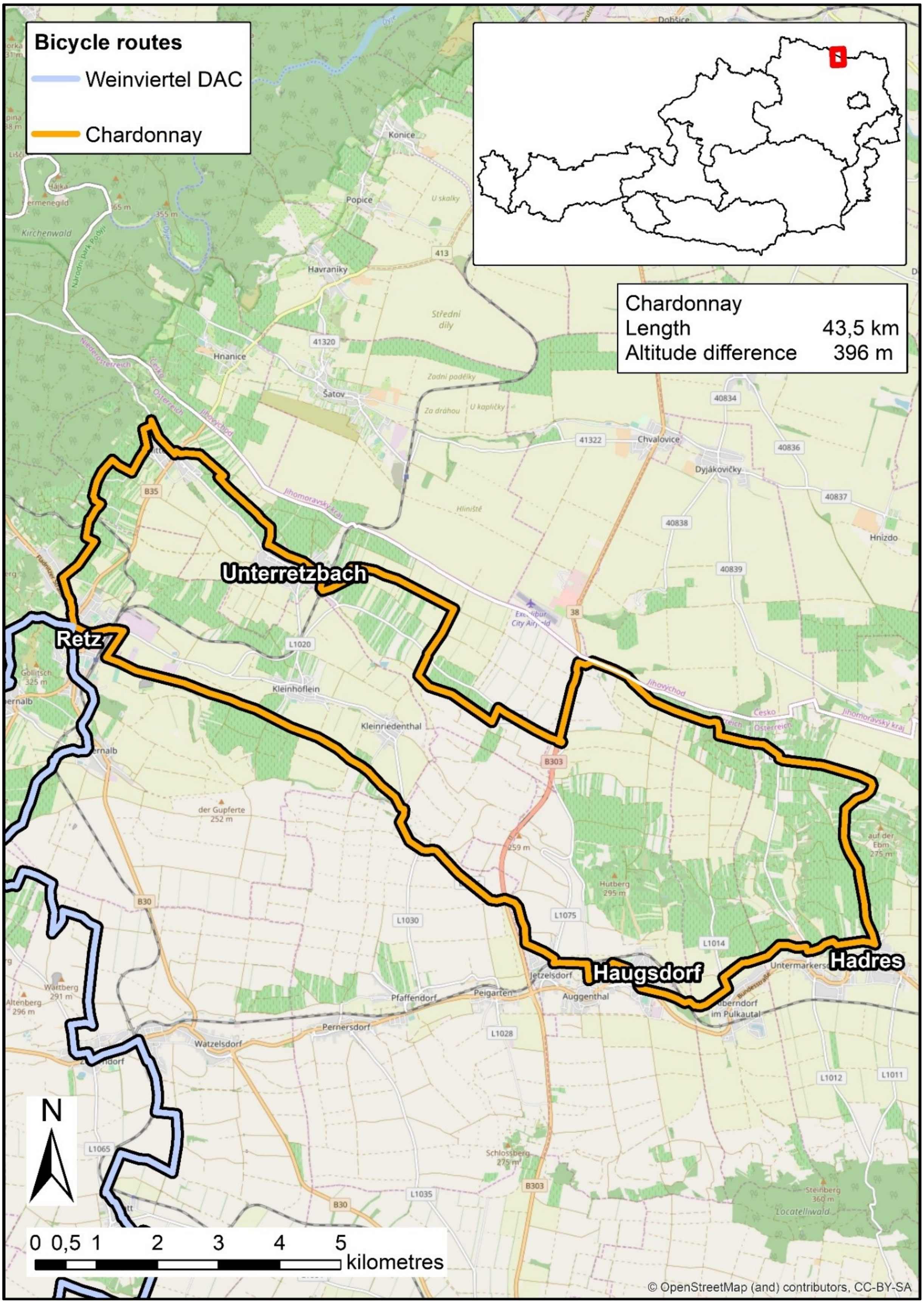

Figure 6: Bicycle route Chardonnay

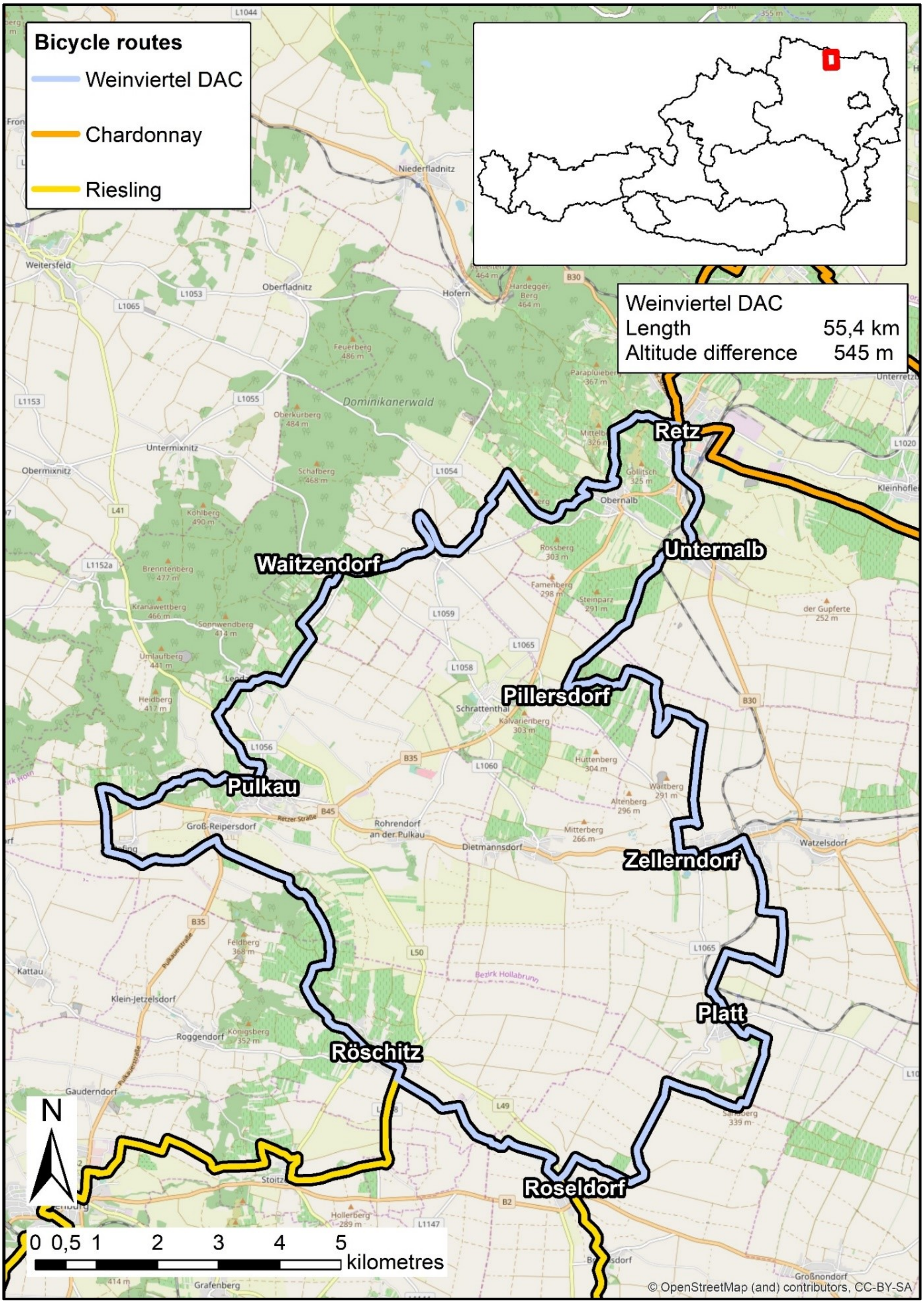

Figure 7: Bicycle route Weinviertel DAC

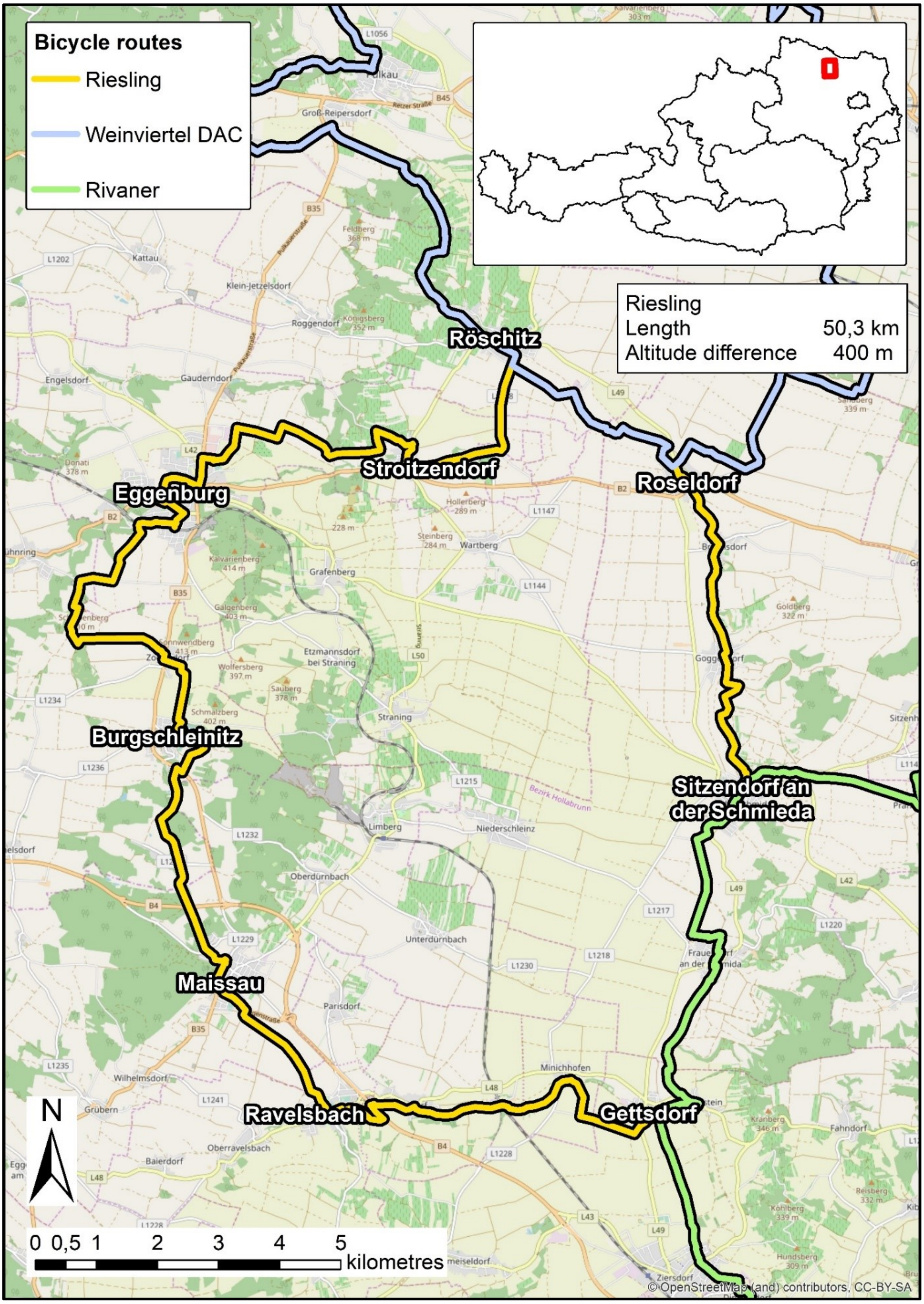

Figure 8: Bicycle route Riesling

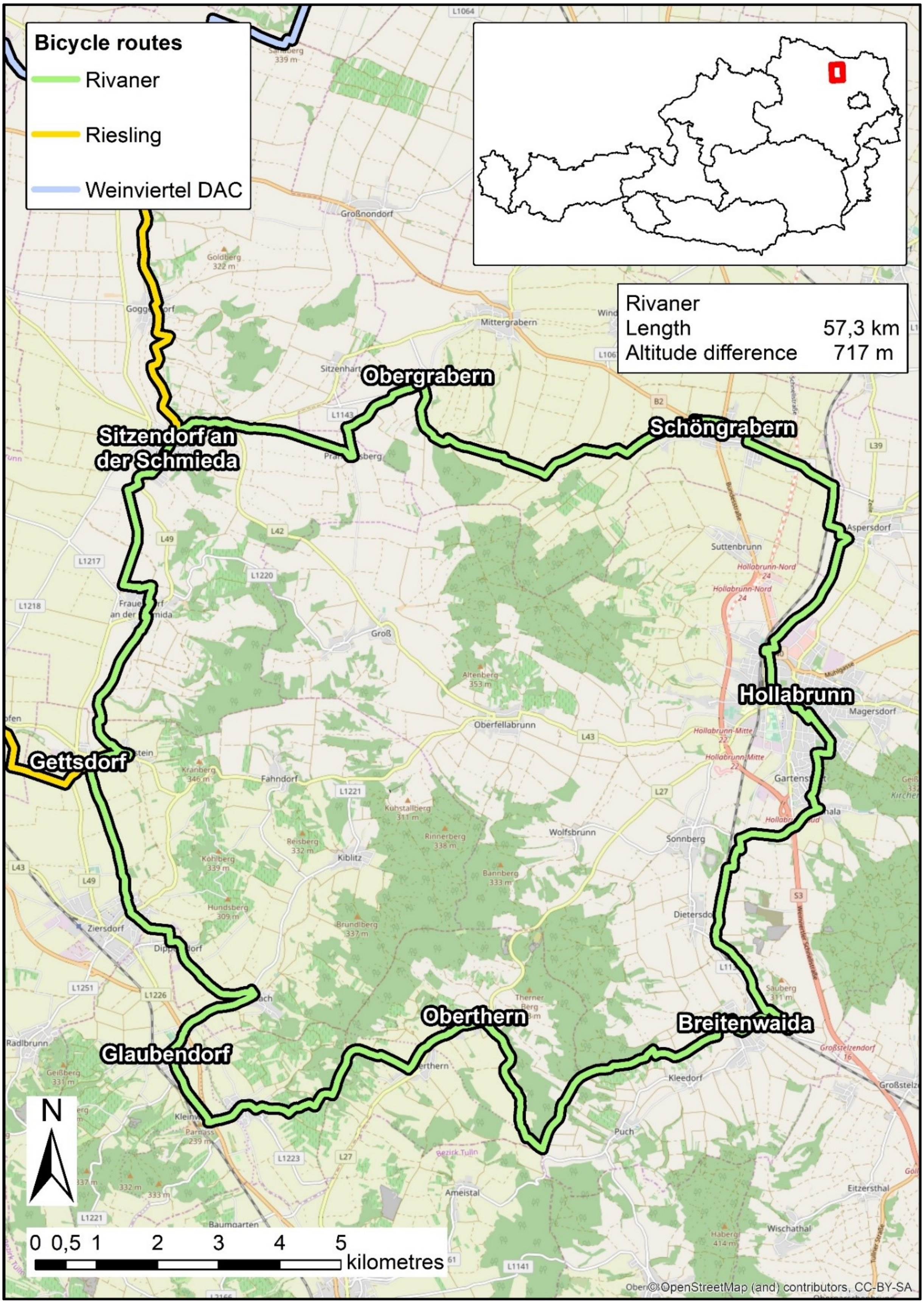

Figure 9: Bicycle route Rivaner

2.7 Sampling design

In ArcMap (ESRI 2017) I generated randomly distributed points at intervals of 300 m on the four selected bicycle routes. Each point I buffered with a radius of 100 m to create sampling circles with an area of 31,416 m^2.

With my sampling design I aimed for a good representation of the spectrum of possible landscape sections in the study area. Thus in the surveyed sampling circles all characteristics of the landscape in my study area are represented. However, highly urban area is excluded because the study is about the experience of nature for cycling tourists, consequently the focus is on non-urban landscape.

I chose a stratified sampling design and created three different strata, one of them with four sub-strata. For all strata, except the sub-stratum for Kellergasse, the urban area according to my categorisation of the 'Central European Habitat Map' (see 2.4 The 'Central European Habitat Map') had to be under 20% coverage for the sampling circle to be selected.
During the selection process I excluded overlapping sampling circles, for example close to turns, in favour of the preceding stratum or sub-stratum.
Originally I selected 89 sampling circles for the survey, 29 in stratum 1 and each 30 in stratum 2 and stratum 3. During the fieldwork I had to reduce the total amount of surveyed sampling circles to 70, because the mapping and data collection took much more time than estimated.

Stratum 1 contains sampling circles with special features that are especially interesting for the study as specified in the description of the sub-strata below. More precisely the buffer areas of those features had to intersect with the sampling circle (see 2.3 Nature conservation in the study area and 2.5 Kellergassen and Points of Interest) and the urban area had to be under 20%. I inspected satellite images of all sampling circles that met the criteria and sorted them out when it was obvious that on-site would be no reasonable relation to the special feature from the sampling circle. From all preselected sampling circles that met the criteria in a sound way I chose the most appropriate sampling circle for every combination of different special features. I considered position, accessibility, other interesting areas in the sampling circle according to the ’Central European Habitat Map’ or to satellite images. This way I got 7 sampling circles in sub-stratum 1.1, 7 in sub-stratum 1.2, 5 in sub-stratum 1.3 and 10 sampling circles in sub-stratum 1.4. These 29 sampling circles represent the full spectrum of sampling circles I got with this method under the given selection criteria for stratum 1. I surveyed 22 of these sampling circles in stratum 1. Although this was not a primary selection criterion 13 of them include habitats assigned to the category ’Potential’ I created for the ’Central European Habitat Map’ (see 2.4 The ’Central European Habitat Map’).

The first sub-stratum 1.1 consists of sampling circles that intersect with the buffer area of both a nature protection area or natural monument and some additional highlight for cycling tourists like a Kellergasse or a POI. The second sub-stratum 1.2 contains sampling circles that intersect with the buffer area of a nature protection area or natural monument but not a Kellergasse or POI. For sub-stratum 1.3, sampling circles with Kellergasse, the urban area was not considered as the Kellergasse itself is classified as an urban area in the ’Central European Habitat Map’. Sub-stratum 1.4 covers sampling circles intersecting with the buffer area of a POI. POIs which are positioned in a Kellergasse, for example rest areas, were not considered in this sub-stratum as Kellergassen are already covered in sub-stratum 1.3.

For Stratum 2 I considered the category ’Potential’ I created for the ’Central European Habitat Map’ (see 2.4 The ’Central European Habitat Map’). It had to be at least 1% coverage in the sampling circle. I excluded all sampling circles that already met the criteria of stratum 1. Three habitat types of the category ’Potential’ intersected with sampling circles with an amount of urban area under 20%. These habitat types were ’broad leaved forest’, ’dry biotopes’ and ’extensive grassland’. In some sampling circles two of these habitat types were present. I could not select an equal amount of sampling circles for each habitat type as ’dry biotopes’ occurred only 7 times but two sampling circles overlapped and one of them had to be excluded. ’extensive grassland’ occurred 6 times, one of them had to be excluded during the mapping as the KML-data of the bicycle route was incorrect and in reality the route did not go through the sampling circle. I selected the other sampling circles of these two categories for the survey and added randomly chosen sampling circles with ’broad leafed forest’ to reach the total amount of surveyed sampling circles in stratum 2.

The selection criterion for the sampling circles in stratum 3 was absence of areas of the category 'Potential' which I created for the 'Central European Habitat Map' (see 2.4 The 'Central European Habitat Map'). A coverage of maximum 1% would have been allowed and the urban area had to be under 20%. Again all sampling circles which met the criteria for stratum 1 were excluded. Stratum 2 and stratum 3 have mutually exclusive selection criteria. From all suitable sampling circles I randomly chose the surveyed sampling circles for stratum 3.

For an overview of all strata and sampling criteria see **Table 7**, the location of the surveyed sampling circles is shown in **Figure 10**.

Stratum / Sub-stratum	Nature protection area or natural monument	Kellergasse (alley of cellars)	Point of Interest (POI)	Potentially interesting habitats*	Urban area < 20%*	Amount of sampling circles
Stratum 1 - sampling circles with special features						**22**
1.1	+	+ or POI	+ or Keller-gasse	~	+	(6)
1.2	+	-	-	~	+	(6)
1.3	-	+	-	~	~	(4)
1.4	-	-	+	~	+	(6)
Stratum 2 - sampling circles with potentially interesting habitats						**24**
	~	~	~	+	+	(24)
Stratum 3 - sampling circles without potentially interesting habitats						**24**
	~	~	~	-	+	(24)
Total						**70**

Table 7: Selection criteria for the surveyed sampling circles
+/green: included, -/red: excluded, ~/yellow: not considered
* Preselected Categories from the 'Central European Habitat Map' (Kuttner et al. 2015) (see 2.4 The 'Central European Habitat Map').

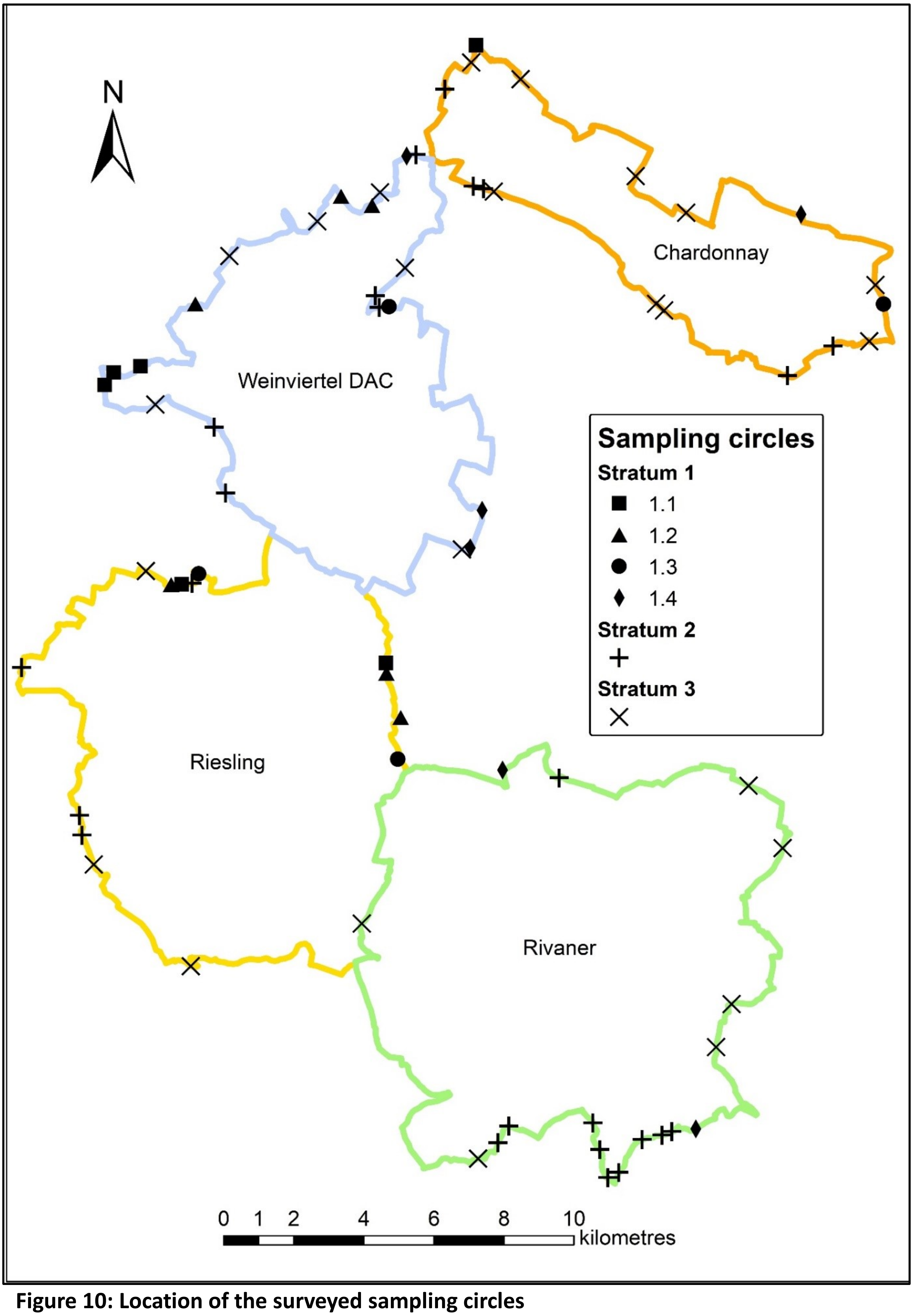

Figure 10: Location of the surveyed sampling circles

2.8 Data collection

2.8.1 General

I conducted my field research on 31 days in the period from 21 May 2018 to 8 July 2018. I mapped each of the selected sampling circles and for each polygon I completed one or two out of three different data entry forms as described in the text below. The abbreviations in the data entry forms do not correspond to the abbreviations and denominations I used in the master thesis. Not all data I gathered was used for the analyses. All processed parameters are specified in the text.

2.8.2 Mapping

For the mapping I printed satellite images of the selected sampling circles on a scale of 1 : 2,000 and covered them with transparent envelopes. On site I marked all distinct structures on the transparent envelopes with a permanent marker. The minimal mapping unit was 25 m^2. I also mapped smaller structures if they were aggregated and in total had more than 25 m^2, for example many small but connected lynchets. Inaccessible private gardens were mapped as one polygon. Each polygon I obtained in this way got a distinct polygon number which I also used on my data entry forms for the unambiguous assignment of the data to the polygon.

2.8.3 Data collection of the landscape structure

For each polygon in the surveyed sampling circles I conducted landscape structure survey, a method described by Wrbka et al. (2015). I followed the instructions of the manual, but I used a slightly adapted data entry form. For every polygon I filled out one sector of my data entry form as shown in **Figure 11**.

HE-Nr	Beschr. ↓	☐ NP	☐ KP	Anz. TE	Breit	Anm		
		☐ LK	☐ BK		VegH			
					NT	HEM	DIA	DIN
					RWT	RWF	RNA	RNR
					RGL	INB	INU	CPL

Figure 11: Detail of the data entry form for landscape structure

Code	Crop land
AI	grain fields intensive
AMI	grain fields medium intensive
AE	grain fields extensive
AFF	forage crops
AHI	root crop intensive
AHM	root crop medium intensive
Code	Meadows & pastures
BWJ	orchard young
BWA	orchard old
BWEA	pasture with old trees
WII	meadow intensive
WMI	meadow medium intensive
WIE	meadow extensive
WEI	pasture intensive
WEMI	pasture medium intensive
Code	Vineyards & fruit plantations
WGI	vineyard intensive
WGM	vineyard medium intensive
WGE	vineyard extensive
GP	fruit plantation
Code	Forests & timber plantations
W	forest undefined
WN	natural forest
WMN	seminatural forest
WFJ	timber plantation young
WFA	timber plantation old
Code	Running water & water bodies
STK	lake artificial
STL	lake natural
PSK	periodic pool artificial
PSN	periodic pool natural
GV	stream artificial
GMN	stream seminatural
GN	stream natural
PFK	periodic stream artificial
PFN	periodic stream natural

Code	Fallow & set aside land
BG	old fallow land with shrubs
BS	old fallow land with tall herbs
BJ	young fallow land
Code	Small biotopes
ALLJ	avenue with young trees
ALLA	avenue with old trees
HB	hedgerow of trees
HS	hedgerow of shrubs
EBJ	young solitary tree
EBA	old solitary tree
FG	small woodlot
FR	field margin
LKA	built up element linear
FKA	built up element
PKA	built up element punctiform
Code	Roads
VB	roads vegetated
VV	paved roads
VW	dirt roads
WS	other unpaved areas
VS	other paved areas
Code	Built up areas
DEP	deposition, land fill
PG	gardens, parks
DFR	suburb
DFRA	suburb vegetated
DFRV	suburb paved
EIG	detached houses
EIGA	detached houses vegetated
EIGV	detached houses paved
EIH	one-family house
Code	Special biotopes
SONK	Special biotopes artificial
SONN	Special biotopes natural

Table 8: Land use types that occurred in the surveyed sampling circles
Adapted from Wrbka et al. (2015).

I determined the land use type for each polygon. 62 different land use types out of a catalogue of 78 occurred in the surveyed sampling circles (see **Table 8**). I used them for several calculations for the analyses.

The hemerobiotic state of the patch describes the impact on nature through human activities which is rated in 7 grades (see **Table 9**).

Code	Grade	Hemerobiotic state
MEH	1	Metahemerob - paved, built up, destroyed
POH	2	Polyhemerob - completely transformed
AEUH	3	a-euhemerob - partly transformed
BEUH	4	b-euhemerob - strongly influenced
MSH	5	Mesohemerob - moderately influenced
OLH	6	Oligohemerob - seminatural
AH	7	Ahemerob - natural

Table 9: Grading of the hemerobiotic state
Adapted from Wrbka et al. (2015).

I determined the anthropogenic disturbance and the natural disturbance. Both are rated in grades from 1 (episodic disturbance), to 4 (intense and periodic disturbance). However, if there is no disturbance at all, no entry is also possible.

Further I recorded in which intensity, if any, a patch is characterized by natural resources. Specifically I surveyed if it is nutrient-poor, nutrient-rich, arid and/or humid. These parameters are also rated in grades from 1 (a noticeable potential of the location), to 4 (a dominance of resource specific coenoses). Again no entry is also valid.

The regeneration of the land unit was assessed if a former used patch shows signs of regeneration. It is rated in four grades as shown in **Table 10**.

Grade	Potential of regeneration
1	mild disturbance and long regeneration period
2	severe disturbance and long regeneration period
3	mild disturbance and short regeneration period
4	severe disturbance and short regeneration period

Table 10: Grading of the potential of regeneration
Adapted from Wrbka et al. (2015)

Furthermore I determined introduced land units. I recorded living introduced land units such as agricultural crops or planted trees and structural introduced land units, for example walls or ditches. If any introduced land units were present in the patch I rated them from 1 (low persistence) to 4 (very high persistence).

2.8.4 Data collection of focus biotopes

Although I did not conduct a selective biotope mapping I used the list of biotopes that are to be mapped at a selective biotope mapping (Wrbka 2015) as a basis for additional data collection. It points out all biotope types that are of significance for nature conservation and describes under which circumstances they are to be mapped at a selective biotope mapping. For each patch, that could be assigned to a biotope type in the list and fitted the mapping specifications, I gathered additional data using the data entry form I created specifically for this study (see **Figure 12**).
To fit the needs of this study I made the following adaptions. I only collected data at patches that could be experienced by tourists which omits private gardens. I adapted the mapping specifications for lynchets and only mapped lynchets with a hemerobiotic state above 2 (see 2.8.3 Data collection of the landscape structure). As the list was designed for another region in Austria I complemented it with 11 additional biotope types in analogy to the pre-existing ones. I recorded 105 different biotope types in my survey. Certain biotope types, for example different types of grassland, can become overgrown with bushes. In that case this information is added to the original biotope type. 16 of the biotope types occurred additionally also with this characteristic.

HE-Nr	Zusatzinfos ↓	Empfehlung	BT-TYP		FFH-LR	☐ genutzt	☐ ungeeignet
						☐ geeignet	☐ sensibel
			FUN	FLG	AZS	LHS	STZ
			BBE	BEN	BEI	BSN	?
			RÄS	RZU	RIN	RSN	?

Figure 12: Detail of the data entry form for focus biotopes

I recorded if a patch consisted of a habitat type according to Annex I of the Habitats Directive (see 2.3.2 The European Protection Area 'Westliches Weinviertel').

I also assessed the condition of the focus biotope in five parameters, namely functionality, size of the area, composition of species, habitat structures and signs of disturbance. They were graded 1 (very good), 2 (good), or 3 (acceptable).

Another four parameters were observed to give information about the influence of people on the patch. These are signs of entering, signs of removal, signs of input and other signs of use. I rated them with the grades 0 (none), 1 (few) or 2 (many).

Further I determined if a patch is already used by cyclists. For this criterion to be true it was sufficient that it can be seen from the bicycle route and therefore already contributes to the experience of nature for cycling tourists.

I also surveyed the perspective of cycling tourists regarding their experience of nature in each patch by recording aesthetics, accessibility, availability of information and other use for cyclists. I rated them with the grades 0 (none), 1 (little) or 2 (much).

Furthermore I assessed the suitability of the patch for multifunctional development. I rated it in four grades from 0 (not suitable) to 3 (highly suitable). I took into account both the potential for nature conservation and for the experience of nature for cycling tourists. I did not use this value for the three overall values ’Natural Value’, ’Cycling Tourism Value’ and ’Land Use Value’. Rather I used it to calculate the ’Suitability for Multifunctional Development, SMD’ for each sampling circle which I compared with the results of my analyses.

2.8.5 Data collection of the bicycle route

In a third data entry form I recorded basic data about the bicycle route itself (see **Figure 13**). It applied to a maximum of two polygons per sampling circle.

HE-Nr	Radweg	Beschr. ↓	Anm				
			☐ Asphalt	☐ Straße	☐ Weg	☐ Schotterweg	☐ kein bef. W.
			FUS	LWV	ANR	PKW	LKW
			Breite in cm				

Figure 13: Detail of the data entry form for the bicycle routes

I estimated the amount of other road users on the bicycle route, specifically for pedestrians, farm vehicles, passenger cars and freight vehicles. I rated them in grades from 0 (none) to 3 (many).

Further I recorded the type of road surface on the path.

2.9 Data entry and additional data

I edited the data from my mapping in ArcMap (ESRI 2017) and embedded it in a geodatabase. I combined all data I collected in the data entry forms in one table in Microsoft Excel (Microsoft n.d.). In the process I revised missing or evidently wrong entries and aligned inconsistent ratings. Then I imported the table into ArcMap and joined it with the polygons via the polygon number. Furthermore I joined the information about the stratum of each sampling circle. Subsequently I exported the combined table with additional spatial data and used it for the analyses.

Additionally based on my digitised mappings and combined data I determined the connectivity of all focus habitats in each sampling circle. I rated it in grades ranging from 1 (none or bad) to 7 (very good). These grades were defined according to the requirements of this study and therefore it would be necessary to add grades to assess the connectivity in a more natural landscape.

2.10 Analyses

2.10.1 Procedure

I processed data from 2567 polygons in 70 sampling circles. For each sampling circle I calculated three overall values, namely the 'Natural Value', the 'Cycling Tourism Value' and the 'Land Use Value' and analysed correlations between them.

From the mapping and the collected data I calculated rescaled values for 28 landscape variables per sampling circle which I used as criteria to compute the overall values. The rescaling of the landscape variables made it possible to set them off against each other. I rescaled solely positive values from 0 to 1 and both positive and negative values around 0 with a range of 1 according to the original values. In any case the raw results defined the lower and upper limit for the rescaling. Therefore the smallest and highest computed values were converted to the smallest and highest rescaled values respectively. This way I obtained rescaled values for 28 landscape variables as per particulars given below (see 2.10.2 The landscape variables).

Then I applied the formulas to calculate three overall values from different points of view for each sampling circle. Each of the formulas uses different criteria that contribute to the particular perception. Again I rescaled the yielded values to range from 0 to 1 resulting in the overall values 'Natural Value', 'Cycling Tourism Value' and 'Land Use Value' (see 2.10.3 The formulas for the overall values).

Additionally I calculated the 'Suitability for Multifunctional Development, SMD' for each sampling circle which I did not use in the formulas but to compare it with the results. In a second analysis I compared the results from the formulas to the strata I used in the sampling design (see 2.7 Sampling design).

I did all this calculations using R (R Core Team 2018), in particular Rstudio (RStudio Team 2016) and additional packages (see 2.1 Software, basemaps and spatial data). In the thesis all results that are not integers, are rounded with an accuracy of two digits after the decimal point.

2.10.2 The landscape variables

Number of patches, NOP

I counted the number of polygons in each sampling circle which yielded values from 10 to 100 before rescaling. A higher amount of landscape components acts as an indicator for a smaller structuring of the landscape. This criterion has a positive effect on the 'Natural Value', but a negative effect on the 'Land Use Value'. In the study area areas of higher land use mainly consist of large fields or urban area. A higher number of patches is a sign for smaller fields, patches of small woodlots, lynchets and dry grassland and provides more habitats than uniform areas cleared from all structures. Of course large patches of ecologically valuable habitats are also an asset for nature conservation and therefore they are considered in other criteria.

Largest patch, LP

I took into account the largest patch per sampling circle to calculate the 'Land Use Value'. Larger patches are more easily worked with machines and additionally in this landscape they are a general sign of more intensive land use. Values ranged from 2527.48 m^2 to 16,005.42 m^2 before rescaling.

Total edge, EDGE

The total edge is another spatial criterion which I used to calculate the 'Natural Value' as edges act as corridors and usually have a higher biodiversity. Before rescaling the sum of all edges per sampling circle ranged from 2904.93 m to 9794.06 m which includes 628.32 m from the circumference.

Shape complexity index, SCI

I calculated this landscape variable applying the MSI (mean shape index) as it is also used in FRAGSTATS (McGarigal & Marks 1995), but without differentiating between different patch types. The application of the formula shown in **Figure 14** results in the value 1 for a circular polygon and increases without limit as polygons become more irregular.

$$MSI = \frac{\sum_{j=1}^{n} \left(\frac{p_{ij}}{2\sqrt{\pi \cdot a_{ij}}} \right)}{n_i}$$

Figure 14: MSI (mean shape index) as it is used in FRAGSTATS (McGarigal & Marks 1995)
Adapted from McGarigal & Marks (1995). i = patch types (classes), j = patches, aij = area (m2) of patch ij, pij = perimeter of patch ij, ni = number of patches in the landscape of patch type (class) i.

Before rescaling the values for the 70 sampling circles ranged from 1.87 to 4.19. I used the 'SCI' in the formula for the 'Land Use Value' as a negative influence as more complex shapes are more labour-intensive to work.

Richness, RICH

The richness is the amount of different land use types per sampling circle. Before rescaling it ranged from 5 to 27 out of the 62 land use types I observed overall during my data collection. I considered this landscape variable to calculate the 'Cycling Tourism Value' as multifaceted landscapes have a highly aesthetic value and are important areas for recreation (Schwaiger et al. 2018).

Diversity, DIV

To calculate the diversity of land use types of each sampling circle I used Shannon's diversity index. It is a component of the package 'vegan' (Oksanen et al. 2019a; Oksanen 2019) for R (R Core Team 2018) and I used the default settings. However, I adapted the definition of the variables of the formula, since in this study I did not calculate the diversity of species but the diversity of land use types (see **Figure 15**).

$$H = -\sum_{i=1}^{S} p_i \log_b p_i$$

Figure 15: The Shannon-Index, adapted for the diversity of land use types
Adapted from Oksanen (2019). pi is the proportion of the area of land use type i, S is the number of different land use types, b is the base of the logarithm.

The results ranged from 0.52 to 2.66 before rescaling, higher numbers representing a more diverse landscape. A higher 'DIV' is positive for the 'Natural Value' and negative for the 'Land Use Value'.

Landscape quality for nature conservation, Q_N

I rated each land use type I observed at the data collection of the landscape structure, from the perspective of nature conservation. I assigned -1 if the land use type indicates a negative contribution to nature conservation like build up area or intensively used agricultural land. For land use types valuable to nature conservation I assigned 1. Neutral categories or those without clear tendency got the value 0. I multiplied these values with the area of the polygons of each sampling circle yielding values from -30,823.96 to 14,445.93. In the sampling circle with the lowest value almost the whole area had a land use type with a negative contribution to nature conservation. After rescaling the results for 'Q_N' ranged from -0.68 bis 0.32 and subsequently I used them to calculate the 'Natural Value' of each sampling circle.

Landscape quality for cycling tourism, Q_CT

Similar to 'Q_N' I determined 'Q_CT'. This time I rated -1, 0 and 1 according to the quality of the land use type from the perspective of a cycling tourist. My area weighted calculations yielded values from -4,057.28 to 27,613.64 leading to rescaled values from -0.13 bis 0.87. The 'Q_CT' is part of the formula for the 'Cycling Tourism Value'.

Landscape quality for land use, Q_LU

To determine the landscape quality from the perception of land use I rated the different land use types once again. This time I rated all categories without a direct utilization with -1. Land use types of extensive use got the value 0 and ones with intensive use were rated 1. I multiplied these values with the area of the polygons and got values from -1456.00 to 30,823.96 for the sampling circles. In the sampling circle with the highest value almost the whole area had land use types which indicate intensive land use. The rescaled results from -0.05 to 0.95 were used to calculate the 'Land Use Value'.

Sealing of the landscape, SEAL

Sealed areas have an especially negative effect for nature conservation. Therefore I determined all land use types that represent sealed patches and summated their areas. For the 70 sampling circles I got values from 0.00 m^2 to 9,290.24 m^2. I used the rescaled values from 0 to 1 as a negative factor in the formula for the 'Natural Value'.

Introduced land units, vegetation, INV

For this landscape variable I first summated the area of all polygons with introduced vegetation. I did not differ between the persistence of different plants as all introduced vegetation is a clear sign for land use. The results ranged from 10,381.29 m^2 to 30,489.75 m^2 which is only 926.18 m^2 less than the total area of the sampling circle. I used the rescaled values of the landscape variable 'INV' to calculate the 'Land Use Value'.

Introduced land units, structures, INS

Similar to 'INV' I calculated 'INS' for introduced structures without differentiating between their persistence. The summated areas ranged from 548.54 m^2 to 21,084.27 m^2. To calculate the 'Land Use Value' I used the rescaled values from 0 to 1.

Anthropogenic disturbance, DIA

I multiplied the given grades of disturbance by the area of the polygon which yielded values from 6587.10 to 124,723.39. In doing so a more intense disturbance and therefore a more intense land use is represented in the results. I used the rescaled 'DIA' in the formula for the 'Land Use Value' as a positive factor as it is a sign of utilization of the patch. Intensively used patches without disturbance, like build up areas, are considered in other criteria.

Natural disturbance, DIN

Other than 'DIA', 'DIN' is a sign of natural processes and therefore I used it as a positive factor to calculate the 'Natural Value' and as a negative factor for the 'Land Use Value'. The given grades multiplied with the area yielded values from 0.00 to 13,260.35 before rescaling.

Naturalness, NAT

'NAT' is one of the landscape variables that can either have positive or negative values. Positive values represent a high naturalness, whereas negative values show much negative impact resulting in a very unnatural sampling circle. I used 'NAT' as a positive factor to calculate the 'Natural Value'. For the 'Land Use Value' a high naturalness is undesirable and therefore 'NAT' is included as a negative factor in the formula. This leads to a reversal of the algebraic sign so that unnatural sampling circles with negative landscape variables count positive for the 'Land Use Value'.

First I weighted the grades for hemerobiotic state which I assigned to each patch at the data collection. The two euhemerob types got the value 0, patches of greater hemeroby were assigned the value -1 and patches of lesser influence got the value 1. I multiplied them with the area of the patches and yielded values from -31,415.61 to 11,021.82. The sampling circle with the lowest value differs only 0.32 from the lowest possible value. The rescaled values of this landscape variable ranged from -0.74 to 0.26.

Characterized by resources, RES

The landscape variable 'RES' is a composite landscape variable calculated from four different entries from the data collection sheets. First I multiplied the grades I determined for arid patches with their area. I repeated this procedure for humid, nutrient-poor and nutrient-rich patches and then I summated the four values for each sampling circle yielding composite values from 0.00 to 53,276.59. The rescaled values for 'RES' were considered as a positive factor in the 'Natural Value' and as a negative factor in the 'Land Use Value'.

Regeneration of the land unit, RGL

I summated the area of all patches that showed signs of regeneration irrespective of the grade of regeneration. The sum of the areas ranged from 0.00 m^2 to 14,851.51 m^2 at the 70 sampling circles. After rescaling I used the 'RGL' as a positive factor to calculate the 'Natural Value' and as a negative factor in the 'Land Use Value'.

Number of focus habitats, NOFH

The total amount of focus habitats ranged from 0 to 58. To calculate the 'Natural Value' I took into account the rescaled values for 'NOFH' as a positive factor.

Largest focus habitat, LFH

The largest focus habitat in a sampling circle had an area of 10,298.29 m^2. The smallest value was 0.00 m^2 as one sampling circle is without a focus habitat. I used the rescaled values to calculate the 'Natural Value'.

Total size of all focus habitats, TSFH

I summated the area of all focus habitats per sampling circles yielding values from 0.00 m^2 to 19,665.04 m^2. The rescaled values of 'TSFH' counted positive for the 'Natural Value' and negative for the 'Land Use Value'.

Connectivity, CON

The connectivity of all focus habitats was determined per sampling circle and therefore the given grades could be rescaled without further calculations. I used them as a positive factor to calculate the 'Natural Value'.

Habitats protected under the habitats directive, HHD

I summated the area of all patches that contain any habitat protected under the habitats directive. The sum of the areas ranged from 0.00 m^2 to 9,439.83 m^2. After rescaling I used the 'HHD' as a positive factor to calculate the 'Natural Value' and as a negative factor in the 'Land Use Value'.

State of preservation, SOP

The landscape variable 'SOP' is another composite value. I calculated it from five different parameters on the condition of the biotope which I assessed during my data collection, namely functionality, size of the area, composition of species, habitat structures and signs of disturbance. These parameters were collected for each focus habitat and I multiplied the determined grade with the area of the patch. Then I summated all values for each sampling circle yielding composite values from 0.00 to 216,196.02. After rescaling I considered the 'SOP' as a positive factor in the 'Natural Value'.

Influence on the habitat, IOH

'IOH' is also a composite value which I calculated similar to 'SOP' using the parameters signs of entering, signs of removal, signs of input and other signs of use. I yielded values from 0.00

to 45,574.88 and after rescaling I used ’IOH’ as a negative factor to calculate the ’Natural Value’.

Nature experience for cycling tourists in the patch, NEC

To assess the perspective of cycling tourists regarding their experience of nature in the patch, I recorded four parameters for each focus habitat. These parameters are aesthetics, accessibility, availability of information and other use for cyclists. I multiplied the determined grades with the area of the patches and summated all values for each sampling circle yielding composite values from 0.00 to 63,264.25. After rescaling I used the values of the landscape variable ’NEC’ as a positive factor in the formula for the ’Cycling Tourism Value’.

Utilization of the patch for cycling tourists, USE

I summated the area of all focus habitats that are already used by cyclists. For the 70 sampling circles I got values from 0.00 m^2 to 14,836.44 m^2. I used the rescaled values from 0 to 1 as a positive factor in the formula for the ’Cycling Tourism Value’.

Pavement, PAV

’PAV’ is another landscape variable which I used to calculate the ’Cycling Tourism Value’. For road cyclists the type of road surface on the path is an important factor. A solid pavement like bitumen is much easier to ride on, compared to a surface which is not dense, like a dirt road or a gravel path. I weighted pavements with a solid surface with 1 and others with -1. As the cycling path can have more than one polygon per sampling circle I calculated the mean. The values ranged from -1 to 1, after rescaling from -0.5 to 0.5.

Traffic, TRAF

To calculate the composite landscape variable ’TRAF’ I took four parameters into account, namely pedestrians, farm vehicles, passenger cars and freight vehicles. Again I calculated the mean of the grades I determined as the cycling path can have more than one polygon per sampling circle. I divided the value for pedestrians by two as pedestrians are not as much disturbance as vehicles and I doubled the value for freight vehicles as they are a major disturbance. I got values from 1 to 11 which I rescaled and used as a negative factor to calculate the ’Cycling Tourism Value’.

2.10.3 The formulas for the overall values

To calculate the 'Natural Value', the 'Cycling Tourism Value' and the 'Land Use Value' I used the rescaled values of the landscape variables. Each of the three formulas consists of two or more value-determining integrants. I computed them by setting off the rescaled values of decisive landscape variables against each other and calculating the mean. Thereby each of the value-determining integrants has the same weight in the formula regardless of the amount of landscape variables that were used to compute it. Moreover, with this method related landscape variables forming one value-determining integrant are not overrepresented, rather they support and complement each other and together form a solid value for the value-determining integrant.
The results from each formula are comparative. The algebraic sign and the value of a result before rescaling solely describe its position. Due to the different structure of the three formulas their results can not be compared directly among each other. Hence I rescaled them to range from 0 to 1 and then analysed correlations between the rescaled overall values 'Natural Value', 'Cycling Tourism Value' and 'Land Use Value'.

Natural Value

The 'Natural Value' describes the perspective of nature conservation and the ecological value of the sampling circle.

Natural Value = Landscape composition & -configuration + Landscape functionality + Focus habitat quantity + Focus habitat quality → rescaled to range from 0 to 1

Landscape composition & -configuration = (DIV + CON + EDGE) / 3
= (Diversity + Connectivity + Total edge) / 3

Landscape functionality = (Q_N + NAT - DIA + DIN + RES + RGL - SEAL) / 7

= (Landscape quality for nature conservation + Naturalness - Anthropogenic disturbance + Natural disturbance + Characterized by resources + Regeneration of the land unit - Sealing of the landscape) / 7

Focus habitat quantity = (NOFH + LFH + TSFH) / 3
= (Number of focus habitats + Largest focus habitat + Total size of all focus habitats) / 3

Focus habitat quality = (HHD + SOP - IOH) / 3
= (Habitats protected under the habitats directive + State of preservation - Influence on the habitat) / 3

Natural Value = (DIV + CON + EDGE) / 3 + (Q_N + NAT - DIA + DIN + RES + RGL - SEAL) / 7 + (NOFH + LFH + TSFH) / 3 + (HHD + SOP - IOH) / 3 → rescaled to range from 0 to 1

Before rescaling the values ranged from -0.32 to 2.03.

Cycling Tourism Value

The 'Cycling Tourism Value' represents the extent of experience of nature for cycling tourists in a sampling circle.

Cycling Tourism Value = Landscape quality + Nature experience + Bicycle route quality → rescaled to range from 0 to 1

Landscape quality = (RICH + NOP + Q_CT + LFH) / 4
= (Richness + Number of patches + Landscape quality for cycling tourism + Largest focus habitat) / 4

Nature experience = (USE + NEC) / 2
= (Utilization of the patch for cycling tourists + Nature experience for cycling tourists in the patch) / 2

Bicycle route quality = (PAV - TRAF) / 2

= (Pavement - Traffic) / 2

Cycling Tourism Value = (RICH + NOP + Q_CT + LFH) / 4 + (USE + NEC) / 2 + (PAV - TRAF) / 2 → rescaled to range from 0 to 1

Before rescaling the values ranged from -0.32 to 1.47.

Land Use Value

To calculate the 'Land Use Value' I adopted the perspective of intensive land use which aims for maximum direct profit.

Land Use Value = Usability + Usage restrictions → rescaled to range from 0 to 1

Usability = (Q_LU - NAT + INV + INS + LP) / 5

= (Landscape quality for land use - Naturalness + Introduced land units, vegetation + Introduced land units, structures + Largest patch) / 5

Usage restrictions = (-DIV - SCI - NOP - DIN - RES - RGL - HHD - TSFH) / 8

= (- Diversity - Shape complexity index - Number of patches - Natural disturbance - Characterized by resources - Regeneration of the land unit - Habitats protected under the habitats directive - Total size of all focus habitats) / 8

Land Use Value = (Q_LU - NAT + INV + INS + LP) / 5 + (-DIV - SCI - NOP - DIN - RES - RGL - HHD - TSFH) / 8 → rescaled to range from 0 to 1

Before rescaling the values ranged from -0.48 to 0.65.

2.10.4 Suitability for Multifunctional Development, SMD

During the data collection I determined the suitability of each focus habitat for multifunctional development. I multiplied the given grades by the area of the polygon whereby both components are weighted equal. After summating the results for each sampling circle I yielded values from 0.00 to 41,056.67. I did not rescalethem, as they were not set off against other values. I used the 'SMD' to compare it with the results of my analyses with a very distinct outcome.

3 Results

3.1 Correlations between the landscape variables

Figure 16 shows the correlation between the rescaled values of all 28 landscape variables that I used in the three formulas. For abbreviations and explanations to **Figure 16** see **Box 1**. Due to the amount of combinations I will only refer to prominent combinations and clusters.

'Shape complexity index, SCI' shows the strongest interrelation in negative correlations to 'Number of patches, NOP' and 'Richness, RICH'. The highest positive correlations are not very distinct to 'Largest patch, LP', 'Landscape quality for land use, Q_LU' and 'Largest focus habitat, LFH'. Contrary to expectations it correlated most to factors that indicate a sampling circle with large patterns and had negative correlation to factors indicating sampling circles with small patches of diverse use. The latter would be assumed to have patches with more complex shapes. A closer look on the sampling circles revealed that indeed a high 'SCI' corresponds to sampling circles of intensive land use with large fields and small lynchets.

'Largest patch, LP' has a strong negative correlation to 'Total edge, EDGE'.

'Introduced land units, vegetation, INV' and 'Landscape quality for land use, Q_LU' have a high correlation.

In the middle of the diagram 'Number of patches, NOP', 'Total edge, EDGE', 'Number of focus habitats, NOFH', 'Richness, RICH', 'Diversity, DIV' form a highly correlated cluster. 'Connectivity, CON' also has a high correlation to this cluster.

I also want to point out the high correlation of 'Influence on the habitat, IOH' and 'Nature experience for cycling tourists in the patch, NEC'.

The pie charts in the lower right section shows a second cluster of highly correlating landscape variables, mainly 'Connectivity, CON', 'Nature experience for cycling tourists in the patch, NEC’, ’Regeneration of the land unit, RGL’, ’Total size of all focus habitats, TSFH’, ’State of preservation, SOP’, ’Landscape quality for nature conservation, Q_N’ and ’Naturalness, NAT’, but also ’Utilization of the patch for cycling tourists, USE’ and ’Largest focus habitat, LFH’, further ’Habitats protected under the habitats directive, HHD’ and ’Characterized by resources, RES’. Except ’NEC’ and ’USE’ they are all used as positive factors in the formula for the ’Natural Value’. ’TSFH’ and ’SOP’ show the highest correlation of all landscape variables to each other.

This cluster also has a strong negative correlation to ‘Introduced land units, vegetation, INV’, ’Landscape quality for land use, Q_LU’ and ’Anthropogenic disturbance, DIA’.

’Landscape quality for cycling tourism, Q_CT’ has its highest correlation to ‘Landscape quality for nature conservation, Q_N’.

’Traffic, TRAF’, ’Sealing of the landscape, SEAL’, ’Introduced land units, structures, INS’, ’Pavement, PAV’ and ’Natural disturbance, DIN’ have no exceptionally strong correlations whatsoever.

Blue pie charts represent positive correlation and red pie charts represent negative correlation between the two landscape variables concerned, the lower left panels show scatter plots of them
Abbreviations: SCI: Shape complexity index, LP: Largest patch, INV: Introduced land units, vegetation, Q_LU: Landscape quality for land use, TRAF: Traffic, DIA: Anthropogenic disturbance, SEAL: Sealing of the landscape, PAV: Pavement, INS: Introduced land units, structures, DIN: Natural disturbance, NOP: Number of patches, EDGE: Total edge, NOFH: Number of focus habitats, RICH: Richness, DIV: Diversity, IOH: Influence on the habitat, HHD: Habitats protected under the habitats directive, RES: Characterized by resources, CON: Connectivity, NEC: Nature experience for cycling tourists in the patch, RGL: Regeneration of the land unit, TSFH: Total size of all focus habitats, SOP: State of preservation, Q_N: Landscape quality for nature conservation, NAT: Naturalness, USE: Utilization of the patch for cycling tourists, LFH: Largest focus habitat, Q_CT: Landscape quality for cycling tourism

Box 1: Abbreviations and explanations for the correlogram of the rescaled values of the landscape variables (Figure 16)

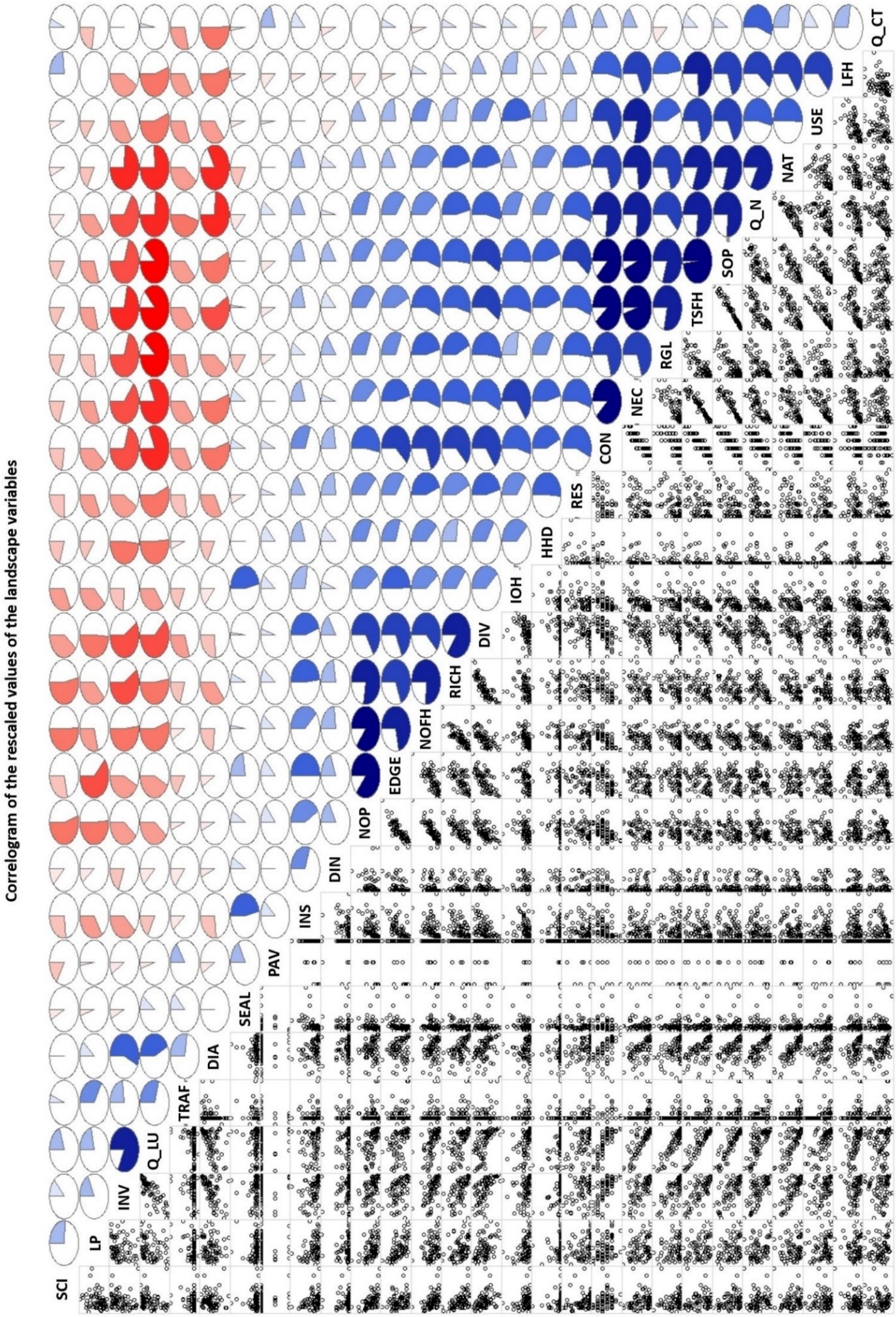

Figure 16: Correlogram of the rescaled values of the landscape variables
Abbreviations and explanations see **Box 1**.

3.2 Results on the overall values

Figure 17, **Figure 18**, **Figure 19** and **Figure 20** show sorted bar charts of the rescaled overall values.

Sampling circles with the highest 'Natural Values' also have very high 'Cycling Tourism Values' but very low 'Land Use Values' (see **Figure 17**). **Figure 18** shows, that the sampling circles with the highest 'Cycling Tourism Value' have also relatively high 'Natural Values' and their 'Land Use Values' that can either be intermediate or low. In the sampling circles with the highest 'Land Use Values' the other two overall values are low (see **Figure 19**).

Figure 20 shows a bar chart sorted by the sum of all three overall values. The sampling circles with highest sums have high 'Cycling Tourism Values', intermediate to high 'Natural Values' and low to intermediate 'Land Use Values'.

The correlation between the three overall values is analysed further below, but a trend is noticeable in the bar charts.

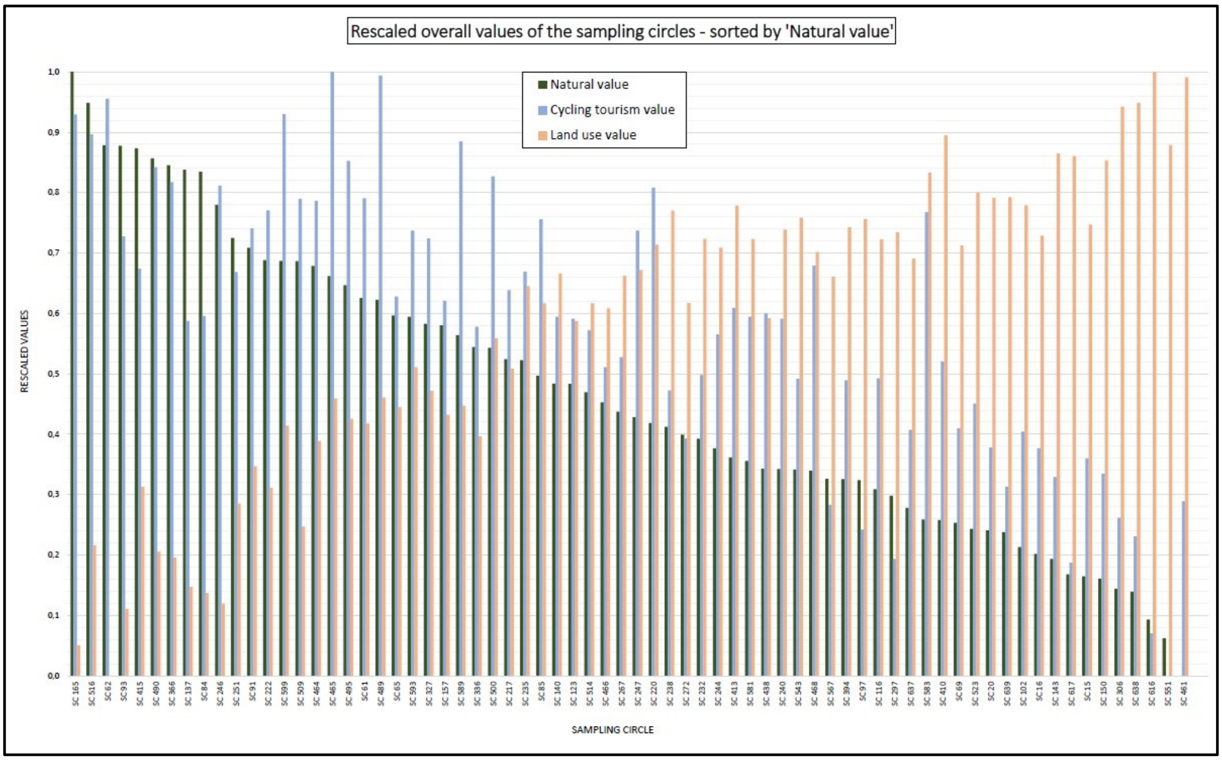

Figure 17: Rescaled overall values of the sampling circles sorted by 'Natural Value'

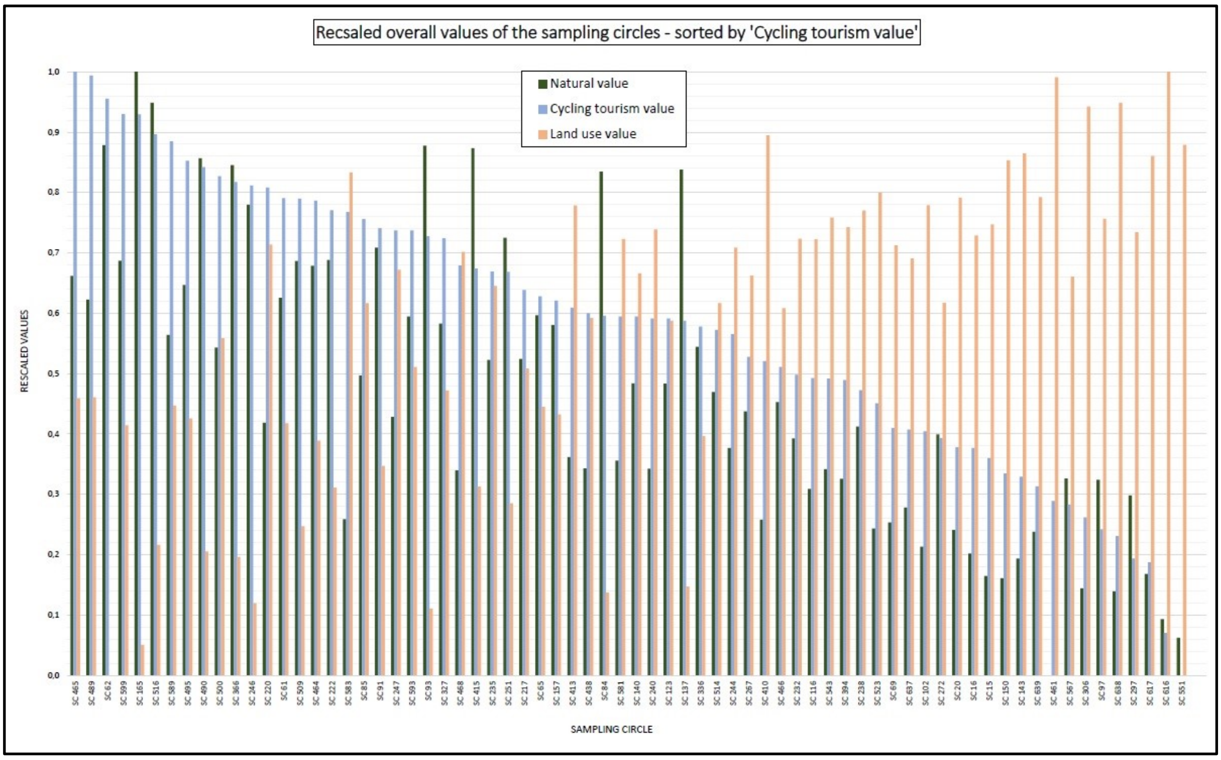

Figure 18: Rescaled overall values of the sampling circles sorted by ’Cycling Tourism Value’

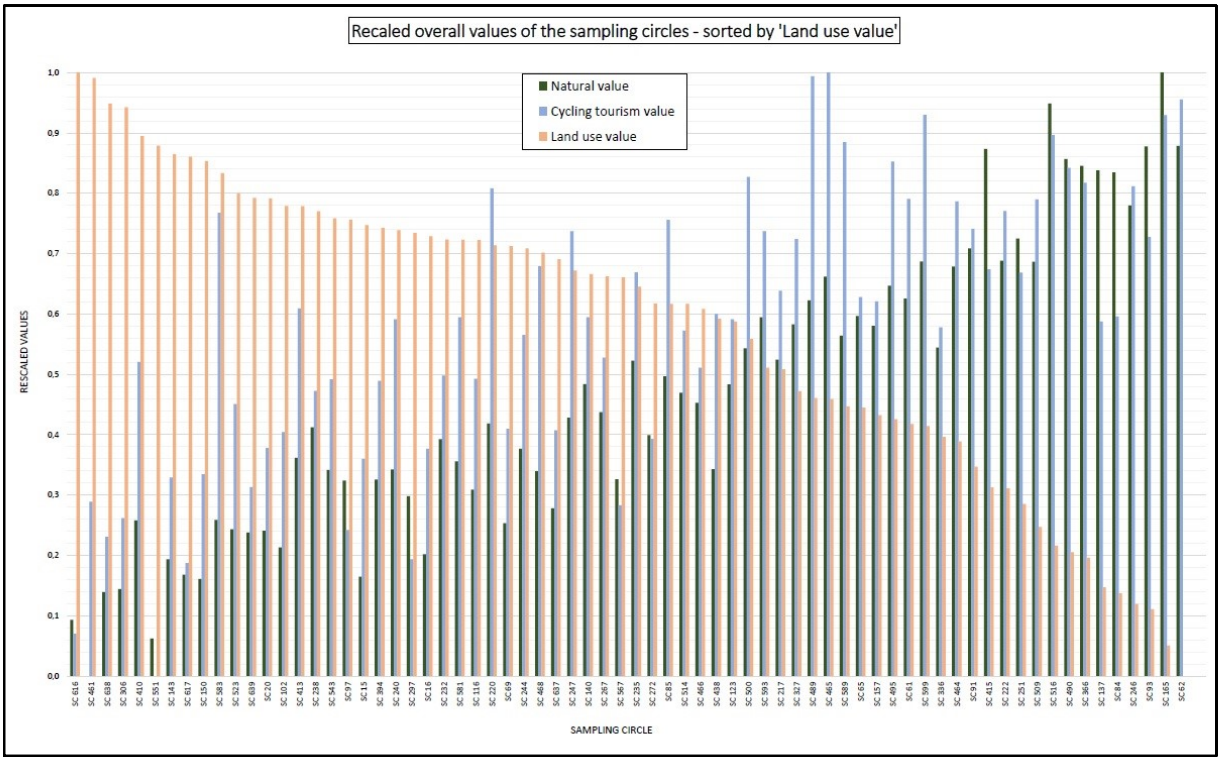

Figure 19: Rescaled overall values of the sampling circles sorted by ’Land Use Value’

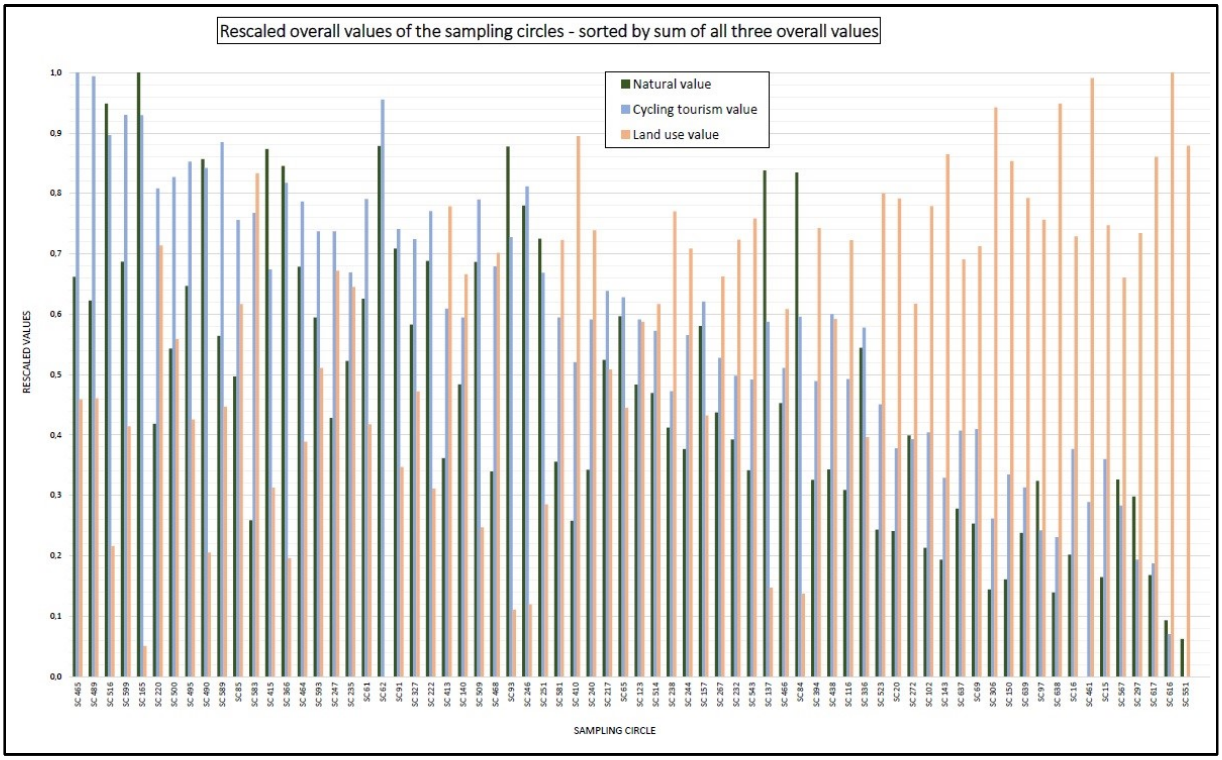

Figure 20: Rescaled overall values of the sampling circles sorted by the sum of all three overall values

The sampling circles with the highest values for each of the three overall values are presented in **Figure 21**, **Figure 22** and **Figure 23**. In the first row the edited polygons of the sampling circle are shown on a satellite image. In the second row the same sampling circle is shown again, with all focus habitats marked in light yellow. In the lower right corner of each map an outline map of the surveyed cycling paths is pictured with the position of the sampling circle marked with a red dot.

Figure 21 shows the two sampling circles with the highest ’Natural Value’. Sampling circle 165 has the highest ’Natural Value’ and additionally ranked forth at the ’Suitability for Multifunctional Development, SMD’ (see 3.5 Results on the ’Suitability for Multifunctional Development’). The second highest rescaled ’Natural Value’ accounted for 0.95 for sampling circle 516.

The two sampling circles with the highest ’Cycling Tourism Value’ are presented in **Figure 22**. Sampling circle 465 has the highest ’Cycling Tourism Value’ and additionally ranked sixth at the ’SMD’ (see 3.5 Results on the ’Suitability for Multifunctional Development’). The second highest rescaled ’Cycling Tourism Value’ of 0.99 was in sampling circle 489.

At both the ’Natural Value’ and the ’Cycling Tourism Value’ sampling circle 62 ranked third. Its values accounted for 0.88 for the rescaled ’Natural Value’ and 0.96 for the rescaled ’Cycling Tourism Value’. Furthermore it ranked last at the ’Land Use Value’. Additionally sampling circle 62 has the highest ’SMD’ and for that reason it is presented in chapter 3.5 (Results on the ’Suitability for Multifunctional Development’) in **Figure 28**.

Figure 23 shows the sampling circle 616 with the highest ’Land Use Value’ followed by sampling circle 461 with a rescaled ’Land Use Value’ of 0.99 and sampling circle 638 with a rescaled ’Land Use Value’ of 0.95.

The highest sum of all three overall values is at sampling circle 465 with a value of 2.12 followed by sampling circle 489 with a value of 2.08. These also had the highest and second highest value at the ’Cycling Tourism Value’ respectively. The third ranked sampling circle 516 has a sum of all overall values of 2.06 and additionally has the second rank at the ’Natural Value’.

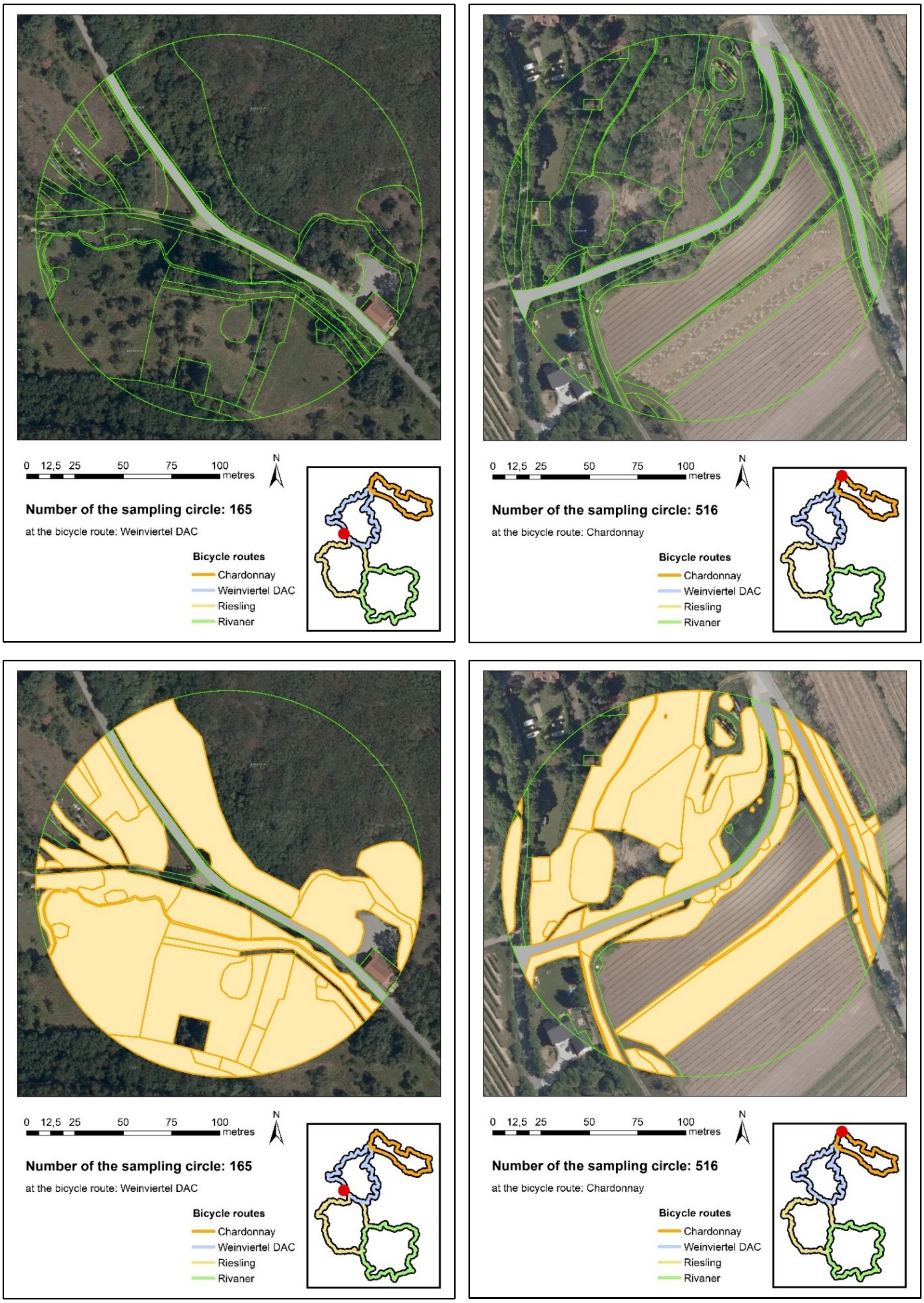

Figure 21: The sampling circles with the highest 'Natural Value'
In the lower maps all focus habitats are marked in light yellow.

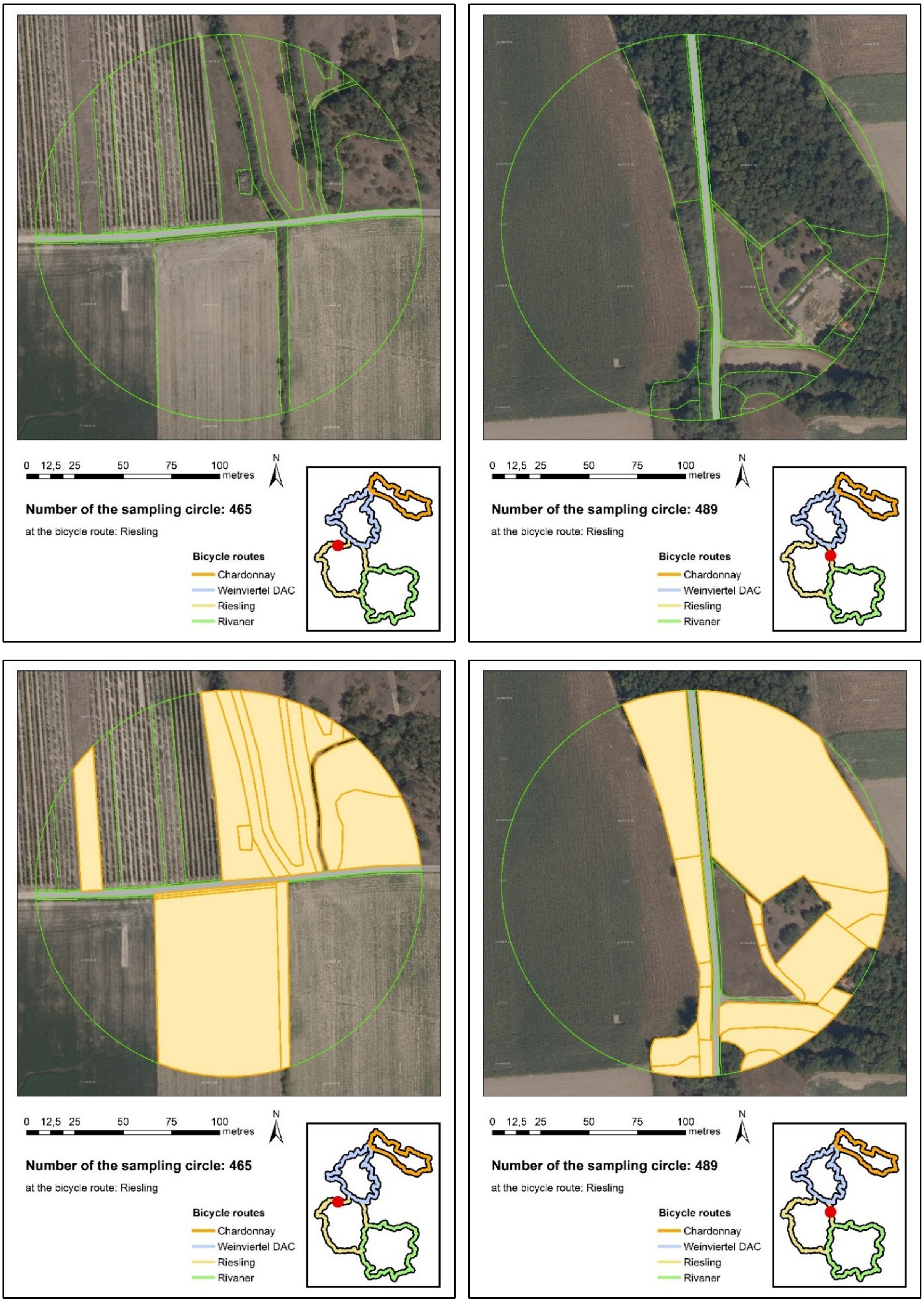

Figure 22: The sampling circles with the highest 'Cycling Tourism Value'
In the lower maps all focus habitats are marked in light yellow.

Figure 23: The sampling circles with the highest 'Land Use Value'
In the lower maps all focus habitats are marked in light yellow.

3.3 Correlations between the overall values

The positive correlation between the 'Natural Value' and the 'Cycling Tourism Value' and their negative correlation to the 'Land Use Value' could be estimated in the bar charts and is clearly confirmed by the correlogram shown in **Figure 24**. Each of the three combinations shows a very strong correlation, pictured in pie diagrams in the upper right panels and in scatter plots in the lower left panels.

In **Figure 25** the correlation between all three overall values is presented in a 3D scatter plot.

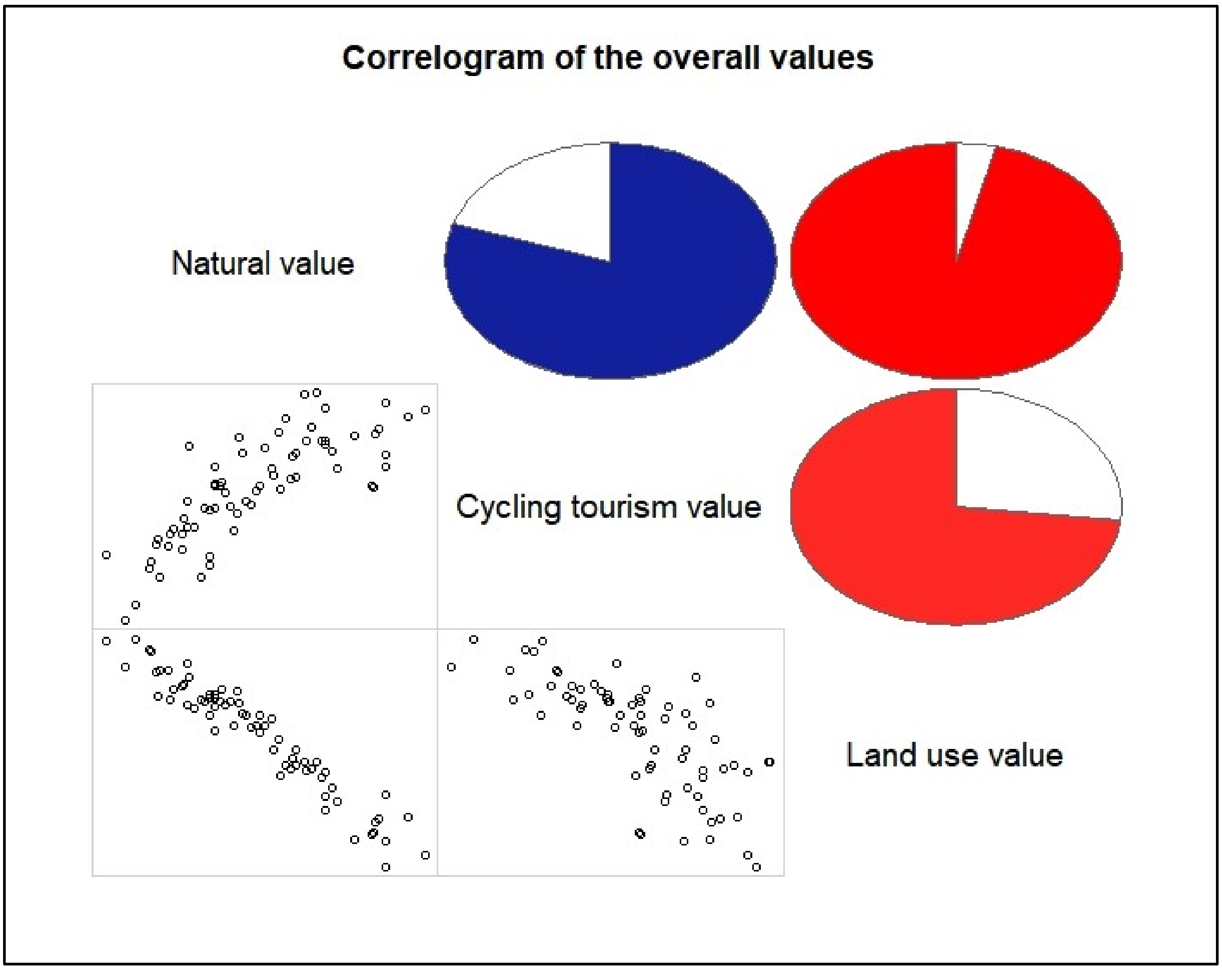

Figure 24: Correlogram of the overall values 'Natural Value', 'Cycling Tourism Value' and 'Land Use Value'

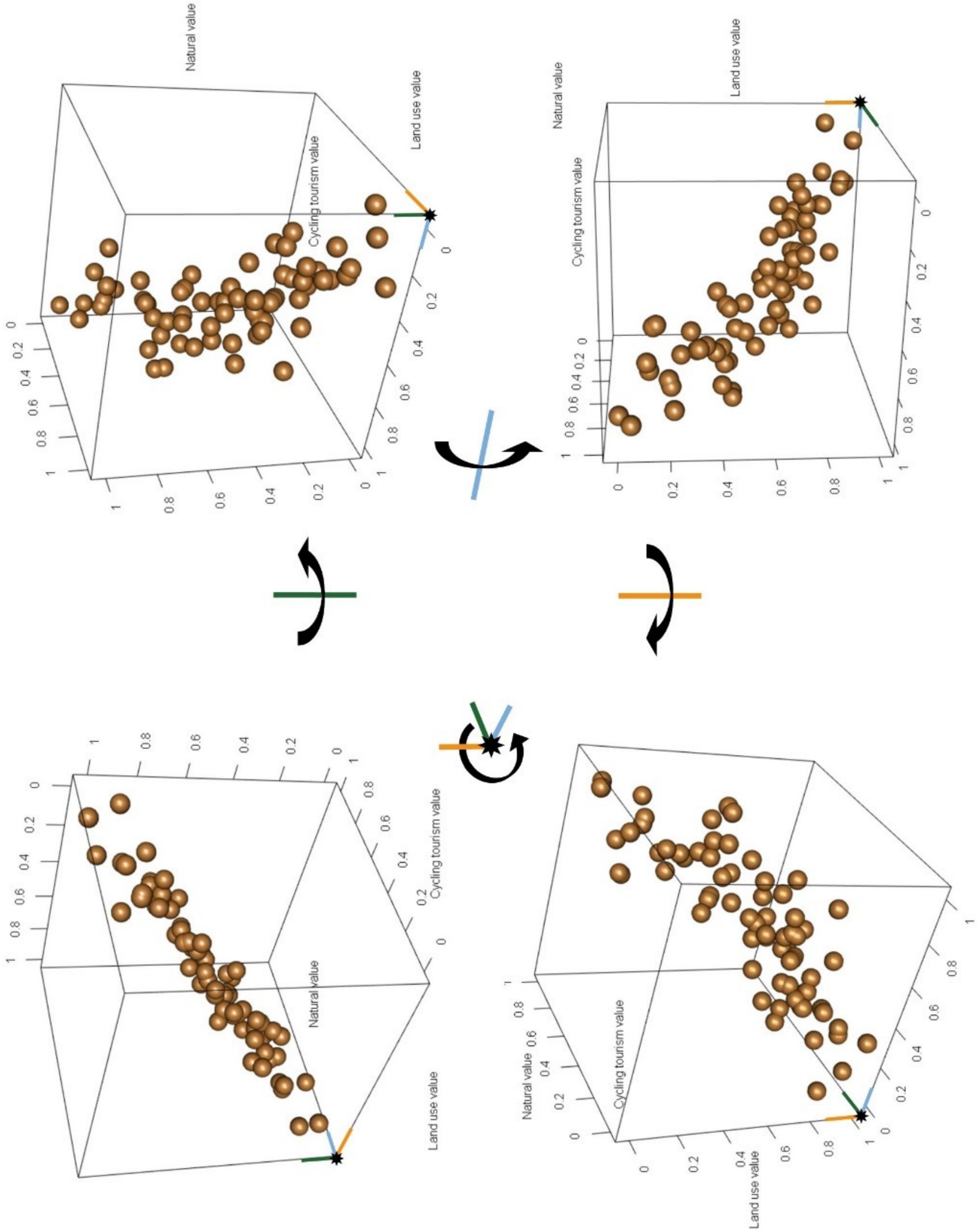

Figure 25: 3D scatter plot of the ’Natural Value’, the ’Cycling Tourism Value’ and the ’Land Use Value’

3.4 Correlations to the strata

Figure 26 shows enlarged scatter plots of the correlation between the three overall values coloured according to the strata of the sampling circles (2.7 Sampling design). A 3D scatter plot of the correlation between the 'Natural Value', the 'Cycling Tourism Value' and the 'Land Use Value' coloured by the strata of the sampling circles is presented in **Figure 27**. For the legend to both diagrams and the number of sampling circles see **Table 11**.

Stratum / Sub-stratum	Short description of the strata	Amount of SC	Colour	Colour
1.1	Nature protection area or natural monument, and Kellergasse or Point of Interest	6x	black	
1.2	Nature protection area or natural monument	6x	dark grey	
1.3	Kellergasse	4x	light grey	
1.4	Point of Interest	6x	white	
2	contains areas of the category 'Potential' I created for the 'Central European Habitat Map'	24x	medium green	
3	absence of areas of the category 'Potential' I created for the 'Central European Habitat Map'	24x	light brown	

Table 11: Strata, amount of sampling circles and legend to Figure 26 and Figure 27
SC = sampling circle

Stratum 2 consists of sampling circles which contain areas of the category 'Potential' I created for the 'Central European Habitat Map' (see 2.4 The 'Central European Habitat Map') while the selection criterion for the sampling circles in stratum 3 was absence of these areas. The diagrams show a clear trend of the sampling circles belonging to these strata. Stratum 2 tends to high 'Natural Values', high 'Cycling Tourism Values' and low 'Land Use Values' whereas for stratum 3 the opposite does apply.

Stratum 1 has not such a clear tendency. Sub-stratum 1.1 represents sampling circles with both natural and touristic special features and its sampling circles are wide spread with a slight trend to high 'Natural Values', high 'Cycling Tourism Values' and low 'Land Use Values'. Sub-stratum 1.2 contains sampling circles that intersect with the buffer area of a nature protection area or natural monument and show a similar pattern. The sampling circles with Kellergassen in sub-stratum 1.3 tend to medium values for all three overall values which applies more distinct for the sampling circles with POIs in sub-stratum 1.4.

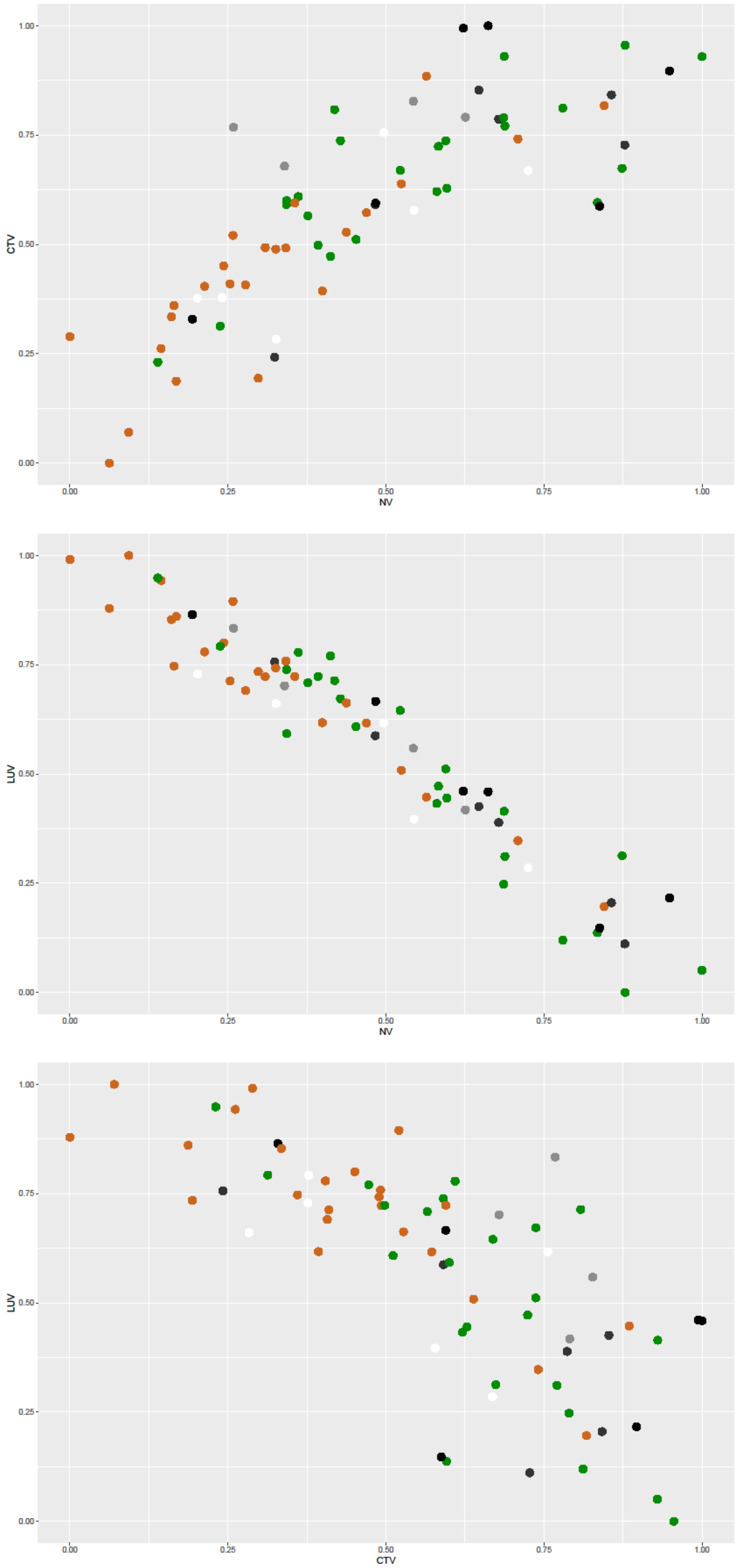

Figure 26: Scatter plots of the correlation between the three overall values, coloured by the strata of the sampling circles
NV = Natural Value, CTV = Cycling Tourism Value, LUV = Land Use Value, Legend see **Table 11**

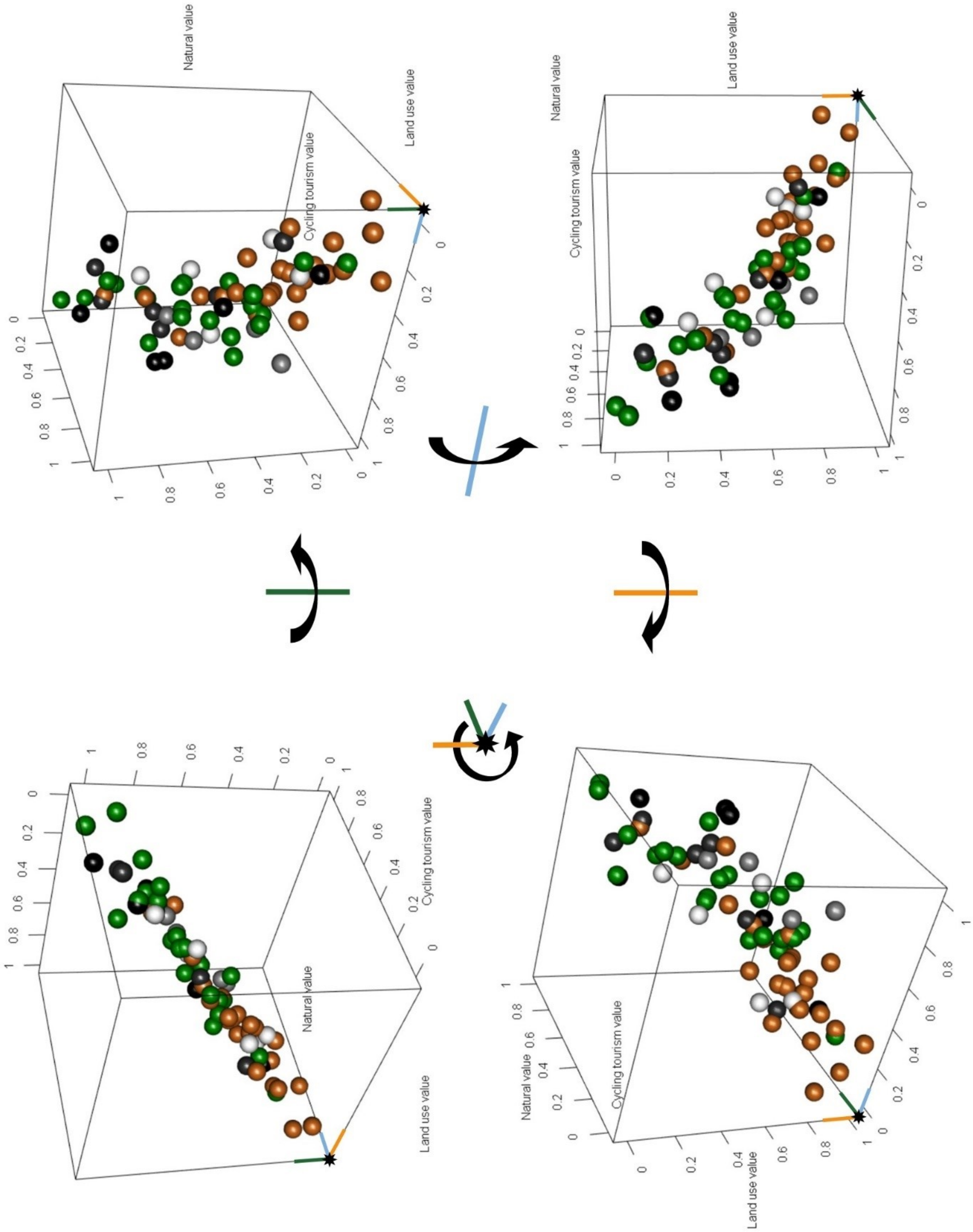

Figure 27: 3D scatter plot of the overall values, coloured by the strata of the sampling circles
Legend see **Table 11**

3.5 Results on the 'Suitability for Multifunctional Development'

The values for the 'Suitability for Multifunctional Development, SMD' ranged from 0.00 to 41,056.67 (2.10.4 Suitability for Multifunctional Development, SMD). Two sampling circles had values above 35,000, another four above 30,000.

Sampling circle 62 with the highest 'SMD' of 41,056.67 was already mentioned above, as it also ranked third at both the 'Natural Value' and the 'Cycling Tourism Value' and last at the 'Land Use Value' (see 3.2 Results on the overall values). With 35,465.81 sampling circle 509 ranked second. Both are presented in **Figure 28**. At sampling circle 509 the KML-data of the bicycle route and the actual routing did not correspond. Nevertheless I mapped it, as the whole section of the route is still inside the sampling circle, but it does not go through the centre as it usually would.

On rank three is sampling circle 490 with a value of 34,536.97 followed by sampling circle 165 with a value of 33,301.33. The latter also had the first rank at the 'Natural Value' and is presented in chapter 3.2 (Results on the overall values) in **Figure 21**. Sampling circle 93 had the fifth rank at the 'SMD' with 30,816.38 followed by sampling circle 465 with 30,065.30 which additionally ranked first at the 'Cycling Tourism Value' and therefore it is shown in 3.2 (Results on the overall values) (**Figure 22**). Sampling circles 490 and 93 are presented in **Figure 29**.

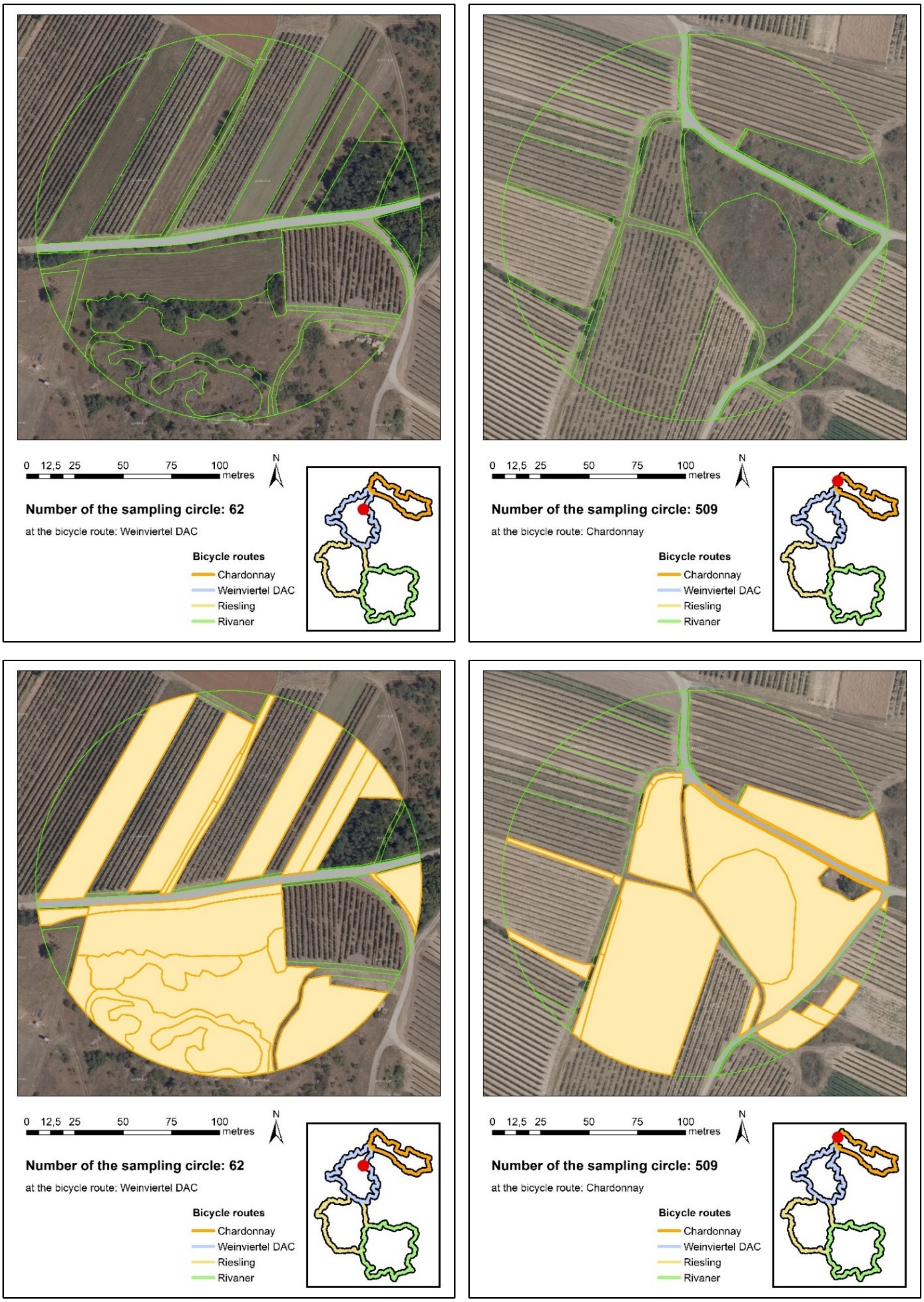

Figure 28: The sampling circles with the highest 'SMD'
In the lower maps all focus habitats are marked in light yellow.

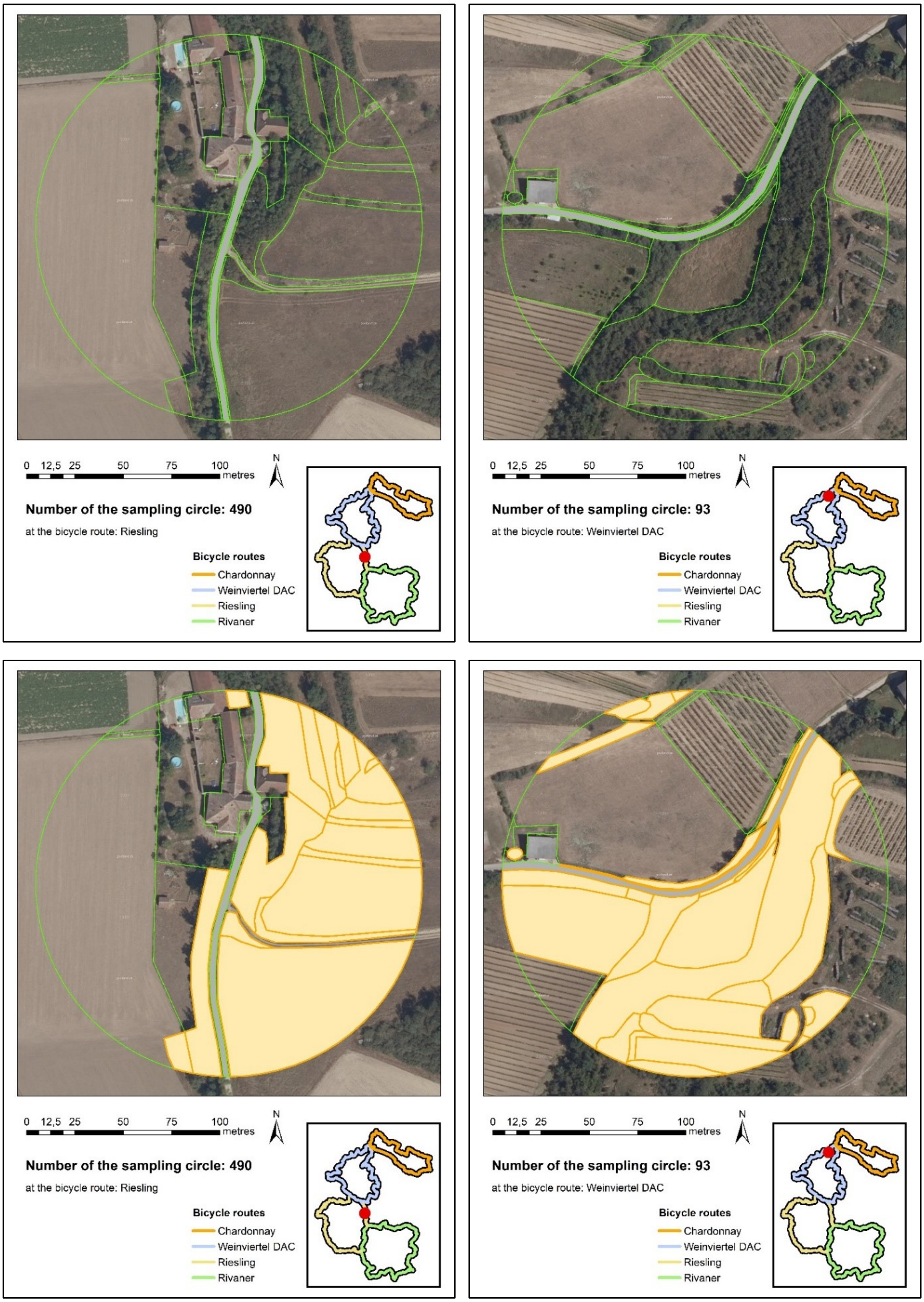

Figure 29: The sampling circles which ranked third and fifth at the 'SMD'
In the lower maps all focus habitats are marked in light yellow.

3.6 Correlations to 'Suitability for Multifunctional Development'

In the scatter plots in **Figure 30** the sampling circles are coloured according to their results at the 'Suitability for Multifunctional Development, SMD'. **Figure 31** shows a 3D scatter plot of the correlation between the three overall values 'Natural Value', 'Cycling Tourism Value' and 'Land Use Value' with the same colouring. For the legend to both diagrams and the number of sampling circles see **Table 12**.

SMD values	Amount of SC	Colour	Colour
> 40,000 & <= 45,000	1x	dark green	
> 35,000 & <= 40,000	1x	medium green	
> 30,000 & <= 35,000	4x	light green	
> 25,000 & <= 30,000	3x	greenyellow	
> 20,000 & <= 25,000	7x	yellow	
> 15,000 & <= 20,000	10x	orange	
> 10,000 & <= 15,000	11x	orangered	
> 5000 & <= 10,000	12x	light red	
<= 5000	21x	dark red	

Table 12: Results on 'SMD', amount of sampling circles and legend to Figure 30 and Figure 31
SC = sampling circles

The results of 'SMD' are highly corresponding to the pattern of the three overall values and have a very high correlation to 'Natural Value' and 'Cycling Tourism Value' and a high negative correlation to 'Land Use Value'.

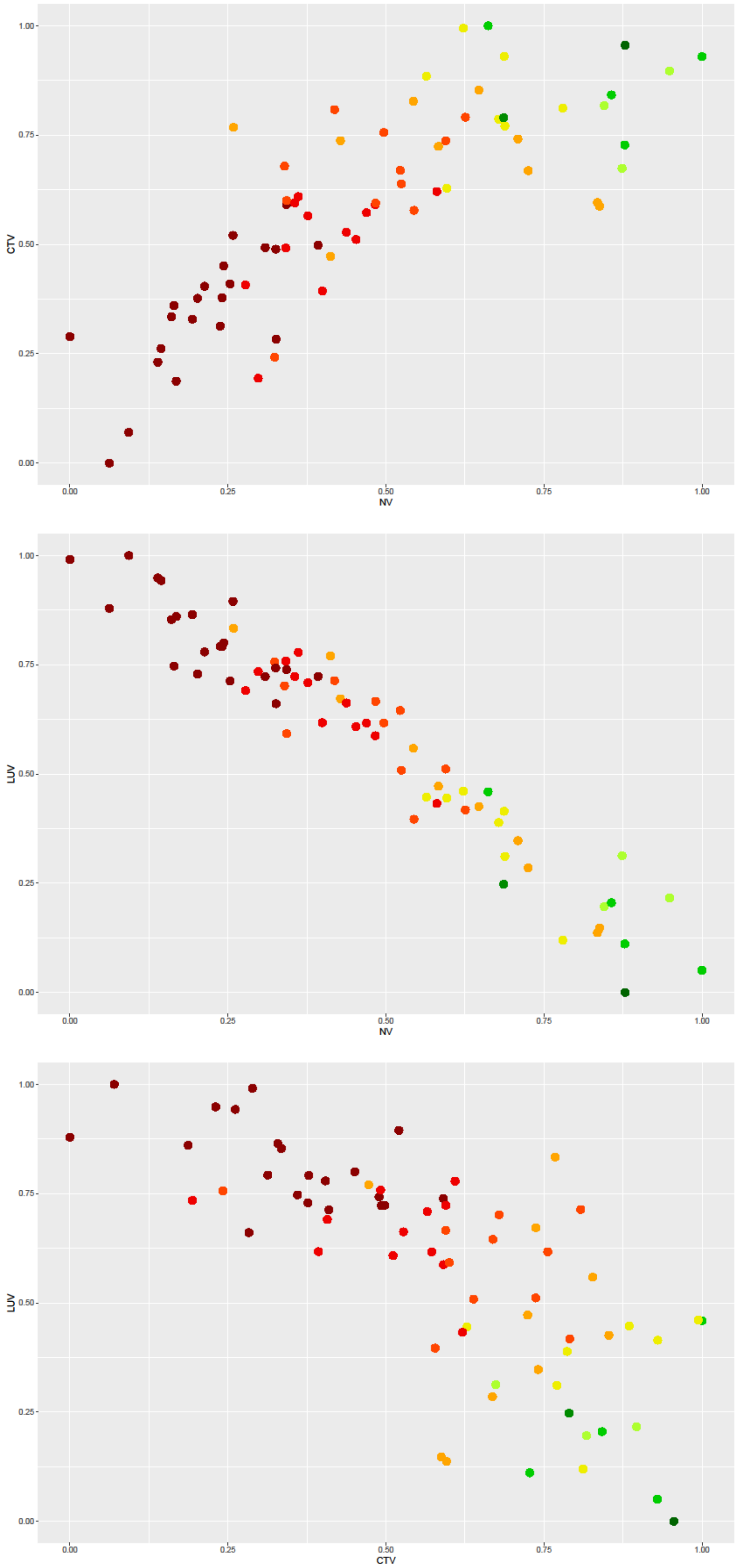

Figure 30: Scatter plots of the correlation between the three overall values, coloured by the 'SMD' of the sampling circles

NV = Natural Value, CTV = Cycling Tourism Value, LUV = Land Use Value, Legend see **Table 12**

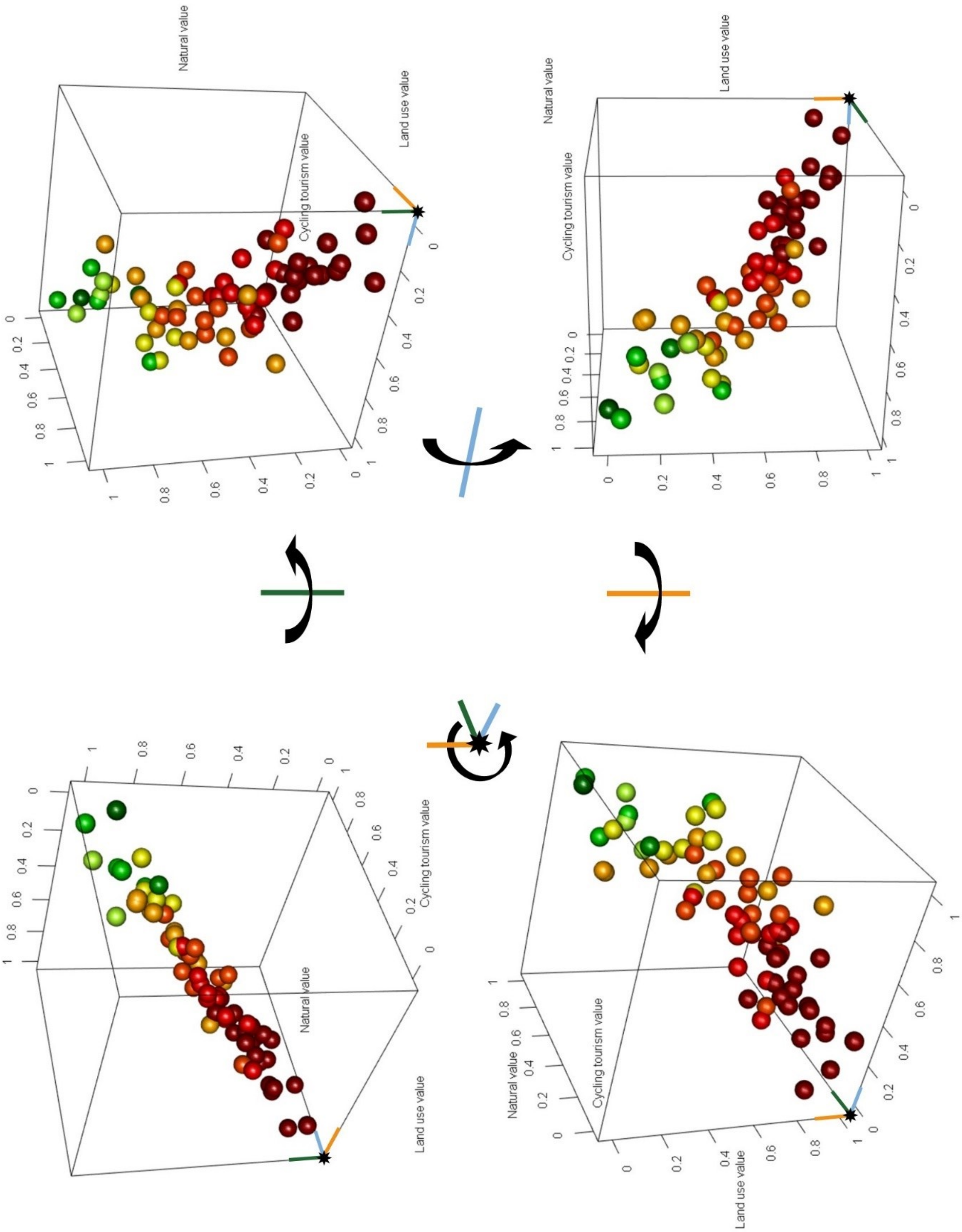

Figure 31: 3D scatter plot of the overall values, coloured by the 'SMD' of the sampling circles
Legend see **Table 12**

4 Discussion

4.1 General

The demonstrated method of evaluating a landscape on a regional scale, based on multiple factors and considering multiple perspectives, performed well.

A possible critique relates to the approach to compute values for landscape services, as it has strengths and weaknesses. It makes it possible to conduct distinct analyses but it is always an abstraction of the complexity of natural systems and details dissolve in the computed value. It is also important to be aware that there might be values that can not be expressed in numbers. Therefore I did not attempt to determine the overall worth of the surveyed areas but rather focused on specific perspectives to compare them to each other. I aimed for a comprehensive representation of each perspective by taking a multitude of specific criteria into account. The values I yielded from the formulas are comparative and enabled analyses within the spectrum of landscape sections in the study area, regarding the research questions of this study.

A general issue during the study was, that the actual routeing of the bicycle routes in some cases did not correspond to the KML-data. I mapped those sampling circles if the bicycle route was still running through it, which could be criticised as the distance of the mapped area to the bicycle route changes. This decision led to the second highest 'Suitability for Multifunctional Development, SMD' in sampling circle 509, but the value might have been even higher with the correct positioning of the sampling circle. Nevertheless there might be room for improvement in further studies in creating a clear guideline on how to address such situations.

The substantial dataset I generated during this study opens up many more possibilities for further analyses. This could be a closer evaluation of the interrelation of the landscape variables. There is potential in further analyses regarding the 'Suitability for Multifunctional Development, SMD' such as determining its correlation to the landscape variables. Also the correlation between the results of the overall values and the European Protection

Area ’Westliches Weinviertel’ could be interesting, although Danzinger (2015) showed, that this might not be the determining factor for the quality and quantity of ecologically valuable habitats. However, an evaluation per bicycle route is not reasonable with the given data, as the sampling design did not aim for an even distribution of all strata over each bicycle route.

A questioning of the cycling tourists would be an interesting topic for an additional study.

In the following the individual analyses and results are discussed in detail.

4.2 The landscape variables

4.2.1 Discussion of results

Contrary to expectations the ’Shape complexity index, SCI’ had the highest values in sampling circles of intense land use with large fields and small lynchets. My intention to represent sampling circles comprising patches with complex outlines did not work using the FRAGSTATS’ MSI (mean shape index) as it calculates with a ratio of edge and area (McGarigal & Marks 1995). With this method a circular patch would get the value 1 whereas for example a rectangle of 100m length and 0.5m width would get the value 8.02 and there is no upper limit. Moreover, by calculating the mean, the size of the patch is not taken into account. Therefore sampling circles with few large patches with low shape indices and some smaller patches with high shape indices yielded high ’SCI’ values. Hence the MSI has not proven to be appropriate for this study. A possible solution would be to take the area into account when calculating the mean or even better chose another index. A good option would be the NSCP-Index (Number of shape characterising points) which describes a shape due to the complexity of its outline (Moser et al. 2002). For each sampling circle its area weighted mean and the sum of all shape characteristic points would be appropriate parameters to calculate an alternative value for the landscape variable ’Shape complexity index, SCI’.

The negative correlation of the spatial criterions ’Largest patch, LP’ and ’Total edge, EDGE’ is as expected.

The high correlation of ’Introduced land units, vegetation, INV’ and ’Landscape quality for land use, Q_LU’ conforms to the fact that agriculture is an important type of land use in the study area, especially as highly urban area was explicitly excluded in the sampling design of the study.

The highly correlated cluster of ’Number of patches, NOP’, ’Total edge, EDGE’, ’Number of focus habitats, NOFH’, ’Richness, RICH’ and ’Diversity, DIV’ shows logical spatial correlations. Furthermore it reveals that in this highly agricultural landscape smaller structured patterns promote the development of a larger number of focus habitats. This in turn leads to a higher connectivity represented in the high correlation to ‘Connectivity, CON’.
Apart from that, the high correlation between ’Richness, RICH’ and ’Diversity, DIV’ indicates that the latter could have been used in the formula for the ’Cycling Tourism Value’ just as well. This is underpinned by De Valck et al. (2017) who determined that outdoor recreationists significantly prefer diverse over uniform landscapes using Simpsons diversity index. As the diversity indices are closely related (Hill 1973) either of them could be used to compute the factor ’Diversity, DIV’ for all three formulas of the overall values.

’Influence on the habitat, IOH’ and ’Nature experience for cycling tourists in the patch, NEC’ have a high correlation which seems to show a negative influence on the focus habitats by cycling tourists. However, all influences on the patch were determined, not restricted to specific users. Therefore the correlation is more likely indicating that a closer distance to the road is causing both more influence on the habitat and more options for use and experience for cycling tourists. Nonetheless an intensification of use of any kind always entails a higher influence on the habitat. This also applies to the experience of nature for cycling tourists which should always be borne in mind. For that reason I recommend once again my previous proposal not to expand the grey infrastructure but on the contrary invest in the development of Green Infrastructure to connect the existing Green Infrastructure to the bicycle route.

The second cluster of highly correlating landscape variables mainly comprises of factors directly connected to nature conservation values. This applies to ’Connectivity, CON’, ’Nature experience for cycling tourists in the patch, NEC’, ’Regeneration of the land unit, RGL’, ’Total size of all focus habitats, TSFH’, ’State of preservation, SOP’, ’Landscape quality for nature conservation, Q_N' and 'Naturalness, NAT', further 'Largest focus habitat, LFH', 'Habitats protected under the habitats directive, HHD' and 'Characterized by resources, RES' with the one exception 'Utilization of the patch for cycling tourists, USE'.

The conflict between intensive agricultural use and ecological values becomes apparent in the strong negative correlation of this cluster to 'Introduced land units, vegetation, INV', 'Landscape quality for land use, Q_LU' and 'Anthropogenic disturbance, DIA'.

The highest correlation of all landscape variables between 'Total size of all focus habitats, TSFH' and 'State of preservation, SOP' is an interesting result which I can not yet explain conclusively. Moreover, the correlation between 'SOP' and 'Largest focus habitat, LFH' is, although high, not as distinct. I used five different parameters of each focus habitat to compute the 'SOP', namely functionality, size of the area, composition of species, habitat structures and signs of disturbance and some of them seem to benefit from a high 'TSFH'. As the other way around is less conceivable a dense mosaic of focus habitats apparently promotes a good state of preservation.

The fact that 'Landscape quality for cycling tourism, Q_CT' has its highest correlation to 'Landscape quality for nature conservation, Q_N' shows that, concerning the land use types, the perspective of cycling tourists on the quality of the landscape coincides well with the perspective of nature conservation.

The lack of exceptionally strong correlations of the remaining landscape variables 'Traffic, TRAF' and 'Pavement, PAV' is obvious, as they are not related to the other landscape variables. A higher correlation between them could have been assumed, but due to the unique structure of the values in 'PAV', which were either -0.5, 0 or 0.5, they did not correlate to the structure of the other values.

Also 'Sealing of the landscape, SEAL', 'Introduced land units, structures, INS' and 'Natural disturbance, DIN' had no exceptionally strong correlations whatsoever, which might indicate that they were not very distinguishing in the surveyed sampling circles.

4.2.2 Critique of methodology

A possible improvement could be to standardize the grades that were given at the data collection. This might not be feasible with all parameters but minimizing the variety of different grading systems would facilitate further processing and even the data collection itself.

I was giving a lot of thought on how best to achieve, that the landscape variables can be set off against each other. I am aware that the decision to rescale all values of the landscape variables to a range of 1 still leaves room for criticism. Nevertheless it seems to be the best realisable method to achieve the objective of computing the overall values on the base of a wide range of influencing factors. This would not have been possible with the raw values of the landscape variables as they had a wide variety of ranges.

With the method of rescaling I was able to keep the information how the single values of one landscape variable relate to each other. This is missing with a mere ranking or dividing in percentiles. But still I lost the information whether the raw values were altogether low, high or had a wide range, as I chose the smallest and highest raw value as lowest and highest limit for the rescaling.

To avoid this, an alternative approach would have been to rescale the raw values according to the minimum and maximum possible raw value. It could been argued, that this would even have made it possible to compare the results of the formulas to those of other landscapes. But this approach causes other and even more severe problems. First of all, it is not always self-evident how to determine the extent of possible results, for example at 'Total edge, EDGE' or 'Shape complexity index, SCI'. Furthermore some criteria are much more likely to cover the whole range of possible results than others. For example, it is no surprise that 'Pavement, PAV' covered the whole range of possibilities, whereas 'Number of patches, NOP' is very unlikely to cover the maximum possible amount of mapped patches, which again would have to be defined first. This would have led to a very unbalanced weighting of different landscape variables in the formulas, why the chosen method was the better choice for this study. However, to compare the results of this landscape to another one, the raw values of each landscape variable should be used.

The rescaling leads to comparative results, representing the positioning of a sampling circle in the current range of possibilities in the surveyed landscape. This is ensured trough the sampling design, where I was aiming for a good representation of the spectrum of possible landscape sections in the study area. Therefore, with the exception of urban area, in the sampling circles all characteristics of the landscape in the study area are represented.

The potential of this landscape for multipurpose use of nature conservation and cycling tourism and the intensive agricultural land use in the area were already evident due to screening of the area by remote sensing and the facts that both bicycle routes and the European Protection Area 'Westliches Weinviertel' are present in the area. Supplemented by expert knowledge, this was the reason for choosing this study area for the survey and developing this method. Thus I want to point out, that the method was not aiming for an answer to the question if those elements are present, but rather how they correspond.

4.3 The overall values

4.3.1 Discussion of results

As expected, the bar charts show an opposing pattern at the 'Natural Value' and the 'Land Use Value'. Whereas high 'Cycling Tourism Values' correspond to relatively high 'Natural Values' and low to intermediate 'Land Use Values'. This indicates, that the experience of nature for cycling tourists is highest in a mixed landscape with a focus on natural characteristics. The maps of the sampling circles with the highest 'Cycling Tourism Value' confirm this interpretation when keeping in mind that the study area is generally characterised by intensive agriculture and that the results are comparative. The maps of the sampling circles with the highest 'Natural Values' and 'Land Use Values' illustrate well the most disparate forms appearing in the surveyed landscape.

Furthermore this results demonstrate the effective operation of the formulas as the computed overall values were highly accordant to the visual interpretation of the maps.

The highest sums of all three overall values can be found in multifunctional sampling circles. I need to stress, that the sampling design and analyses of this study aimed to answer the research question and did not take further values into account. The sum of all three overall values is not to be misinterpreted as an overall evaluation of the landscape as for that many more values needed to be considered. However, these results demonstrate again, that a mixed landscape with a focus on nature leads to a high ’Cycling Tourism Value’ which is essential to yield a high sum of all three overall values.

The results presented in the correlogram of the overall values are very distinct. The conflict between nature conservation and intensive land use is obvious. Developing the formula for ’Land use’ I adopted the perspective of intensive use without taking further benefits like ecosystem services or landscape services into account. The results demonstrate that the one-sided approach of maximum exploitation is not only at the expense of nature but also of other landscape services. This becomes apparent in the strong negative correlation between ’Land Use Value’ and ’Cycling Tourism Value’. The latter represents the experience of nature for cycling tourists and is therefore an indication for a recreational landscape service. Furthermore it also indicates cultural value of the landscape and creates possibilities to benefit from educational landscape services.

On the other hand ’Natural Value’ and ’Cycling Tourism Value’ have a strong positive correlation. Therefore valuable areas for nature conservation provide also a high level of experience of nature for cycling tourists. Conversely also a high ’Cycling Tourism Value’ has only little negative impact on the ’Natural Value’.

This results provide valuable insights to the research question. They show, that a high specialisation on land use is at the expense of nature as well as on the experience of nature for cycling tourists and therefore the touristic value of the bicycle route. But there are good prospects to enhance both, with a slight reduction of intensive land use. High sums of all three overall values are possible even with intermediate ’Land Use Values’.

4.3.2 Critique of methodology

Again the scaling of the results could be criticised. This became necessary due to the different structures of the formulas of the three overall values. They are computed with two to four value-determining integrants, each consisting of a various amount of different landscape variables which could be taken into account positively or negatively. An early attempt to design the formulas with a similar structure was given up fast, as from different perspectives different factors are relevant. Thus I yielded results of different ranges which made the rescaling of the results necessary, to get comparable results.

A limitation of this approach relates to the incomparableness of the results to those of other studies. The study design was only meant to evaluate the current situation in my study area in respect of the research question. However, a repetition of the study could reveal changes in the landscape, when compared to the results of this study.

To use the formulas in other landscapes, or a different scale for the data collection, it might be necessary to adapt the formulas. Which criteria are taken into account and how they are calculated depends on the current use of the landscape and the objective of nature conservation, which requires expert knowledge of the study area. Nevertheless, with minor adjustments the method can be transferred to other study areas and even to other research questions.

In this study I demonstrated a method of evaluating a landscape on a regional scale based on multiple factors and considering multiple perspectives. I am aware, that it is in an early stage of development of the method and that it can be improved. An example thereof is the calculation of the 'Shape complexity index, SCI', which yielded values contrary to the intention and needs to be computed with another index in future. Despite this, the formulas worked well and the results would have been even more decisive with a corrected 'SCI'. Thus this is a confirmation of the robustness of the method.

4.4 The strata

The correlation of the three overall values to the strata shows clear tendencies for the results based the favoured habitat classes from the 'Central European Habitat Map' (CEH) in the expected manner. The sampling circles which contain areas of the category 'Potential' I created for the 'CEH' (see 2.4 The 'Central European Habitat Map') tended to high 'Natural Values', high 'Cycling Tourism Values' and low 'Land Use Values'. Therefore the 'CEH' is proves to be very useful to detect potential areas for multipurpose use of nature conservation and the experience of nature for cycling tourists. Herein lie possibilities to easily evaluate large areas in respect of this question. However, I need to stress that the definition of the category 'Potential' is not universally valid. I defined it specifically for this landscape depending on the natural ecosystems in the area, the current use of the landscape and the objective of nature conservation. To survey other landscapes with this method, the category 'Potential' needs to be adapted.
Stratum 1 also contains sampling circles with 'CEH' habitats of the category 'Potential' which is not represented in the results and provides opportunities for further analyses.

The dispersed pattern of stratum 1 has several reasons. The sub-strata are based on different criteria and their results show different patterns. Therefore they have to be examined separately. Although the small amount of sampling circles per sub-stratum is a disadvantage for detecting clear patterns.

Sampling circles of sub-stratum 1.1 and sub-stratum 1.2 had to intersect with the buffer area of a nature protection area or natural monument in order to be selected, sub-stratum 1.1 additionally required an intersection with the buffer of a Kellergasse or a POI. In general both tend to medium to high 'Natural Values' and 'Cycling Tourism Values' and medium to low 'Land Use Values'. Not many nature protection areas or natural monument are directly bordering the bicycle route and often they could not be experienced from there. Also the presence of a natural monument is no guarantee for a high 'Natural Value' of the sampling circle, as it can be for example a single tree surrounded by streets and fields. Possibly the trend of the sampling circles in sub-stratum 1.1 and sub-stratum 1.2 is not so much because of their position in the 500 m buffer of special features, but rather due to the hand picking selection process of the most promising sampling circles from the pre-selection via remote sensing.

The sampling circles with Kellergassen in sub-stratum 1.3 have high 'Cycling Tourism Values', intermediate 'Natural Values' and medium to high 'Land Use Values'. Certainly the small set of only four values causes a high degree of uncertainty in the interpretation of a trend. Nevertheless I regard the results as quite representative for the function, use and appearance of Kellergassen.

The sampling circles from sub-stratum 1.4, which are in the buffer area of POIs, have scattered intermediate values at all overall values, even at the 'Cycling Tourism Value'. I need to stress that the focus of the survey was on the experience of nature for cycling tourists and the overall values were computed from the entirety of the patches in the sampling circle. Therefore a sampling circle of sub-stratum 1.4 can have a low 'Cycling Tourism Value' even if the POI itself has a high touristic value from another perspective such as cultural. Land use and nature conservation are not directly related to the selection criterion POI.

A possible improvement of the sampling design could be to chose a smaller buffer distance for the special features nature protection areas, natural monuments, Kellergassen and POIs. At the edge of the used buffer distance of 500 m, mostly the buffered special feature is not recognisable any more in the sampling circle. The panoramic view from a sampling circle could not be taken into account in this study and I observed, that the special features often are tightly bounded islands in the landscape. The decision to use a 500 m buffer nonetheless was based on the assumption that this distance might still provide opportunities for bicycle tourists to take a detour. Presupposed that there is an access road to the area of interest, a well placed information board could possibly engage cycling tourists to visit a rare special feature that is slightly off the route. As I chose the most appropriate sampling circle for every combination of different special features during the selection process, the larger buffer area gave me more choices. But the reference sampling circles in stratum 1 are only pertinent if the POI is located directly in the sampling circle, in immediate vicinity or maybe if a turnoff to the POI is located in the sampling circle. Therefore distant and unsuitable sampling circles were sorted out. Even with the large buffer area I only obtained a total of 29 suitable sampling circles with unique combinations for the entire stratum 1, of which I surveyed 22.

POIs which are embedded in urban area proved to be unsuitable for the selection. In the study area this applied to the most edificial POIs like churches or castles. If no nearby sampling circle has under 20% urban area it is not reasonable to use this POI for the study about the experience of nature for cycling tourists. POIs which are already related to nature worked well, such as non urban rest areas, viewpoints and other sights which constitute a part of the scenery. Just like Kellergassen they usually tend to be close to the bicycle route. With a smaller buffer distance many unsuitable sampling circles get discarded automatically. Nonetheless this bears the risk of missing relevant reference sampling circles. This applies especially to nature protection areas and natural monuments and therefore the buffer distance should be adapted separately. The appropriate distance depends on the landscape, the frequency of special features, the correctness of the editing of the source data and the nature of the special feature. For Example for Kellergasse a buffer of 100 m, if any, would be enough, for nature protection areas a 500 m buffer might still be a good choice in this landscape as they are rare and remote.

This demonstrates well, that there is potential to enhance the experience of nature for cycling tourists regarding nature protection areas and natural monuments. Combined with the results of the strata based on the 'Central European Habitat Map', this evidences that by investing in green infrastructure on the areas between these special features and the bicycle routes, not only the experience of nature for cycling tourists will benefit but also nature conservation. This is exactly in line with the proposed approach and an important part of answering the research question of this study.

4.5 The 'SMD'

The results on the 'Suitability for Multifunctional Development, SMD' provided interesting additional findings. The high correlation of the 'SMD' to the pattern of the three overall values proved it as an efficient tool to determine the suitability of sampling circles for multipurpose use for nature conservation and the experience of nature for cycling tourists.

The method needs expert knowledge to determine the potential of a patch for both nature conservation and the experience of nature for cycling tourists. That provided, it is possible to map a large route section quickly and accurately regarding the specific question. That again can provide a solid basis to find the most suitable areas to enhance the Green Infrastructure along the bicycle route, to make it more valuable for both nature conservation and experiencing nature.

This method could also be easily adapted to other landscapes and maybe even other perspectives. Although it does not consider other factors or trade-offs the ’SMD’ is very accurate and efficient regarding a specific question. I demonstrated that by comparing the results to the results of the complex formulas of the overall values which yielded a highly correlating pattern. This method is especially interesting for stakeholders as it is an economic approach to assess specific Green Infrastructure projects which is a necessary basis for their successful implementation. Therefore I regard the ’SMD’ method as a promising approach for specific Green Infrastructure evaluations. It could be analysed and tested more closely in further studies and I recommend the refinement of the method, including the development of a guidline, an exact definition of the grades and its components, and a manual.

5 Conclusion

In this study I demonstrated a method of evaluating a landscape on a regional scale, based on multiple factors and considering multiple perspectives. I assessed the Green Infrastructure along four bicycle routes in the case study area of Western Weinviertel applying newly developed formulas to compute overall values for each sampling circle from three different points of view. The ’Natural Value’, the ’Cycling Tourism Value’ and the ’Land Use Value’ were then compared to detect correlations and conflicts aiming to deliver a scientific background for enhancing both, nature conservation and the experience of nature for cycling tourists. The demonstrated method performed well and from additional analyses further interesting insights could be obtained.

It has to be kept in mind that the approach to compute values for landscape services has strengths and weaknesses. The overall values are comparative and enabled analyses within the spectrum of landscape sections in the study area regarding the research questions of this study. The newly developed formulas proved their effective operation. Furthermore the robustness of the method was confirmed. However, the method is in an early stage of development and can be refined.

The research of this study was limited to three specific perspectives, further perspectives and landscape services could not been taken into account. Additional analyses would have gone beyond the scope of this study, but there are interesting possibilities such as analysing the landscape variables more closely.

Due to the stratified sampling design the spectrum of possible landscape sections in the study area was well represented. Both specialised and multifunctional sampling circles were surveyed.

The results on the correlation of the three overall values were very distinct. The conflict between nature conservation and intensive land use was obvious. These perspectives were represented in the ’Natural Value’ and the ’Land Use Value’ respectively. Also the ’Cycling Tourism Value’, which represented the experience of nature for cycling tourists, had a negative correlation to ‘Land Use Value’. However, ‘Natural Value’ and ’Cycling Tourism Value’ had a high positive correlation. Therefore valuable areas for nature conservation provide also a high level of experience of nature for cycling tourists and in turn the latter has only little negative impact on the ’Natural Value’.

Therefore an enhancement of Green Infrastructure for both nature conservation and the experience of nature for cycling tourists is possible, as these perspectives are highly correlating and little conflicts are to be expected. A high specialisation on land use is at the expense of nature as well as on the experience of nature for cycling tourists, but both can be enhanced with a moderate reduction of intensive land use. Keeping in mind that the study area is generally characterised by intensive agriculture and that the overall values are comparative, their results indicate that the experience of nature for cycling tourists is highest in a mixed landscape with a focus on natural characteristics.

The demonstrated method could be transferred to other study areas and even to other research questions, but minor adjustments would have to be made depending on the current use of the landscape and the objective of nature conservation.

Furthermore, findings show that to detect potential areas for multipurpose use of nature conservation and the experience of nature for cycling tourists, the 'Central European Habitat Map' (CEH) is very useful. Again the applied method can be transferred to other study areas but has to be adapted. For further studies, closer analysis of the results regarding the 'CEH' categories could be interesting.

The nature protection areas and natural monuments can be enhanced which would also benefit the experience of nature for cycling tourists. The proposed approach to invest in the Green Infrastructure between these special features and the bicycle routes was proved to benefit both, people and nature.

Additionally I developed the 'Suitability for Multifunctional Development, SMD', which is a promising approach based on expert knowledge. It is a very accurate and efficient tool to determine the suitability of sampling circles for the specific multipurpose use according to the research question. It could be adapted to assess other Green Infrastructure projects regarding specific perspectives. As this method is very economic it is especially interesting for stakeholders. It could be analysed and tested more closely in further studies and I recommend the refinement of the method, including the development of a guidline, an exact definition of the grades and its components, and a manual.

Enhancing the Green infrastructure along the bicycle route is a valuable contribution to the recovery of natural habitats. It also increases the experience of nature for cycling tourists and therefore the touristic value of the area. The intensive land use will have to recede suitably to implement that. But seeing the bigger picture of sustainability and landscape services this might be the necessary future trend in any case.

The next steps could be to adopt a transdisciplinary approach to develop practical steps towards the implementation of a nature themed bicycle route.

But there is also another dimension of this proposal. To me it is obvious that things have to change fundamentally to develop towards a better future. And I believe that this change will evolve out of individual growth, personal perceptions and values of every individual. A nature themed cycling path might be just a tiny step, but many small steps in the right direction can have a great effect. If people have enriching experiences of nature, it changes the way they treat nature out of personal affection.

So much valuable knowledge has been gained by science so far. I look forward to see it put into action for the greater good of all beings.

6 Lists

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7 References

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