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Establishing a sound scientific base for an evaluation and a reissue of the management plan "Landscape protection area *Großer Ahornboden* in the Alpine Park Karwendel" (Tyrol, Austria)

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MASTER THESIS

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List of abbreviations and acronyms[1]

a – Old/ancient tree

a.s.l. – Elevation above sea level (in m)

BHD – Diameter at breast height (German: Brusthöhendurchmesser)

DBH – Diameter at breast height (German: Brusthöhendurchmesser)

Exclusion area (German: Ausschlussfläche) – Area defined in the MMP, where replanting seems not reasonable.

g – Large tree

ha – Hectare

i – Intact; vital tree

ID – Identification code of a sycamore maple in the tree cadastre

k – Small tree

LAI – Leaf area index

Large tree – 16 to 25 metres in height

LPA – Landscape protection area "Großer Ahornboden" in the Karwendel Nature Park

m – Middle-aged tree

m – Middle-sized tree

MMP – Management plan of the LPA "Großer Ahornboden" (Schreiner, 2004); MMP adopted in 2005

Measure unit/Management unit 1,2,3 (German: Dringlichkeitsflächen 1,2,3) – Areas defined in the MMP based on age structure and urgency of replanting

Middle-aged tree (m) – 100 to 300 years

Middle-sized tree (m) – 7 to 16 metres in height

Old/ancient tree (a) – 300 to 600 years

p – Unclassified point feature in the 2022 tree cadastre

Small tree (k) – 0,1 to 7 metres in height

Young tree (j) – 1 to 100 years

z – Mortality of a tree

2001 tree cadastre/2001 survey – Data basis for the preparation of the MMP

2022 tree cadastre (3202 elements) – 1st volume

2022 tree cadastre (3291 elements) – revised tree cadastre/2nd volume; contains elements which may have died unnaturally

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[1] *Other abbreviations and acronyms:* Appendix 2 - "Erfassungs- und Bewertungsbogen für den Ahornbestand am Großen Ahornboden. Beurteilung des ästhetischen, ökologischen und kulturellen Wertes und der Vitalität".

Acknowledgements

Figure 1: *"Wer nur vorwärts geht, sieht seine eigenen Spuren nicht." Aufschrift auf der Lehne einer Bank am „Großen Ahornboden". Quelle: Authorin.*

Vielen Dank an den Naturpark Karwendel für das spannende Thema und das in mich gesetzte Vertrauen für dessen Bearbeitung. Insbesondere Herrn Hermann Sonntag für die schnellen Reaktionen auf meine Fragen, die konstruktive Kritik und die sachliche Beratung. Du hast den gesamten Prozess intensiv begleitet und mich sehr unterstützt.

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Abstract

The landscape protection area (LPA) "Großer Ahornboden" in the nature park Karwendel (Tyrol, Austria) is a cultural landscape that has developed by the interaction between the natural environment and agriculture. It represents not only a magnificent patrimony of scenic beauty, history, and culture of Tyrol, but also an immense biodiversity hotspot.

Although "Großer Ahornboden" has a special position and pioneering role in terms of public perception, maintenance, protection status and the state of research compared to other sycamore wooded pastures, the last extensive survey of the sycamore maple population dates back more than 20 years. 2001 to 2004, a well-founded management plan (MMP) was drawn up and passed in 2005. My goal is to evaluate the success of measures undertaken as well as to identify a potential need for action.

I present here the first review of the 2001 tree cadastre in its entirety, including summaries of the distributions and status of the trees in 2022, changes in size and age structure of the sycamore maple population between 1953 to 2022, and key information about the recording process and maintenance of the database. For the assessment of the tree population, the respective specific strengths of orthophoto, laser data and field work were exploited. The 2022 tree cadastre, comprising 3291 records, contains 2427 vital sycamore maples.

Statistical analysis of the dataset suggests that an overaging of the old stand as well as a lack of regeneration and conflicting management interests will be the main threats to "Großer Ahornboden" in the near future. This research emphasises to consider the characteristic landscape structure and specific habitat requirements of individual species or genera as well as interests of all stakeholders involved, when planning appropriate management or conservation strategies. I highlight the invaluable benefits of the database to conservation stategies and encourage for continued efforts to maintain and expand the tree cadastre.

It is not so much for its beauty that the forest makes a claim upon men's hearts, as for that subtle something, that quality of air that emanation from old trees, that so wonderfully changes and renews a weary spirit

Robert Louis Stevenson

Zusammenfassung

Eine der größten Bergahornweiden des Alpenraums stellt das Landschaftsschutzgebiet *(LPA)* „Großer Ahornboden" im Naturpark Karwendel (Tirol, Österreich) dar. Die *sycamore maple wooded pastures* wurden über Jahrhunderte durch die Interaktion zwischen Landwirtschaft und Naturlandschaft geformt und bieten heute ein vielfältiges Angebot an Landschaftsleistungen. Das unregelmäßige Mosaik aus Baumveteranen und offenen Weideflächen besticht durch den hohen ästhetischen Wert, bietet Raum für Erholung und landwirtschaftliche Nutzung, bewahrt ein wertvolles historisches sowie kulturelles Erbe und spielt eine nicht zu unterschätzende Rolle für den Tourismus. Nicht zuletzt stellt der „Große Ahornboden" aus Sicht des Naturschutzes ein Zentrum der Biodiversität (*hotspot)* dar, das sich insbesondere auch durch das Vorkommen gefährdeter und geschützter Arten auszeichnet. Innerhalb der Bergahornweiden nimmt der „Große Ahornboden" hinsichtlich seines Bekanntheitsgrades, Forschungsstandes, Managements und seines Schutzstatus eine Vorreiterrolle für ein.

Eine Inventur der Bergahornpopulation im Jahr 2001[2] legte die alarmierend hohe Zahl an absterbenden und abgestorbenen Bäumen bei fehlender Regeneration dar. Auf diese Situation reagierte man bereits vor über zwanzig Jahren mit der Erstellung eines Managementplans (*MMP*), der die entscheidenden Weichen stellen sollte, um diese einzigartige Kulturlandschaft langfristig zu erhalten. Da aktuelle Kennzahlen über den Baumbestand jedoch fehlten, führte ich im Rahmen meiner Masterarbeit im Frühjahr und Sommer 2022 eine Bestandsinventur der Bergahornbäume am „Großen Ahornboden" durch. Ich setzte mir zum Ziel, den aktuellen Zustand der Bergahornpopulation zu beschreiben sowie meine Ergebnisse mit der Inventur 2001 zu vergleichen und relevante Entwicklungen aufzuzeigen. Darauf aufbauend kann der Erfolg, der im MMP vorgeschlagenen Maßnahmen evaluiert werden und potenzieller Handlungsbedarf aufgedeckt werden.

Der finale Baumkataster für das Jahr 2022 enthält 3291 Elemente, wovon 2427 vitale Ahornbäume und 118 Laub- oder Nadelbäume darstellen. Eine natürliche Regeneration konnte in elf Bereichen beobachtet werden. Für den Zeitraum 2001-2022 sind 426 Baummortalitäten vermerkt. Es wurden 52 Dürrständer, 50 Baumstümpfe und 116 Bäume, die vermutlich abgeschnitten wurden, gezählt. Die Gesamtbilanz der Bergahornpopulation für den Zeitraum 2001-2022 ist negativ. Eine zunehmende Überalterung des Bestandes kombiniert mit fehlenden

[2] Im Managementplan (MMP) ist die Rede von der Baumpopulation im Jahr 2000. Die Luftbildaufnahmen, auf Grundlage derer die Baumpopulation erhoben wurde, stammen jedoch aus dem Jahr 2001.

Nachpflanzungen und konkurrierende Schutz- und Nutzungsinteressen stellen auch weiterhin die größten Herausforderungen der kommenden Jahre dar.

Baumgreise bilden den prozentual größten Anteil der Bergahornpopulation. Ein Großteil hatte bereits im Jahr 2001 seine natürliche Altersgrenze erreicht. Aufgrund dieser unvermeidbaren Mortalitäten scheint die Totholzkontinuität zumindest mittelfristig gesichert. Langfristig werden ökologisch wertvolle Habitatstrukturen (wieder) weiter zunehmen, wenn junge Bergahornbäume zu Veteranen *(veteran trees)* oder Baumgreisen (*ancient trees*) werden. In Anbetracht der zeitlichen Dimension, die ein Bergahornbaumleben umfasst, stellt eine kontinuierliche Nachbildung sowie uneingeschränkte Erhaltung des Altbestandes *die* zentrale Säule zur Erhaltung des „Großen Ahornbodens" samt seiner vielfältigen Landschaftsleistungen dar.

Erfreulicherweise konnte die Ausfallquote der Pflanzungen seit dem Jahr 2001 auf Null reduziert werden. Die Verwendung von autochthonem Pflanzgut, das Anlegen von Pflanzgruben, das Einhalten der im Management definierten Ausschlussflächen sowie eine Umzäunung der Jungpflanzen zum Schutz gegen Verbiss scheinen sich absolut zu bewähren. Die Zahl der Nachpflanzungen liegt jedoch deutlich unter den im MMP geforderten Sollwerten. Sollte sich die Verjüngungssituation in den nächsten rund zwanzig Jahren nicht deutlich verbessern, schätze ich die nachhaltige Sicherung des Bergahornbestandes in seiner heutigen Form als gefährdet ein. Angesichts der vielfältigen, teilweise gegensätzlichen Nutzungsansprüche drängt sich die Notwendigkeit auf, die Kulturlandschaft bewusst zu gestalten und zu erhalten. Bei der Planung von Maßnahmen sollten die Interessen aller menschlichen, tierischen und pflanzlichen Bewohner-, Betrachter- und BewirtschafterInnen mit einbezogen werden.

Eine standartisierte Vitalitätsbeurteilung der Bergahornbaumpersönlichkeiten am „Großen Ahornboden" scheint keine aussagekräftigen Ergebnisse zu liefern.

Die beste Zeit einen Baum zu pflanzen, war vor 20 Jahren.
Die nächstbeste Zeit ist jetzt.

Sprichwort aus Uganda

Chapter 1 – Introduction

1.1. Sycamore maple wooded pastures - cultural landscapes with various functions in the past, present, and future

Sycamore maple wooded pastures represent a man-made cultural landscape of the mountain area in the northern European Alps (Kiebacher et al., 2018). "Großer Ahornboden*"* in the nature park Karwendel, Austria, represents the largest known (Kiebacher, 2016b; Sonntag & Straubinger F., 2019). The formation of these remarkably flat pastures with their characteristic structure of stocked and unstocked areas is not conclusively clarified. In the literature, several reasons are mentioned how the sycamore maple population (Lat. *Acer pseudoplatanus*) could establish itself on the pastures there. Most frequently mentioned are cattle plagues, and the Thirty Years´ War (Czell et al., 1966; Gosteli, 2016; Schreiner, 2004; Sonntag et al., 2019). Also, a selective promotion of sycamore maple trees might be a reason (Czell et al., 1966). In former times, the trees were valued for their range of possibilities of use, such as fodder, bedding and as ingredient of medical or food products (Kiebacher et al., 2018; Machatschek, 2002). Nevertheless, there is a broad consensus that the interaction between the natural environment and agriculture has already lasted for many centuries (Czell et al., 1966; Gosteli, 2016; Schreiner, 2004; Sonntag et al., 2019) and that the establishment of the sycamore maples dates to a time when the grazing at "Großer Ahornboden" had been interrupted for some time. Today, the historic landscape forms a famous cultural asset of the landscape in Tyrol, visited by many people for recreation every year. Beside the aesthetic and cultural heritage, the wooded pastures are immensely valuable for nature conservation and are described as key stone structures for biodiversity (Hertel, 2009; Kiebacher, 2016a). Such ecosystems consist of various habitats at a small scale and are home to various creatures. The ancient sycamore maples are home to "the largest *Tayloria [rudolphiana*, Rudolphs Trompetenmoos – remark of author] population of the Alps" (Kiebacher, 26.02.2022). This bryophyte is a globally rare species and critically endangered (Rote Liste Zentrum, 2018; Tan et al., 2000). It is assumed that the ecological importance of *Acer pseudoplatanus* will continue to increase in the context of climate change (Brosinger & Schmidt, 2009b).

1.2. Relevance and objectives of this master thesis

The interest and appreciation for historic landscape forms and ancient trees in the alpine region is presently increasing. Nevertheless, in the last century, the total area occupied by sycamore maple wooded pastures in the Alps decreased due to management intensification or abandonment (Kiebacher, 2016b; Obrist, 2018), lack of regeneration (Kiebacher, 2016) and soil degradation (Kiebacher et al., 2017), e.g. The LPA "Großer Ahornboden" has a special position and pioneering role in terms of public perception, maintenance, protection status and the state of research (Pleitenbacher & Stoer, 1999).

The first active measures for the preservation of the protected landscape area "Großer Ahornboden" were already initiated around 1950 (Alpenpark Karwendel, 2005). Nevertheless, the success of the planting efforts was limited and the area faced some of the major threats mentioned (Schreiner, 2004). To ensure the continuance of the eponymous sycamore maple stand with its characteristic structure, from 2001 to 2004 a well-founded management plan (MMP) was drawn up and adopted in 2005 (Schreiner, 2004). The document was originally drafted for 10 years (Schreiner, 2004, p. 35). Consequently, there is a high demand for monitoring the success of measures undertaken as well as for identifying a potential need for action. This master thesis aims at answering the following research questions regarding the sycamore maple population and its vitality:

1) *The sycamore maple population and its management:*
   How many vital sycamore maple trees can be counted at "Großer Ahornboden" in 2022, and what is the age-class distribution regarding the whole landscape protection area (LPA) and each measure unit? Since 2001, has the sycamore maple population at "Großer Ahornboden" or its age structure changed, and how have the individual measure areas developed? Have the proposed measures of the management plan been effective? For the near future, what recommendations can be derived from the data collected to improve the management of the LPA?

2) *Vitality and habitat potential*
   Is it possible to create a specific sycamore maple assessment procedure to assess the vitality and the habitat potential of these trees at "Großer Ahornboden" effectively? Does a computer-assisted laser data analysis substantiate the results of the visual tree inspection in terms of vitality? Is it possible to collect information about the sycamore maples´ vitality by means of laser data?

Chapter 2 - The landscape protection area "Großer Ahornboden" in the Karwendel Nature Park and its sycamore maple population

2.1. Geographic location and protection status of the study area

The Karwendel Mountains are the largest range of the Northern Limestone Alps and stretch from the Inn Valley between Zirl and Jenbach (Tyrol, Austria) to the Isar Valley (Bavaria, Germany). This mountain massif is bordered to the west by the Seefeld saddle and to the east by the Achensee lowlands.

From an ecological point of view, the bordering Bavarian nature reserve Karwendel and Karwendel promontory forms a unit with the Austrian part. However, this study focuses on the Karwendel Mountains within the Austrian borders (Figure 2). This entire area is protected partly as the regional nature park Alpine Park Karwendel by the Tyrolean Nature Conservation Act and partly as the EU-Natura 2000 area Karwendel. The Alpine Park Karwendel was founded in 1928 and encompasses an overall mountainous area of 726.7 km² (§12 TNSchG). It is the oldest and largest nature park in Austria (Sonntag, 2019). Its core region is the Karwendel Nature Reserve (Table 1). 1988, 256,62 ha of the nature park Karwendel in the municipality Vomp were declared as the LPA "Großer Ahornboden" (Figure 2&3, Table 1). However, the idea of protecting this high valley and its extraordinary landscape was met as early as 1927 when it was designated as a natural monument.

The sycamore wooded pasture at "Großer Ahornboden" is located at the bottom of the Enger Valley just over the German-Austrian border near Mittenwald. The "Eng" is one of the widest and flattest valley floors in Karwendel Nature Park (Alpenpark Karwendel, 2005). Its vertical extension ranges from roughly 1080 m a.s.l. up to 1300 m a.s.l. The Enger Valley is bounded in the east by the Sonnjoch group (max. 2457m a.s.l.) and in the west by the Gamsjoch group (max. 2452m a.s.l.).

Table 1: *Categories, size, and legal declarations of the conservation reserves of the Karwendel Mountains. Source: Naturpark Karwendel (2022a).*

Conservation reserve	**Reserve category and legal framework**	**Area (squkm)**
Alpine Park Karwendel	Nature park §12 TNSchG; LGBl 26-58/2009	727
Natura 2000 Karwendel	EU- FFH Directive & Natura 2001 SPA; EU- Bird Directive, 1995	727
Nature protection area Karwedel	Nature reserve §21 TNSchG; LGBl Nr 26 VO 23.3.1989)	543
Landscape protection area "Großer Ahornboden"	Landscape protection area §10 TNSchG; LGBl Nr 26 /2005 (28. VO, 20.12.1988)	2.7

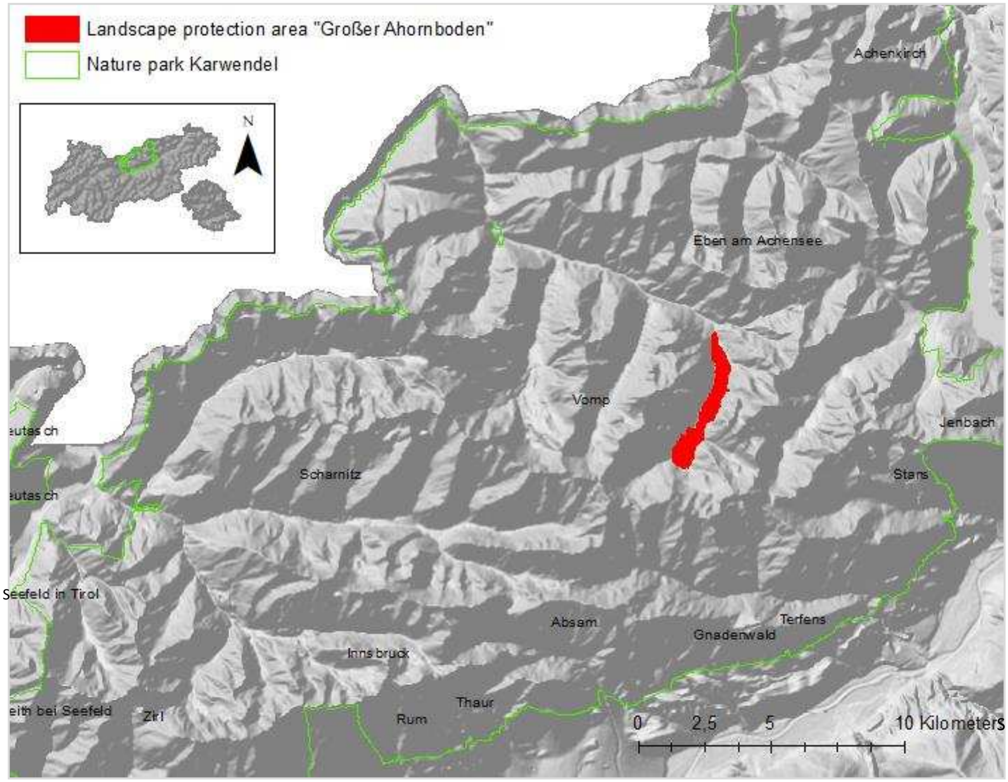

Figure 2: *The study area (red) and its location in the Karwendel Nature Park (green), Tyrol. Source: Author.*

2.1. The current management plan for the land protection area "Großer Ahornboden" in the Alpine Park Karwendel

The MMP for the landscape protection area "Großer Ahornboden" in the Alpine Park Karwendel was passed in 2005 and includes 45 pages (Naturpark Karwendel, 2022b). Legal basis for its creation and implementation are the provisions §7, para (1) and (2) of the Tyrolean Nature Conservation Act, LGBI no. 15/1975. The extent of the LPA, the purpose of protection, and actions requiring authorisation or exempted from authorisation are detailed in the legal text of the 28th Ordinance of 20 December 1988. A revision of the MMP and its objectives was considered at the earliest ten years after its conception. The MMP is based on the survey and evaluation of the current status in 2001 of the sycamore maple population, its age structure at "Großer Ahornboden" and the comparison of these results to those of 1953. Based on the findings, general and specific management objectives were formulated, and measures proposed. The following points are overarching and should also be paid special attention to in a future management concept:

- The tree population should remain constant and include about 2200 sycamore maples.
- A balanced age structure is to be striven for.

- The alternation between completely treeless areas, loosely stocked areas and a few denser groups of trees must be maintained by targeted replanting on places where trees died.
- Vital and dead trees must be left in the LPA, tree surgery measures are not allowed, and heavy standing or lying dead wood that is thicker than 30cm must not be removed.
- The various interests of agriculture, forestry, tourism, and environmental protection should be discussed and integrated.
- The regulations of the LPA "Großer Ahornboden" provide for an agricultural and silvicultural use that is customary for the locality.
- Replanting and fencing measures must be taken according to the recommendations of the management plan. They must be documented.
- The management plan also defines an exclusion area (ASF) and three measure units (D2, D2, D3). The age structures of the individual measure areas defined, where replanting had priority. The highest urgency for replanting was assumed in measure area 1, the lowest urgency in measure area 3. Due to unfavourable environmental conditions and low prospect of success, no replanting effort should be wasted in the exclusion area.

Figure 3: *The LPA "Großer Ahornboden" in March 2022. Source: Author.*

2.2. The sycamore maple population at "Großer Ahornboden"

In the area of the Northern Limestone Alps, the sycamore maple (*Acer pseudoplatanus*) is a tree species typical for gorge and mixed forests at altitudes between 1000m to 1500m a.s.l. It often can be found associated with beeches or oaks (Erwald, 1997). Otto (1994) assigns it to the tree species with a high ecological potency. *Acer pseudoplatanus* tolerates various site factors and is resistant to biotic and abiotic hazards to a high degree, but it has high demands on nutrients, soil moisture and quality (Schmidt, 2009, p. 13). Some background-knowledge is important to assess the attributes in the tree cadastre, to draw conclusions from potentially recognisable patterns in population changes, and for the assessment of tree vitality. Therefore, in the following, the sycamore maple in the environment of "Großer Ahornboden" will be described in more detail.

2.2.1. Phenology, biology, and biotic agents of the sycamore maple (*Acer pseudoplatanus*)

Acer pseudoplatanus is classified as a semi-shade tree species (Pasta et al., 2016). While it tolerates shade in youth (Brosinger & Schmidt, 2009a, S. 20; Schmidt, 2009), its need for light increases and is high when old (Konrad et al., 2021). The structure of the sycamore maple population at "Großer Ahornboden" meets these requirements. Its characteristic feature is loose, single-layered stands alternating with areas that are treeless. Only at two places the tree population is locally denser and forest-like. Old solitary sycamore maples are often imposing "tree personalities" that own a mighty, uniformly round to dome-like crown and are 30 to 40 metres high (Schmidt 2009, p. 13). In the literature, the physiological age limit of sycamore maples is about 500 years, depending on site conditions (Roloff & Schmidt, 2009). *Acer pseudoplatanus* therefore is classified as medium- or long-lived tree species (Schmidt 2009, p. 13). A large part of the sycamore maples seems to be already 300 to 600 years old and thus at the natural age limit (Schreiner, 2004).

According to Brosinger & Schmidt (2009b), old and free-standing sycamore maples in particular fructify every year. Their fruits are characterised, among other things, by high abundance, germination capacity and flight ability, which means that usually even only a few single trees are sufficient for a natural regeneration of larger areas (Brosinger und Schmidt 2009, p. 20). Browsing by game, however, is a serious danger for sycamore maples (Alpenpark Karwendel, 2005; Brosinger und Schmidt 2009, p. 19). Additionally, at "Großer Ahornboden" grazing cattle is counteracting natural regeneration. Although the sycamore maple, other than the fir, often survives browsing damage, the natural regeneration of the sycamore maple population at "Großer Ahornboden" seems futile for the reasons mentioned (Höllerl & Mosandl, 2009, p. 27) and must be promoted by targeted replanting. *Acer pseudoplatanus* is well suited for the reforestation of bare areas (Brosinger und Schmidt 2009, p. 20). To succeed, accompanying measures such as adapted cloven-hoofed livestock, fencing of individual trees

and control of the accompanying vegetation must be applied (Brosinger und Schmidt 2009, p. 20). Although young trees have a strong competitive power against accompanying vegetation, on grasslands, mice or other rodents do them harm (Brosinger und Schmidt 2009, p. 20).
October 1981, a review of the sycamore maple population showed that "in branch forks, partly directly on the trunk and especially at sites of former wounds, [there was] a heavy fungal infestation" (Schreiner, 2004). The spread of red pustule disease (*Nectria cinnabarina*) and of tree cancer (*Nectria galligena)* led to a "moderate success of the plantings" (Schreiner, 2004). 1988, roughly 40% of the young trees were ill. On older trees, the tar spot disease and the white spot disease are particularly noticeable (Brosinger & Schmidt, 2009a, S. 20). Another decisive factor for the success of plantings is the provenance of the seeds. If possible, seeds from mother trees from the region should be selected. They guarantee resistance against fungal infestation and adaption to the alpine climate. Suitable planting material that complies with the recommendations for forest reproductive material is sufficiently available at the plant camp in Bad Häring.

2.2.2. The sycamore maple population and abiotic site factors at the LPA "Großer Ahornboden"

Geology

In general, the sycamore maple can develop a rather strong deep growth in soils affected by backwater (Hoffmann). Waterlogging, however, has a strongly negative influence on its vitality, because toxic metabolic products accumulate in the tissue (Macher, 2009, p. 35).
In the literature, fresh to moist, loose, deep-rooted, fine-textured soils rich in nutrients and bases provide for ideal growing conditions (Aas 2009, p. 8). *Acer pseudoplatanus*, however, also thrives on well-moistened scree soils (Brosinger & Schmidt, 2009a, S. 19). Less advantageous are heavy clay soils, pure sandy soils, and shallow, dry rendzinas (Brosinger & Schmidt, 2009a, S. 19).
At "Großer Ahornboden", four main soil types can be identified: Gravel raw soil, protorendzina, gauzy rendzina and oligotrophic brown soil (brown loam) (Figure 4). In the northern part of Enger Valley, a moraine reservoir developed after glacial retreat (Mair et al., 2016; Schreiner, 2004), in which a sandy clay layer of up to three metres has deposited.

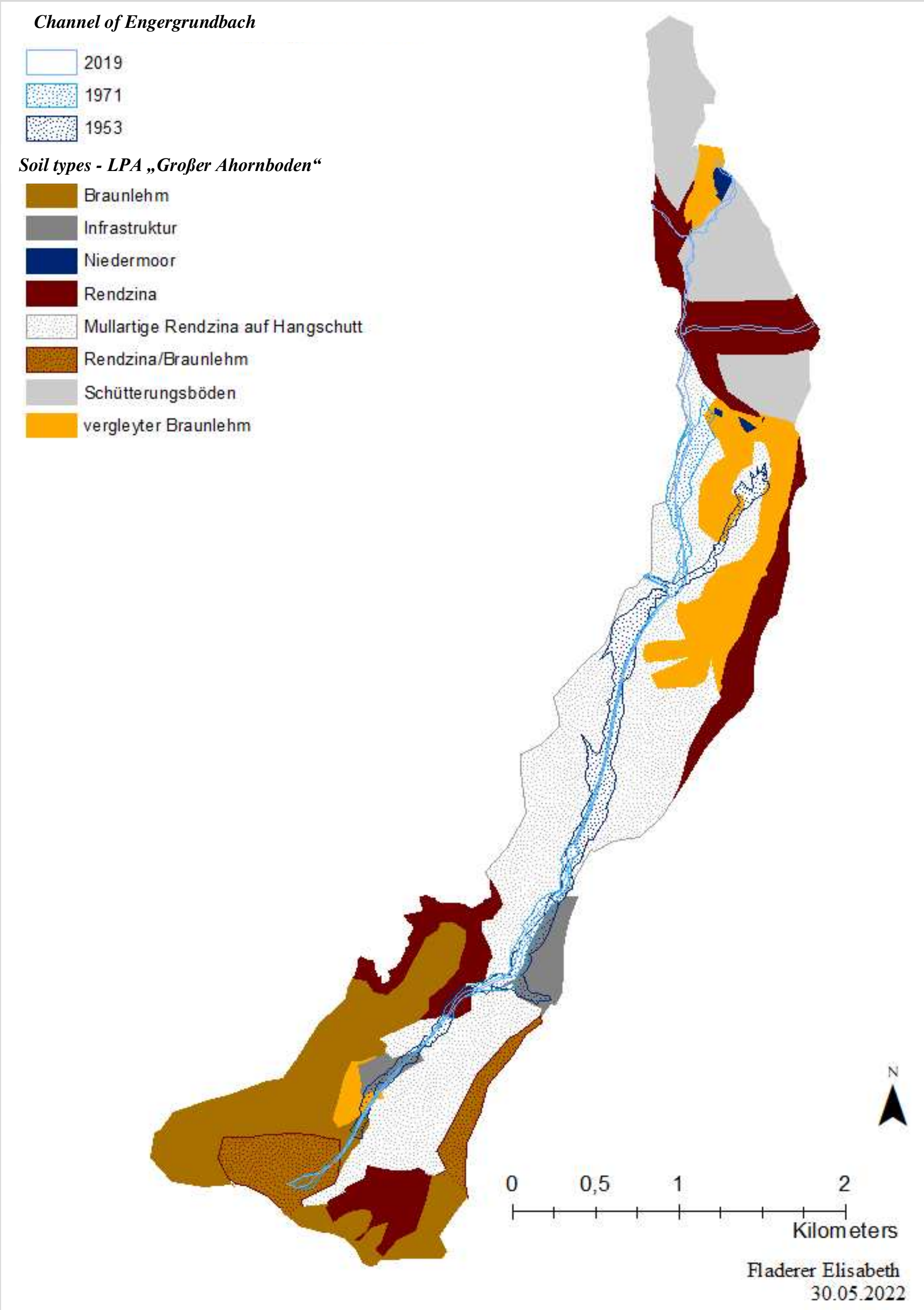

Figure 4: *Soil map of the study area "Großer Ahornboden" and the course of Engergrundbach in 1953, 1974, and 2019 (Braunlehm = brown loam; Niedermoor = fen; Schütterungsböden = gravel raw soil; mullartige Rendzina auf Hangschutt = fine-grained sediments, buried by gravel; vergleyter Braunlehm = clayey silt). Source: Author following Munk (2006) in Tappeiner (2007).*

More recently, during the last 1500 years, the thickness of the sediments at "Großer Ahornboden" has increased by about five metres. The last massive material supply by debris flow took place about 1550 AD. To some extent, it changed the hydrological conditions and the stratification of the soil since the growing of the first sycamore maple population (Schreiner, 2004). Research showed that some sycamore maples are overburdened up to 1.20 metres. The sycamore maples at “Großer Ahornboden” have adapted to such soil conditions. Their heart sinker root system (Aas 2009, p. 12) even in a compacted subsoil horizon still reaches great depths by developing advetitous roots. The ability of developing such roots is also described by Köstler et al. (1986) and Nordmann (2009). They observed that sycamore maples can “develop two rootstocks on rubble layers. One in the loose topsoil and one in the subsoil that has a greater supply of nutrients and water.” Although old trees have adapted to the prevailing conditions, seedlings and young trees are negatively affected by the poor water retention capacity and the low nutrient content of the scree and gravel masses. Even though the seedling root of young sycamore maples shows extraordinarily strong deep growth and reaches up to five decimetres already in its second year (Kösterer et al. 1986), in juvenile stage their roots cannot pass the thick sediment layer to reach the clay soils and brown loam (Czell et al., 1966; Schreiner, 2004, p. 13). To minimise the effects of the frequent overmudding and overburdening of valuable pastures, in 1960 technical measures were taken. “The stream regulation of Engergrundbach [had] already changed the landscape substantially [in 2001]“ (Schreiner, 2004). It can be assumed that this intervention had its impact also on the hydrological conditions (Appendix I/Figure 1).

Climate

The climate of the survey area is described as temperate, in the mountains cool, humid and with a distinct cold season, large amounts of snow and high precipitation (Wallner & simon, 2019). The region around Rißtal in terms of humidity is strikingly favoured because it lies north of the main mountain range where high precipitation air flows in (Czell et al., 1966). Due to the accumulation of wet air at the northern edges of the mountain range and fostered by the high altitude of most areas, rather cool and moist summers and long snow-rich winter conditions prevail. As visible in figure 5 the greatest amounts of precipitation fall in June, July and August and correspond to the warmest month in the “eastern northern Alps“ (Czell et al., 1966). The average annual area precipitation at *“*Großer Ahornboden*”* ranges between 1400 and 1800 mm/m (Appendix I/Figure 2). On average, snow cover duration lasts about five months (Czell et al., 1966) and the mean snow height is approximately two metres. At “Großer Ahornboden”, the daily mean temperature is around 5°C. Frosts can occur from September to June. Temperature maxima have a high amplitude, they range from -30°C in the winter (Czell et al., 1966) to around 32°C in the summer (Tappeiner, 2007b). Climate change might have changed this data to some extent. Sycamore maple is a characteristic representative of deciduous broadleaf forests in the nemoral zone with a climate tolerance like beech (Brosinger und Schmidt 2009, p. 22). *Acer pseudoplatanus* can often be found in upland or mountainous areas around 1700m a.s.l. (Macher, 2009, p. 33) and grows “particularly well in the cold“ (Roloff, 2009). It is a tree species relatively tolerant of late frost (Brosinger & Schmidt, 2009a, S. 20) and well adaptable to summer warmth and winter cold after a sufficiently long vegetation period. Sycamore maples growing in low mountain ranges will probably profit from climate change. On the one hand, the assumed longer vegetation period will be favourable (Roloff, 2009), on the other hand, longer dry periods can be expected more often, while there will still be cold snaps and frost in the winter (Brosinger & Schmidt 2009, p. 22).

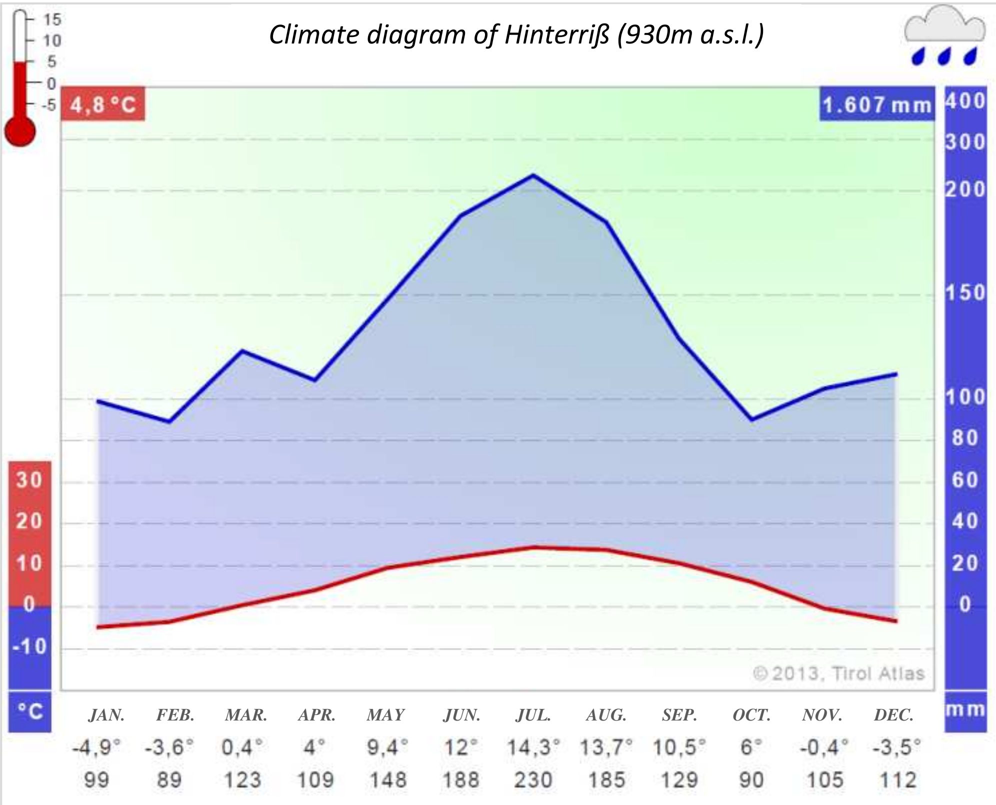

Figure 5*: Climate graph of Hinterriß, Tyrol. Monthly mean temperature (in °C) and monthly mean precipitation (in mm) during the climate period 1980-2001 in the Riß Valley: Wet, hot summers and cold, dry winters. Highest mean precipitation rates of 185–230mm per m² in combination with highest mean temperatures of 12–14,3 °C during June, July, and August. Source: Tirol Atlas 2013.*

3.1. Data and software

3.1.1. Orthophoto

The orthophotos used in this thesis were provided by the Geoinformation Department of the province of Tyrol (Figure 6; Table 2). The most recent aerial photographs of the survey area date from 2019 and are therefore the best reference for the current state. The 2001 orthophotos were used for cross-validation of the last complete survey of the tree population. Due to a shadow cast by the mountains bordering to the east some sycamore maples could not be identified. For these trees, 2016 orthophotos were used, where shadowing was no problem. Additionally, historic orthophotos (1953, 1974) were included in the analysis.

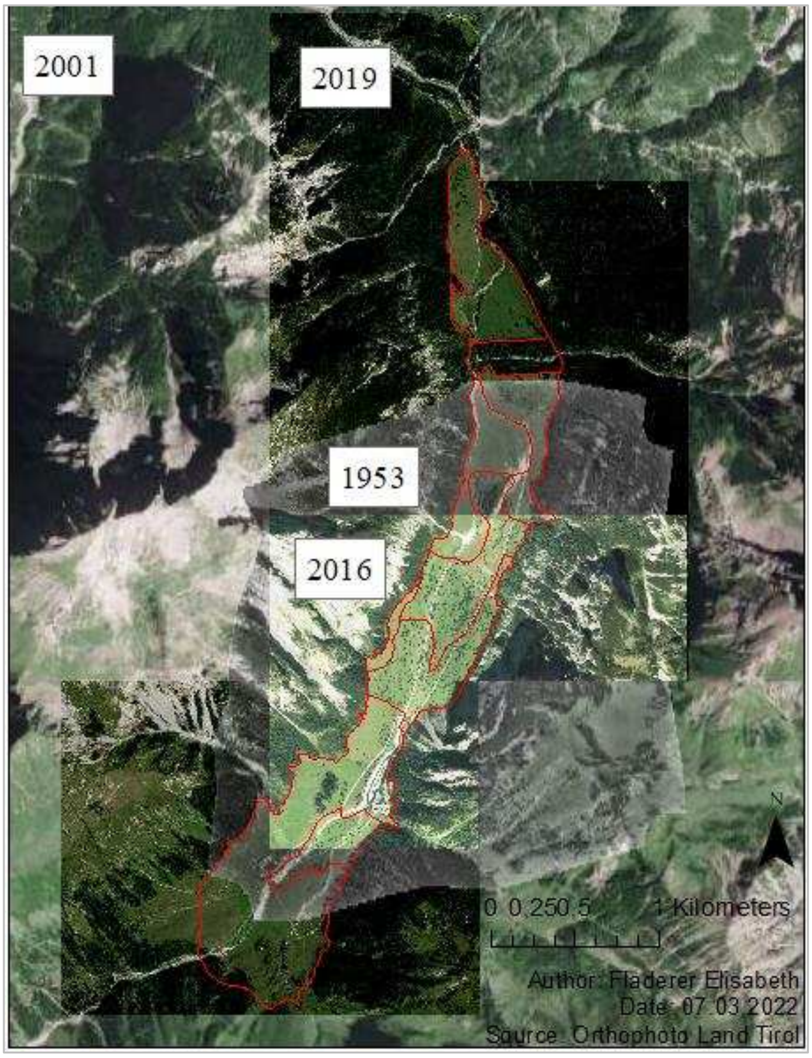

Figure 6: *Spatial extent of the orthophotos used. In red, the landscape protection area "Großer Ahornboden". Source: Author. Orthophoto Land Tirol.*

Table 2: *Metadata of the orthophotos used. 1953 and 1974 aerial photographs are available as black-white images (BW). For all other years, true-colour (RGB) images at disposal; the most recent orthophoto is also available in colour-infrared (CIR). Source: Land Tirol.*

Acquisition year of orthoimage	Resolution (m)	Colour	Number of tiles	Source
1953	0.2	BW	1	Free Orthophoto WMS, Land Tirol
1974	0.2	BW	1	Free Orthophoto WMS, Land Tirol
2001	0.2	RGB	1	Free Orthophoto WMS, Land Tirol
2005	0.2	RGB	1	Free Orthophoto WMS, Land Tirol
2009	0.2	RGB	1	Free Orthophoto WMS, Land Tirol
2013	0.2	RGB	1	Free Orthophoto WMS, Land Tirol
2016	0.2	RGB	3	Orthophoto of the Geoinformation Department, Land Tirol
2019	0.2	CIR	1	Free Orthophoto WMS, Land Tirol
2019	0.2	RBG	11	Orthophoto of the Geoinformation Department, Land Tirol, free download application

3.1.2. Laser data

The most recent laser data (Table 3) of the study area was collected between August and October, 2020. The laser scanner Riegl VQ-780II was mounted on the a Diamond Aircraft DA 42. The airborne survey produced a total of 24 flight legs and was performed on 6 days at medium absolute flight heights of 2200 m to 3200 m above the ground and an average flying speed of max. 67 m/s. The ALS was operated with 1.230 kHz scan rate. Data were registered by the data provider province of Tyrol in the coordinate system UTM32/ETRS89 (EPSG:25832).
The resulting laser point cloud consists of an average echo density of at least 31 points/m2. (± 10 standard deviation) According to Hellesen and Matikainen (2013), a density of two points/m2 can be sufficient for the detection of individual trees. The data used is well above this threshold. Data was collected in autumn. Therefore, full LAI can not be assumed. The accuracy of the used ALS data from 2020 is around ±10 cm for height and ± 20 cm for the location. The height accuracy is sufficient to characterise and detect even young sycamore maple trees.

Table 3: *Overview of the most recent laser data covering the area of "Großer Ahornboden". Source: Land Tirol.*

Acqisition dates	Coord. syst.	Point density	Flight height	Source
2020-08-25 2020-09-04 2020-09-05 2020-11-10 2020-11-11 2020-11-12	ETRS89	Achieved: 31 pt/m^2 Requiered: 8 pt/m^2	~2200m - 3200m	Land Tirol/Department of Geoinformation

3.1.3. Acquired data - tree register and management units

When recording the original tree population dataset (Table 4), all sycamore maples were noted as point features and assessed regarding their age and size. Supplementary information had also been included into the data sets, where appropriate. Also, each tree was assigned a number

(*Ahorn_ID*) to avoid confusions. In subsequent years, the original data set was extended to include replanting (Table 5).

Table 4: *Overview of the meta data of the tree cadastre 2001 (Ahorn_gdb) and the management unit dataset (ahornboden_maßnahmenfl). The 2001 tree cadastre contains information about the tree population in 1953 and 2001 (Table 5); the management units define, where replanting had priority. Source: Land Tirol.*

Name	Feature class	Feature type	Coordinate system	Number of features
Ahorn_gdb	Geodatabase	point	Austria GK West Zone	2962
ahornboden_massnahmenfl	ESRI shapefile	polygon	Austria GK West Zone	4

Table 5: *Relevant information stored in the attribute table of the tree register 2001. Source: Schreiner (2004), Land Tirol.*

Abbreviations: AHORN_ID=*Unique tree identification code;* ALTER53=*estimated age group, 1953;* ALTER00=*estimated age group, 2001;* GROESSE53=*estimated size class, 1953;* GROESSE53=*estimated size class, 2001;* BEMERKUNG=*additional information;* PFLANZUNG=*acronym including the consecutive number and the year of a planting.*

···	AHORN_ID	ALTER53	ALTER00	GROESSE53	GOESSE00	BEMERKUNG	PFLANZUNG	···

3.1.4. Field data

Tree-physiological measurements and information about vitality-reducing safety defects were gathered in leaf-off conditions between 28 April and 11 May 2022. Data was obligatory registered for all sample trees (3.3.) and occasionally for all other trees if relevant attributes were noticed. For the field inspection, the primary attribute table resulting from the orthophoto analysis and laser data analysis was supplemented by further parameters (Table 6). These are potentially ecologically relevant or informative in terms of vitality. Columns with content overlaps were summarised. Where possible, drop-down selection fields were included in the application QField to ensure a uniform data entry and time-efficient working in the future. Furthermore, the X and Y coordinates of each tree were noted to ensure that each tree can unambiguously be located even with a weak GPS signal of the smartphone. The localisation was done with a Garmin and a sports watch Suunto Ambit (location setting).

Table 6: *Overview of the variables collected in the field survey.*

Variable	Unit	Measurement principle
Coordinates (X, Y) of individual sample trees	m (WGS84 coordinate system)	Non-differential GPS. Used in case of poor GPS reception.
Diameter at breast height (DBH), perimeter	cm	Calliper, measuring tape
Tree height and crown height	m	Ultrasonic measurement with *VERTEX III*
Crown width	m	Measuring tape. Mean of two perpendicular measurements.
Data about field survey, tree type and tree attributes (indicating vitality, ecological value, and relationship with neighbouring trees)	---	Using the assessment key proposed in this study.

3.1.5. Programmes used for data processing and evaluation

The software ArcMap (Version: ArcGIS Desktop 10.8, ESRI©) was used in this thesis for storing the information about each maple trees as a point feature, exploring intermediate results from the orthophoto interpretation, analysing and processing vector and raster data, and for the visualisation of the results. Laser data was explored by using ArcGIS Pro. In preparation of the field work, ArcGIS data were imported to QGIS (www.qfield.org). To collect data in the field survey and for site localisation, the mobile application QField was used which is a freely accessible extension of the GIS programme QGIS. Statistical analysis was conducted with SPSS and Statistica.

3.2. The 2022 survey of the tree population at "Großer Ahornboden" and the detection of changes since 2001

Figure 7 shows the workflow of the generation of the 2022 tree cadastre. The individual steps are described in detail in the following section.

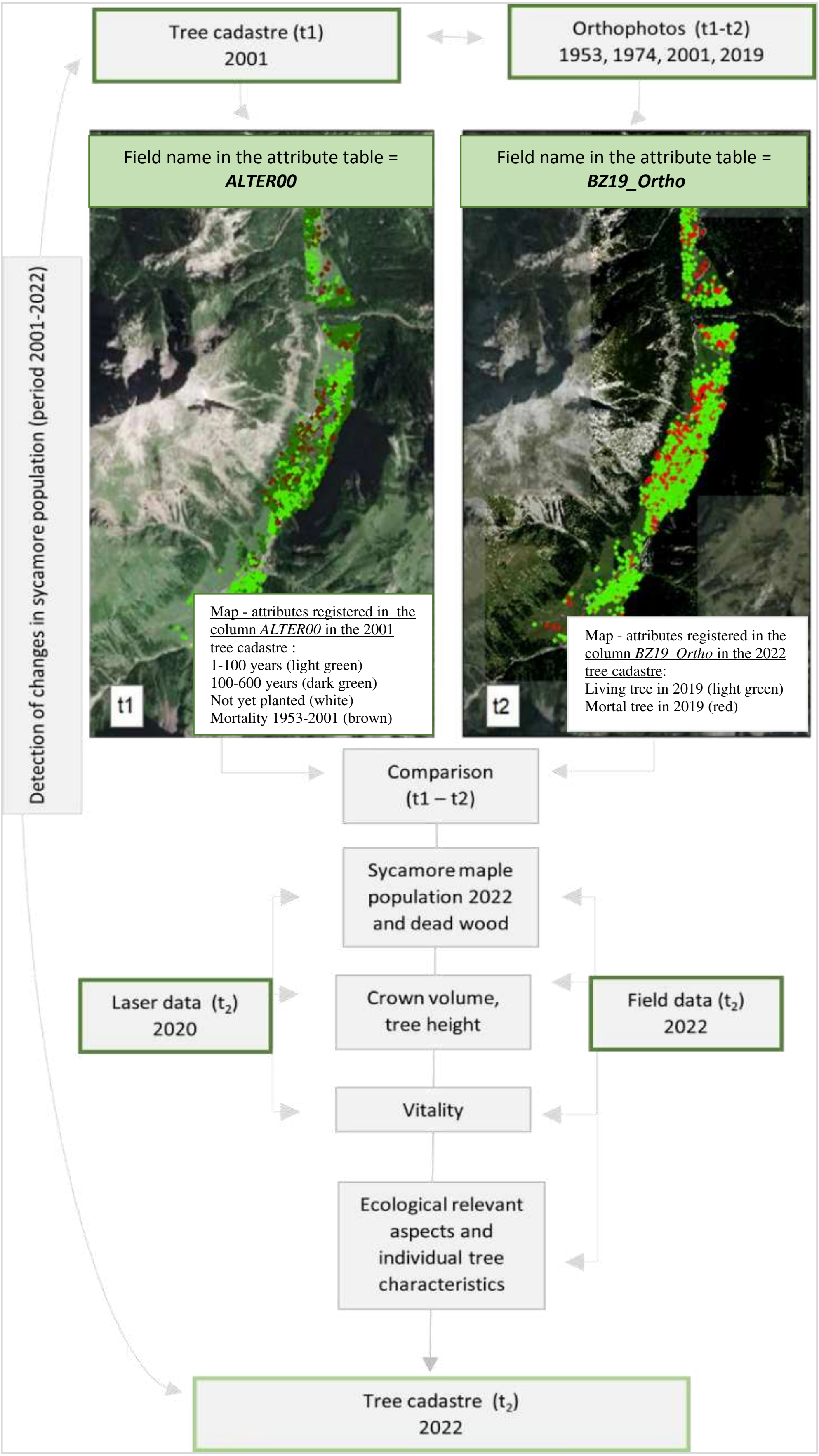

Figure 7: *Workflow for the tree cadastre of the sycamore maple population in 2022 at "Großer Ahornboden" (light green). The 2001 tree cadastre, available orthophotos, laser data and field data served as input (dark green). Finally, changes in the number of sycamore maples as well as the age-class distribution were detected by comparing the population at timestep 1 (t_1=2001) with the population at timestep 2 (t_2=2022). Source: Author. Orthophoto Land Tirol.*

Abbreviations: ALTER00=*Field name; this column of the attribute table of the tree cadastre contains the estimated age of a sycamore maple (young tree: 1-100 years; middle-aged and old trees: 100-600 years);* BZ19_Ortho= *Field name; this column of the attribute table of the tree cadastre contains the tree condition according to interpretation of the othophoto of 2019 (alive or dead).*

3.2.1. Comparative orthophoto interpretation

The survey of the current tree population at “Großer Ahornboden“ is based on a comparative interpretation of the aerial photos of 2001 and 2019. Its methodology is guided by that of the survey carried out in the framework of the 2005 MMP.

First, the existing tree cadastre, in which the sycamore maples were registered as point features, was loaded into ArcGIS. Second, it was reviewed by using the 1953, 1974, and 2001 orthophotos. Third, the reviewed and revised tree cadastre was superimposed on the 2019 aerial image. Fourth, each tree registered in the cadastre was checked for its existence in 2019.

In addition, the individual shapes and sizes of the shadows allowed for presumptions about the general condition, the species, and the height of the trees. The results of the interpretation of the 2019 orthophoto were included into the attribute table of the tree cadastre which, therefore, was extended by two columns. For the field work, the 2019 condition of a tree (*BZ19_Ortho*) as well as information to be checked or helpful *(BEMERKUNG)* within laser data analysis or during field work were each noted in a column. Table 7 shows the individual attributes and notes used.

Table 7: *Attributes used in this master thesis to describe the tree condition in 2019 (*BZ19_Ortho*) according to the orthophoto interpretation are shown (far left column of table 7). In the column* BEMERKUNG *of the attribute table of the 2022 tree cadastre information to be checked or helpful for subsequent steps were noted. The meaning of the expressions used are more accurately described in the explanation of the columns. Source: Author; designations following those of the 2001 survey.*

BZ19_Ortho	*Explanation*	**BEMERKUNG**	*Explanation*
i	*Intact:* *In the data base of the survey 2001 recorded and on the 2019 orthophoto clearly identifiable.*	**Number**	*The orthophoto gives the impression of two or more trees at this location.*
		Stream bank	*Engergrundbach*
		Tree species OR N?	*Suspicion: Coniferous tree?*
		Size	*Check! Strong deviation of the attribute assigned to in 2001.*
		Condition	*Check tree vitality!*
		<NULL>	*Undoubtedly.*
i16	*Identifiable on a 2016 orthophoto. Not identifiable on a 2019 orthophoto due to shadow cast of the mountains in the east.*	**See remarks “i“**	---
Z	*Mortality:* *1) “z“ verified according to 2001 survey OR* *2) 2001 identifiable and meanwhile dead.*	**Dead wood**	*Tree stump or dead wood identifiable on the orthophoto.*
		<NULL>	*Undoubtedly.*
P	*Check:* *1) According to the data base, tree is existing, but cannot be checked on current aerial photo OR* *2) tree is registered in the data base, but it is not possible to assign the data set clearly to a certain tree on the orthophoto*	**Shadow**	*In the shadow cast of another tree or of the mountains, could not be identified on the 2016 orthophoto either.*
		Unclear	*The site conditions make it impossible to distinguish the tree crowns from the environment.*
		Classification	*Clear assignment of a sycamore maple ID is not possible.*
		<NULL>	
N	*Coniferous tree*		

For both better transparency and distinctness, the identification code was used to categorise the trees (Table 8). Point features with a number starting from 1 to 5999 and 7000 to 7999 are trees, which are within the management unit of the LPA "Großer Ahornboden" and have already been recorded in 2001. A few of the ID numbers 1 to 5999 were occupied twice. In these few cases, the identification code of one sycamore maple was left the same. For the second tree, the ID was set to a number between 7000 and 7999 by changing the first digit. Trees that have been newly registered in this master thesis, were assigned to a sycamore maple ID between 8000 and 8999. Sycamore maples outside the measure areas can be identified by an ID between 6000 and 6999.

Table 8: *Description of identification codes. The ranges represent certain tree characteristics.*

Range of ID	**Description**
1-5999	Numbers that were in the original data base.
6000-6999	Trees outside the measure areas.
7000-7999	Sycamore maple ID number that was assigned twice. One of the trees gets a number between 7000-7999.
8000-8999	Supplement: Identifiable tree on the orthophoto; according to its shape it could be a sycamore maple but so far has not been registered in the data base.

3.2.2. Integration of laser data and field data into the orthophoto analysis – detection of the 2022 tree status and tree age

Laser data and field inspections served the purpose of verification of the set points with the aerial photo interpretation. All elements of the tree cadastre were double-checked both by laser data and in the field. Especially when point features in the tree cadastre could not clearly be classified by aerial images, laser data was accessed. When the laser data analysis did not allow for a clear assignment either, this was noted and clarified on site. The results regarding the tree status were registered in separate columns (*BZ_LAS, BZ1_Feld;* German: Baumzustand laut Laserdaten bzw. Feldbegehung) in the tree cadastre. For state designations, basically the same abbreviations were used as in the orthophoto interpretation (Table 7); for field recording, the cadastre was extended by "L" for deciduous tree (German: Laubbaum), by "Jp" (German: Jungpflanzen) for areas with a natural regeneration.
The latest recorded and corrected condition description of each sycamore maple was registered in the column „*BZ22*" (German: Baumzustand im Jahr 2022). Dead trees are registered either as "z" (dead since 2001) or "zz" (dead before 2001). The latter were left as such in the data set to locate areas with a potentially higher mortality rate during a longer observation period.

Tree age was estimated in the field for some trees and registered in the column *AL_Feld* (German: Alter im Feld beurteilt); the classification in the tree cadastre was taken over from the MMP. The age recorded by field work served as primary source for detection of the tree age in 2022 (column is named: *AL22;* German: Alter im Jahr 2022). But also, crown width and tree heights determined by laser data and orthophotos were used for an estimation as well as information about tree age.

3.2.3. Survey of changes in the tree population and the age structure between 2001 and 2022 by selecting a reference tree population

Changes in the age structure of the sycamore population

By combining each registered age-attribute in the column *ALTER00* (tree age 2001) with the corresponding attribute in column *BZ22* (tree condition 2022) changes in the tree population at “Großer Ahornboden“ could be determined. The combinations were noted in column *Vgl_0022* (German: Vergleich des Baumzustandes 2001 und 2022) in ArcGIS, figure 8 shows the corresponding illustration. Figure 9 shows an explanation of the graphs used to represent the results.

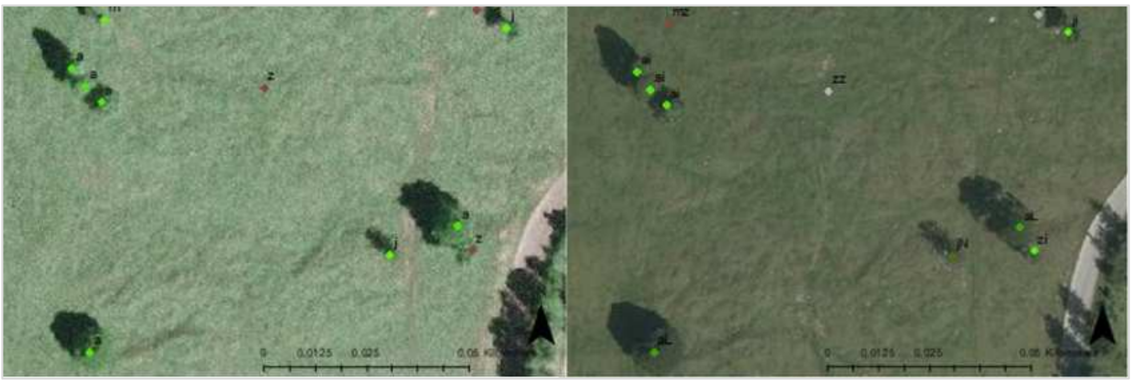

Figure 8: *The orthophoto of 2001 with assigned classification of the tree status in 2001 (left). The orthophoto of 2019 in combination with the tree status 2001 and 2019 (right). Source: Author. Orthophoto Land Tirol.*

Abbreviations: ai = in 2001 registered as an old tree (a) –in 2019 as vital (i); mz = in 2001 registered as middle-aged tree (m) –in 2019 orthophoto shows no tree (z); zz = in 2001 registered as dead (z) – in 2019 tree mortality is undoubted (z); jN= in 2001 registered as a young tree (j) - in 2022 identified as a coniferous tree (N).

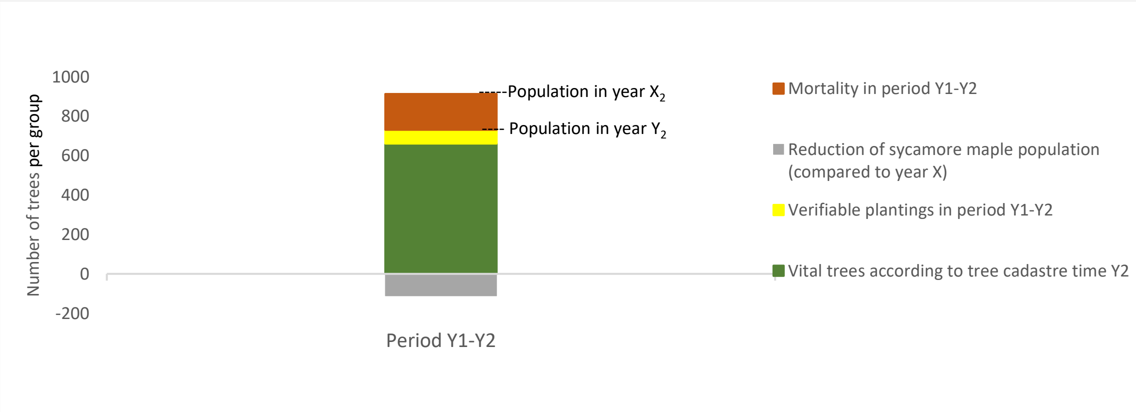

Figure 9: *Description of the graphs used to describe the changes in the sycamore maple population. Definitions: Population year X_2 – stock of population registered according to the last survey (1953 respectively 2001); population year Y_2 – stock of population in the period under consideration; Y_1 – first year of period under consideration; Y_2 – last year of the period under consideration. Source: Author following the MMP.*

Determination of a reference tree population to analyse changes

Table 9 shows the number of dead ("z") and vital trees ("i") for the time periods 1953-2001 and 2001-2022. Trees classified as "mortal sycamore maple" or "vital sycamore maple" are differentiated in table 9 according to old growth or new plantings for the respective periods. The MMP of "Großer Ahornboden" registered 2217[3] vital sycamore maples for the year 2001 (MMP 2005, p. 24). The exactness of it could not be verified within the framework of this master thesis - the recalculation resulted in 2782 sycamore maples for the year 2001. The difference of 565 trees ($\text{Difference}_{\text{Surveys}}=2782_{\text{Master thesis}}-2217_{\text{MMP}}$) for the sycamore population in 2001 arises mainly from the newly added point features within the framework of this master thesis (Table 15) and 165 points classified differently (Table 10).

Table 9: *Changes in the sycamore maple population at "Großer Ahornboden" in the periods of 1953-2000 and 2001-2022. The respective population stock for 1953, 2001, and 2022 is highlighted in grey. .*

	1953 – 2001[4]		**2001**	**2001 – 2022[5]**		**2022**
	i	**z**	**Total**	**i**	**z**	**Total**
Old stand	2080	-375	1705	2782	-426	2356
Replanting	+840	-328	512	+71	0	71
Total	2920	-703	2217[2]	2853	-341	2427

The formation of the reference tree cadastre is based on three main steps. First, elements outside the measure units have been removed from the 2022 tree cadastre. For a better comparability of the changes in the population, all sycamore maples that have been added in the framework of this master thesis were subtracted. Third, trees that in the 2001 data were assigned to other

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[3] *According to MMP (p.24) the number is 2218 sycamore maple; following the autor´s calculation the number is 2217 (MMP, p. 25: 11+ 501+ 25 + 50 + 109 + 7 + 191 + 14 + 1309 = 2217).*

[4] *The calculations for the period of 1953-2001 follow the MMP; the number of failures of replanting are based on the author´s calculations following the MMP.*

[5] *[3]The calculations for the period of 2001-2022 are based on the author´s data and recalculations.*

categories were aligned. In the 2001 cadastre for “Großer Ahornboden“ 87 point features were falsely negative classified as dead. 74 points were falsely positive classified as sycamore maples which in fact weren´t, these are 46 coniferous trees and 27 deciduous trees (Table 10). Considering the false negative and false positive elements, the total number of vital sycamore maples at ”Großer Ahornboden” of the reference data set only slightly increases from 2217 to 2240 trees for 2001 (Appendix 1/Table IV, Table 11).

Table 10: *Calculation basis for the reference population. Number of elements classified differently (false positive/negative) and elements that are consistent. Source: Author´s calculation based on MMP and own data.*

	Number of point features
False positive[6]	74
False negative[7]	91
Consistent	2124

Table 11: *Composition of the reference tree populations for the years 2001 and 2022.*

Abbreviations: i = vital ; n = not (yet) existent; zz = in 2001 already registered as dead; z = mortality since 2001; L/N = identified as a deciduous tree (L) or coniferous tree (N). Calculation of the stock in 2001 (2240 trees): Population 2022 + mortality 2001 to 2022 - new plantings since 2001. Source: Author´s calculation (details see appemdix1/table IV) based on MMP and own data.

Tree status / **Reference population**	**i**	**z**	**zz**	**n**	**N**	**L**	**Total number of features**
2001	2240	290	n.a.	71	47	30	2678
2022	1991	319	290	1	47	30	2678

6 *iL = 27, iN = 46, in = 1*

7 *zi = 87, zL = 3, zN =*

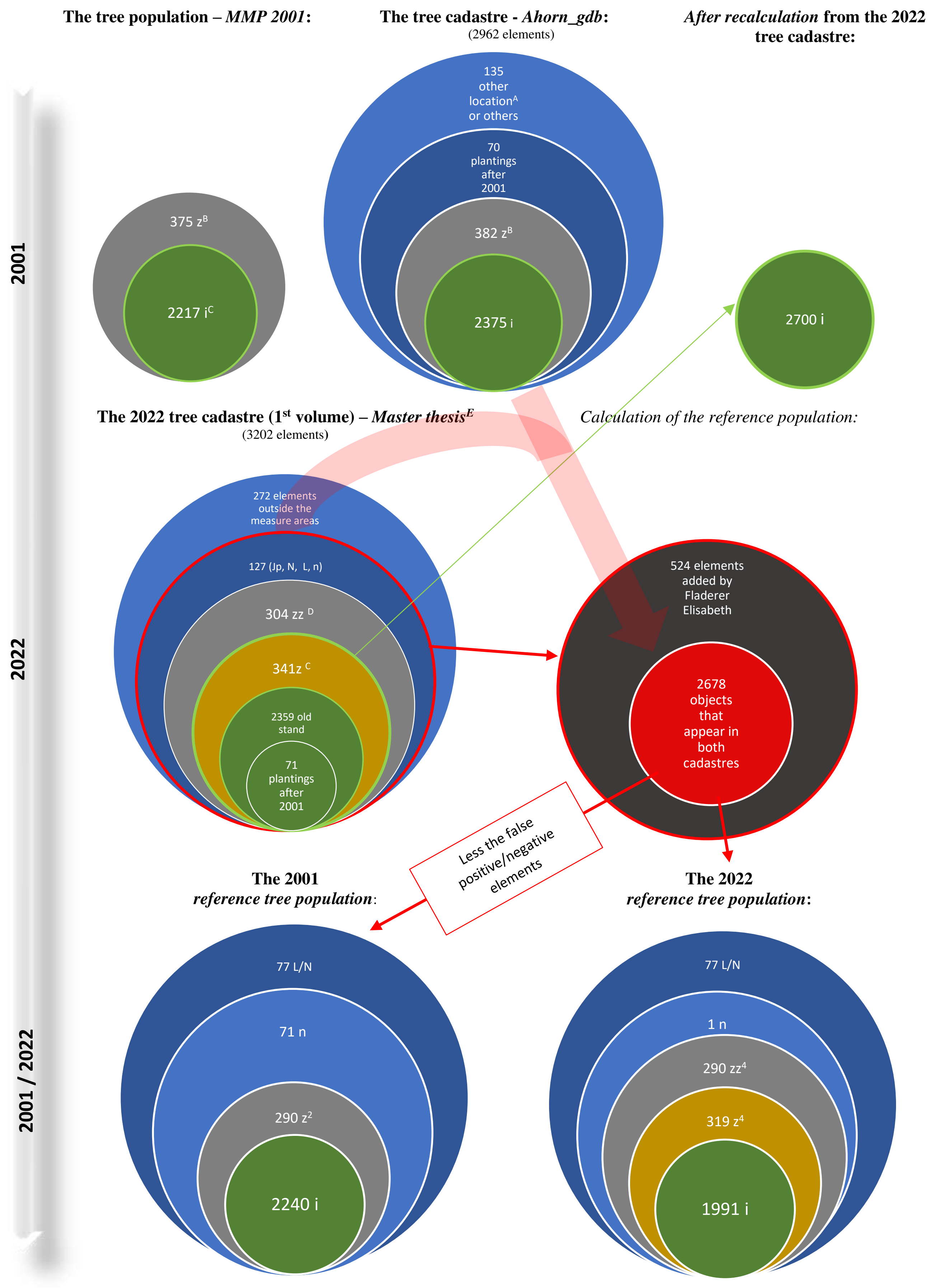
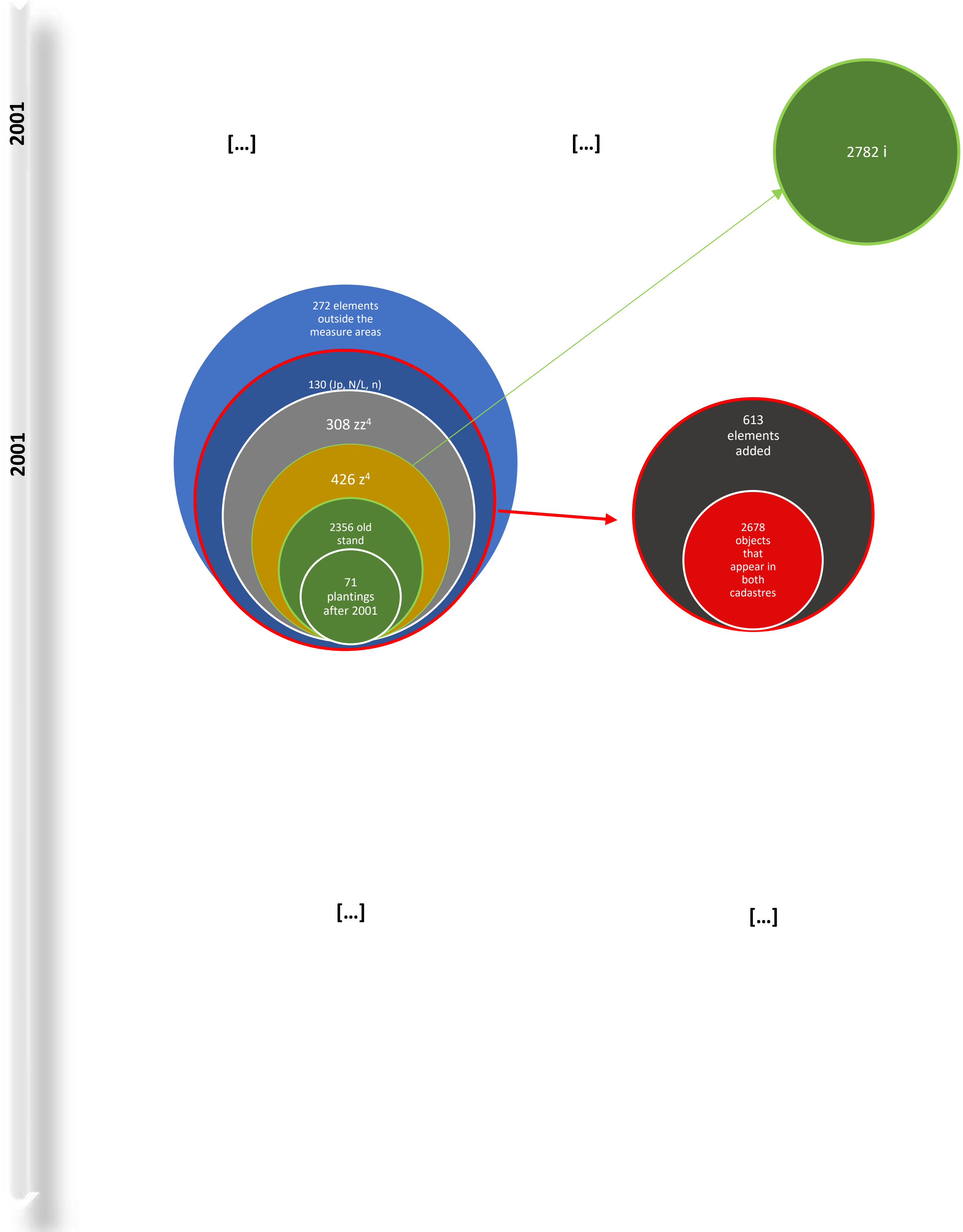


Figure 1: *Top left:The MMP registered 2218 sycamore maples for the year 2000; 375 sycamore maples had died in the period 1953-2000 (MMP, p. 24). Center: The original database, on which the inventory of this master thesis is based on, contains 2375 vital sycamore maple trees (column* ALTER00 *in the attribute table). Right: The exactness of these numbers could not be verified within the framework of this master thesis - the recalculation resulted in 2700 sycamore maples for the year 2001. Middle left: The 2022 tree cadastre contains 3202 elements (red circle). Middle/bottom: The formation of the reference tree cadastre is based on three main steps: 1) Subtraction of elements outside the measure units; 2) Elimination of all elements added within the framework of this master thesis; 3) Alignment of elements that have been classified differently in 2001. Source: Author.*

[A] *Other location = Kleiner Ahornboden or Kleinkristental; others = additional elements (f.e. B65)*
[B] *z = Mortality 1953-2000*
[C] *2218 (MMP, p. 24); 2217 (MMP, p. 25)*
[D] *zz = = Mortality 1953-2000; z = Mortality 2001-2022*
[E] *The 2022 tree cadastre (1st volume) contained 3202 elements before the follow-up visit and renewed analysis of the trees registered as dead according to the 2022 tree cadastere in order to detect trees which may have died unnaturally. The* ***revised 2022 tree cadastre*** *containes 3291 elements (left, red frame), the* ***common intersection*** *of the original database (ahorn_gdb) and the revised 2022 tree cadastre on which the calculation of the reference population is based on (middle, red cycle) and the number of vital sycamore maples in 2001 after* ***recalculation from the revised 2022 tree cadastre*** *(right).*



3.2.4. Trees classified as dead - elimination and verification of features

After the completion of the data processing and data evaluation, new questions arose with regard to the trees classified as dead and a revision of the 2022 tree cadastre (1st volume with 3202 registered objects) was conducted. Therefore, this group of trees was looked at again more closely. Also, there was an additional field inspection where the attention was focused only on trees registered as dead or their remains.

For reasons of complete traceability of tree mortalities, all aerial images available were considered in the evaluation (1953, 1974, 2001, 2005, 2009, 2013, 2016,2019). For all traceable mortalities between 1953 and 2019, the expression "verifiziert" (English: verified) was noted down in the column *z_test*. Also, the year of the orthophoto on which the sycamore maple was identified as still existent and the year of the orthophoto on which a mortality was detected was recorded in an extra column (*z_test_anm*; German: Anmerkung zur Spalte *z_test*) of the attribute table. If it was impossible to make a secure statement if the tree had ever existed, this was also noted in the tree cadastre (*z_test*="Existenz fraglich").

The field control work was conducted in systematic searching by walking up and down in parallel stripes in eastern western direction. The method aimed at tackling the risk of overlooking any sign of a dead tree. A significant need for field validation was given for two reasons. First, sometimes a tree was registered as dead in the 2022 tree cadastre (*BZ22:* "z" or "zz") but the orthophoto interpretation could not make a reliable statement if the tree had ever existed (*z_test*="Existenz fraglich"). Second, identifying if the tree had been felled or the stump had been removed or the tree had died naturally. If any verifiable proof could be found in the field to substantiate one of the just mentioned cases, it was noted in the column *BZ2_Feld*. The abbreviations used to note potentially found remnants of a tree as well as associated explanations are shown in table 12.

***Table 12**: Excerpt of the relevant columns (*BZ22, z_test, z_test_anm, BZ2_Feld*) of the 2022 tree cadastre and their respective attributes used to double-check the registered tree mortalities.*
In the column z_test *of the attribute table all mortalities between 1953-2019, traceable by orthophoto interpretation, are equipped with the expression "*verifiziert*"; the year of the orthophoto on which a sycamore maple was identified as still existent and the year of the orthophoto on which a mortality was detected is recorded in the column* z_test_anm*. If it was impossible to make a secure statement if the tree had ever existed, the expression "Existenz fraglich" can be found in the column* z_test *of the 2022 tree cadastre. The column* z_test *contains the expression "verifiziert im Feld" if any verifiable proof could be found in the field to substantiate one of the just mentioned cases; then in the column* BZ2_Feld *the type of evidence (2011, Entf., DS, WS, n.a., Sonst.) is also noted.*

BZ22	z_test	z_test_anm	BZ2_Feld	
			Abbreviation	**Explanation**
z *OR* *zz*	***1. Verifiziert im Feld***	*[year]i; [year]z*	*2011*	It is assumed the tree had been felled in 2011.
			Entf.	There exists a reasonable suspicion that the stump had been removed.
			DS	Standing dead tree or trunk >1,3m
			WS	Tree stump; tree died of natural causes.
			n.a.	There is no evidence of a (living or dead)tree.
			Sonst.	Other forms of evidence that there has been a tree (local depression/elevation e.g.)
	2. Verifiziert	*[year]i; [year]z* *[year]i;[year]DS*	Remarks and explanations see "verifiziert im Feld"	
	3. Existenz fraglich	*[year,year] not* *???* *[year]?*	*Sonst.* *n.a.*	Explanations see "verifiziert im Feld"

3.2.5. Selection of sample trees

Although tree-physiological parameters can directly be measured from laser data, appropriate field data are required for reasons of calibration, refinement, and validation. For the validation of the laser data measurement, only vital (attribute "i") trees were selected as reference trees from the statistical population. The statistical population is the result of the orthophoto interpretation. The number of sample trees was set at two hundred. Trees were selected proportionately to the population of the four management units (Table 13/Step 1): n1=986 trees in measure area 1, n2=771 trees in measure area 2, n3=376 trees in measure area 3, n4=200 trees for the exclusion area (ASF). In the next step (Table 13/Step 2), the age structure of the sycamore maple population of the individual measure areas was defined, then the age class distribution was transferred to the individual strata (D1, D2, D3, ASF) (Table 13/Step 3). Finally, the sample trees in each subpopulation were almost randomly selected using the tool "create random points" in ArcGIS (Figure 11).

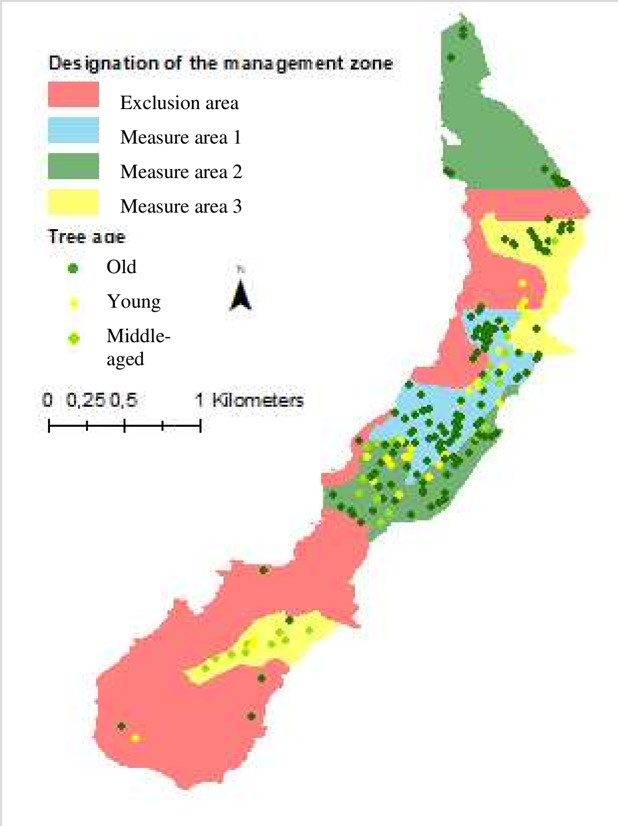


Figure 11: *Selected sample trees (n=200) differentiated per age class and measure area after using the tool "create random points" in ArcGIS. Measure areas and colouring following the MMP. Source: Author.*

Table 13: *Calculation of the 200 sample trees. The total number of vital sycamore maples (SM) after the orthophoto interpretation is congruent to the statistical population (N=2315). The last row shows the number of sample trees per age-class and measure area (m. area).*

Step 1: Selection of sample trees per measure area																	
Measure area	D1				D2				D3				ASF				Total
SM./m.area (absolut)	968				771				376				200				2315 (SM)
SM/m. area (%)	42				33				16				9				100 (%)
Sample trees /m. area	84				66				32				18				200 (Sample trees)
Step 2: Proportion of sample trees with respect to the age structure in the measure areas (p = planting; y.= young; m = middle-aged; o.= old)																	
Age-class	p.	y.	m.	o.	p.	y.	m.	o.	p.	y.	m.	o.	p.	y.	m.	o.	
SM/Age-class (absolute)	70	98	31	769	0	234	8	529	0	162	24	190	0	129	9	62	2315 (SM)
SM/Age-class (%)	7	10	3	80	0	30	1	69	0	43	6	51	0	65	4	31	100 (% per m.area)
Step 3: Number of selected sample trees per area and age class																	
	6	8	3	67	0	20	0	46	0	14	2	16	0	12	1	5	200 (Sample trees)

3.3. Determination of structural tree parameters of the sycamore maples

3.3.1. Field measurements

Tree measurements included tree height, tree crown width and height, and tree stem diameter at breast height (DBH). Tree height and crown height were measured by using a hypsometer (Haglöf Vertex IV; www.haglofcg.com, Figure 12). The average crown width was derived from two perpendicular measurements with a measuring tape to account for crown asymmetries. DBH up to 65 cm was measured using a calliper (Figure 12). If the DBH was larger than 65cm, the perimeter was measured by using a measuring tape. The conversion of the measured stem circumferences was done online with a circular calculator (Kummer, 2022).

Figure 12*: Instruments used for hight amd DBH measurements. Source: Author.*

3.3.2. Measurements derived manually from laser data

Tree heights have been assigned to all sycamore maple trees in the sample data set. Therefore, the point features of all trees were uploaded together with the laser-point-cloud in ArcGIS Pro. The point cloud was displayed in the profile view, as shown in figure 13. Using the measuring tool, tree heights were extracted and registered in the tree cadastre. The same was done for crown heights.

Crown parameters were extracted from the laser point cloud for all sample trees. Crown width was manually measured in N-S and E-W direction with the measuring tool in ArcGIS Pro. Then, the mean was calculated, and the value assigned to the attribute table. To determine the crown length, the point cloud was viewed in the profile view, as described for tree height extraction.

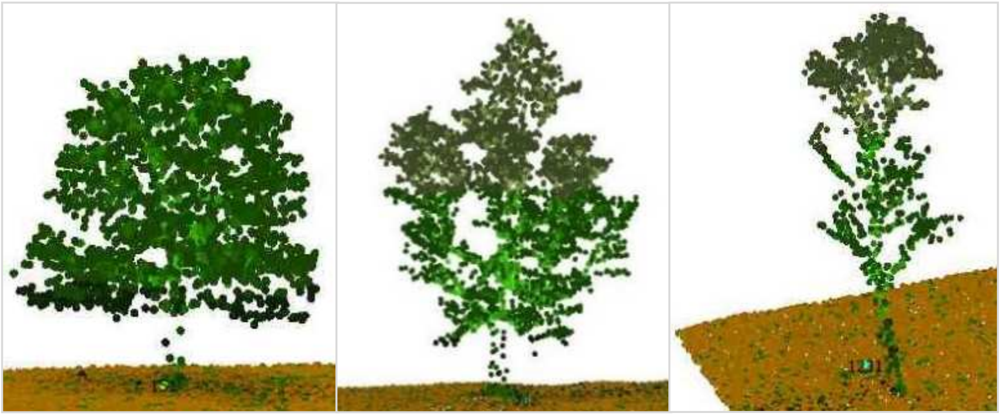


Figure 13: *Left, the tree ID 151. The crown is very regular, and the measurements are easy to manage. Middle, a profile of sycamore maple ID 782. The crown apex is quite well identifiable; however, it is difficult to determine where the crown starts. Right, the tree ID 1231 has a very crooked crown. It is unclear if the lower branches are dead. Remark: A picture of every measured tree in ArcGIS Pro was taken and saved in a folder. Source: Figures extracted from the laser point cloud, Land Tirol.*

3.4. Vitality assessment of the sycamore maples at „Großer Ahornboden"

Recognising the signs of unhealthy trees and identifying the causes is important both for sustaining the cultural, provisioning, supporting, and regulating services, and for the effective conservation of the unique landscape and its ecosystems. The vitality (Lat. *vitalitas*) of an organism is hereditary as well as modified by environmental influences (Weihs, 2017b). Whereas the methods of determination of the parameters described and the conditions of the trees are defined clearly, a tree´s vitality is not directly measurable (Dobbertin, 2005). To grasp the complexity of the vitality assessment of a tree and to obtain a holistic picture of a tree´s condition, an indicator set was invented to try and describe how healthy individual sycamore maples are in the study area. The indicators do not have any meaningfulness in themselves, but they are measurable and calculable factors, which makes them useful for the quantitative evaluation (Noldin, 2015).

The indicators used in this context should (1) be appropriate to represent the vitality of the sycamore maples, (2) be able to be assessed easily by the LiDAR data available or during field inspection, (3) be measurable and internally consistent, (4) include as many different facets as possible in terms of the triangle of forces of growth and reproductive capacity, stress tolerance and regenerative capacity, and longevity and habitus, and (5) the field indicators should not correlate with laser data analysis indicators.

3.4.1. Derivation of an estimation procedure to assess the vitality of the sycamore maples at "Großer Ahornboden" considering ecological conditions and habitat characteristics based on recorded field data

The field inventory was necessary to compare the crowns and the general conditions of the trees in the field with the parameters collected by the laser data analysis and thus to measure the success of the data-based vitality analysis. Therefore, for this master thesis, a specific tree assessment procedure for the sycamore maple trees of "Großer Ahornboden" has been developed, by which both the vitality and the habitat potential of these trees can be assessed equally effectively. To some extent, the assessment is based on the recording instructions for the crown approach on the "Sanasilva areas" and the "LWF areas" (Dobbertin et al., 2016).

In the following, the parameters growth and reproductive capacity, stress (tolerance) and regenerative capacity, and longevity and habitus will be used as criteria for vitality. Probably, the tree vitality status also depends on the frequency, intensity, and duration of biotic or abiotic stress (Elling et al., 2007) and the life phase of the individual tree (Figure 14). Therefore, these factors were also considered in the control sheet where possible. All sample trees were assessed in terms of their vitality and habitat characteristics. Other trees have been evaluated where it was convenient or specific features and characteristics were identified during a field inspection.

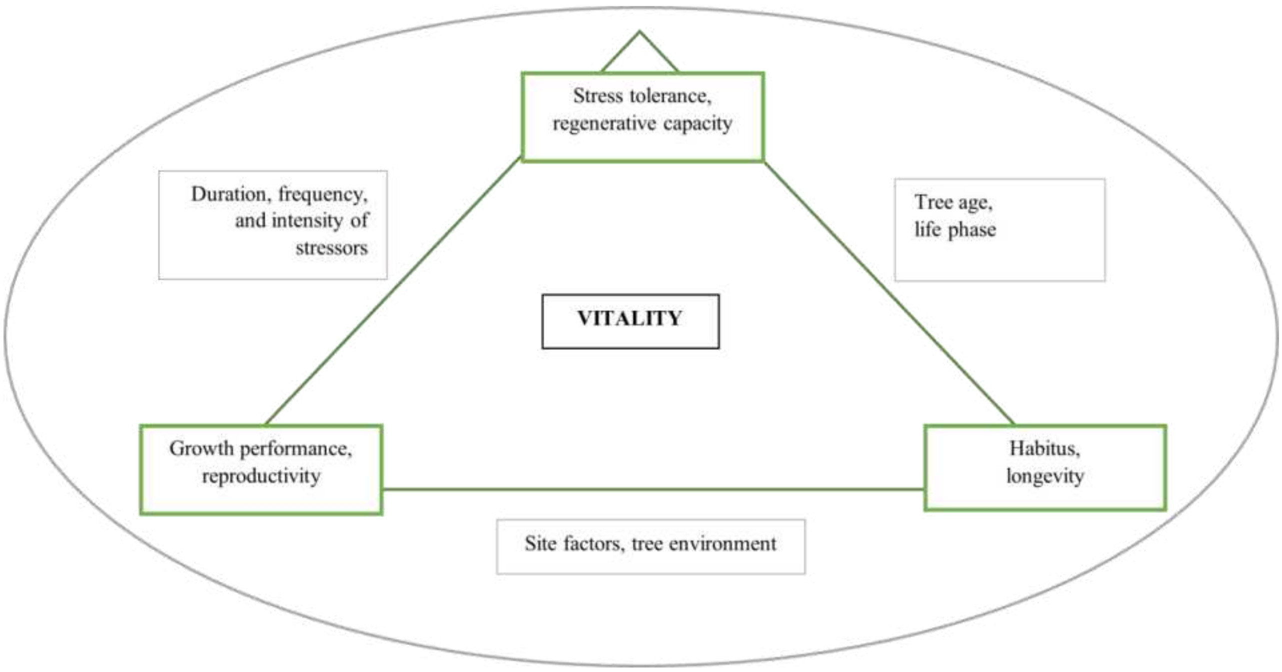


Figure 14: *The sycamore maple´s vitality is defined by resilience, ability to grow and reproduce, persistence, and its habitus. Assessment must consider the environment, the tree age, and the duration, frequency, and intensity of stressors. Source: Author following Elling et al. (2007).*

The proposed assessment sheet (Appendix II) uses the following indicators and parameters in terms of vitality for the sycamore maples at “Großer Ahornboden” (Figure 15; Annex I/Table 1):

Category 1: *Decay, defects, disease symptoms, and biotic environment of the individual tree*
Defects detected were differentiated according to their location on the wood body. A total of three kinds of damages could be noted but the notation of the location and wound closure was limited to defects 1 and 2 (*Stg1_Feld, Stg2_Feld*). Additionally, the total number of rotten spots larger than two palms were recorded to be able to assess the total extent of damage on the wood body. Also, suspected diseases were noted.
Forest condition surveys use tree crowns as bioindicators by inferring vitality from crown structure and crown thinning (Roloff, 2001). The visual assessment of tree crowns in this thesis consisted of the metrics a) crown drought, b) crown dieback, c) parts of crown missing. Crown dieback was defined as the proportion of dead branches to the total number of branches. They were identified and assessed according to the bark appearance and the existence or absence of buds and leaves.
Tree inhabitants, habitats, epiphyte species and quantity, dead wood with its special features were recorded. Defects with a particular ecological relevance (mulm cavities) or with an indication of specific biotic factors (holes with drill dust, woodpecker cavities, e.g.) were assessed separately.

Category 2: *Growth performance*
The formation of tree reiteration shoots can be an indicator for vitality (Weihs, 2017a). Such shoots at the crown base of sycamore maples can indicate a stress reaction. Due to senscence, sycamore maples form sporadical reiteration shoots only at the crown mantle (Gleissner, 1998; Hoffmann). Roloff (2001) also describes an increased sprouting of dormant buds on dying sycamore maples.
During the spring field inspection, the time of sprouting respectively the time of bud development in relation to the total population was assessed. Healthy trees tend to have a longer growth period (Plietzsch, 2017). Pronounced flowering can also indicate a high vitality, whereas the absence of flowering and fruiting rather indicate a reduced vitality (Weihs, 2017b).
The degree of wound closure on the reference trees was assessed following the CODIT principle (Shigo & Harold, 1997). The “Compartmentalisation of Decay in Trees”- model describes the wound reaction of trees to intrusive pathogens and is largely recognised to this day.

Category 3: *Tree environment and site conditions*

Environmental site conditions have an impact on trees. At the “Großer Ahornboden”, there are different soil types, over-gravelled areas, and local soil complexions, which may have an impact on a sycamore maple´s vitality. To account for these differential parameters, changes in the channel of Engergrundbach were derived from time series of orthophotos (1953, 1971, 2001, 2019). Then the change layer was overlaid with the tree-vitality map and the tree mortalities to examine possible relationships between environmental factors and tree health. The same was done for soil types. The social status and the extent of crown competition were considered, also.

Category 4*: Crown growth habit and relevant information for the comparison with laser analysis*

Foliation strongly determines all tree growth processes but can be reduced by various stress factors. Foliar density can be approximated by the assessment of crown transparency. In this thesis, crown transparency was estimated by means of the already green buds. However, crown transpareny is also related to the number of branches and a certain branching structure of the crown. A loosely branched tree´s vitality is not automatically reduced. Thus, for a meaningful assessment of the vitality of deciduous trees, crown shape and architecture must be considered, too. There are four main types of crown architecture of sycamore maples, by which the trees at “Großer Ahornboden” can be described meaningfully (Appendix II/4 - Additional assessment criteria for sample trees). Category 4 was introduced with the idea of having a central linking point with the computer-assisted laser data evaluation (3.5.1.) of the sycamore maple tree´s vitality.

Category 5*: Other factors relevant for the estimation of vitality*

The sycamore maples` age and life phase was always reconsidered as a thinner crown foliage and a reduced growth not necessarily indicate a reduced vitality of older trees. There is also a significant but natural difference between the flowering vigour and habit of younger and older trees. Büntgen et al. (2019) showed that rather slow-growing species, like the sycamore maple, growing in the open and allowed to become large are likely to live longer and be less prone to disease and water stress. One should also bear in mind that ancient trees have already proved their strong basic constitution in terms of longevity.

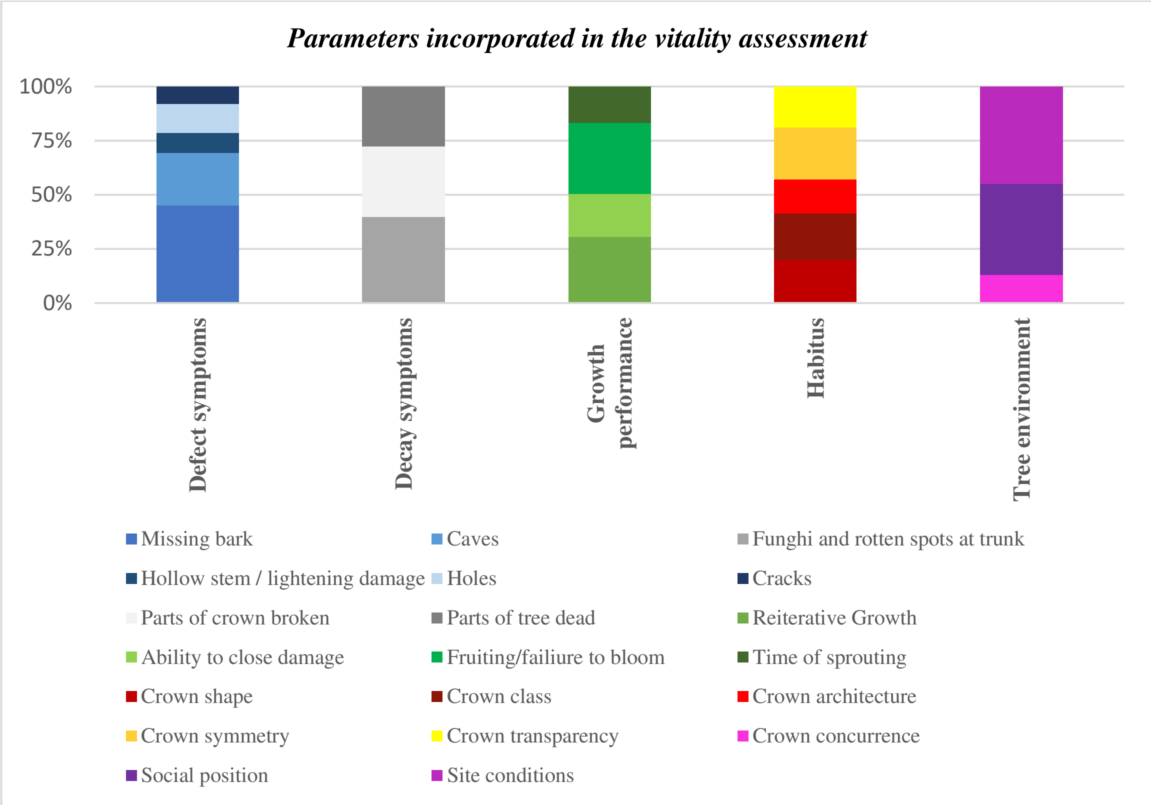


Figure 15: *The bars represent the superordinate classes of the vitality assessment of the 200 reference trees: 1) defects, 2) decay, 3) growth performance, 4) growth habit and, 5) the tree environment. The categories within each bar represent the factors it is composed of. The percentage represents the number of trees observed with this specific variable. Source: Author.*

Evaluation scheme

Each of the indicators was assessed between -1 (prove of vitality) and 4 (strong indication of a weakened tree individual). A value of 1 was assigned when the condition seemed neutral. The overall vitality of the sample tree then was determined by averaging all criteria collected. By combining the many different individual values, a holistic insight into the tree´s vitality was possible, even if some values were missing (Annex I/Tables 2 and X).

Vitality level 1 (healthy trees, no substantial damage features) is composed of all average-values ranging between 0 to 1. Mean values higher than 1 and 2 were summarised and represent trees with a slightly weakened vitality. Vitality level 3 contains trees which seem to be stressed (mean values between 2 and 3). Vitality level 4 is formed by all mean values higher than 3 and is an indicator for a strongly stressed tree. The table with the assigned values for calculation of the individual tree´s vitality values is attached to the appendix. A four-stage scale can be found in literature several times (f.e., vitality stages by Roloff or the defoliation and decolouration scheme by EC-UN/ECE (1996) and, therefore, was used in this master thesis. The assignment of the values 1-4 allows to quantify, rank, and compare vitalities. To split field-measured indicators into defined classes also avoids subjectivity in class assignment. Corresponding vitality stages can be found in table 14.

Table 14: *Vitality stages used to describe the sycamore maple´s vitality. The calculated vitality of each sample tree is based on a vitality assessment in the field.*

Vitality stage	Description
1	Healthy sycamore maple (no substantial damage features or other obvious signs of poor state of health)
2	Slightly weakened (good general condition but evidence of small defects or clues that may be related to the start of a diminishing health performance)
3	Weakened (tree´s health seems to be negatively influenced by several factors, no direct risk of dying-off)
4	Seriously weakened (the visual overall impression shows a stressed tree individuum and possibly heavy signs of damage, evidence of reduced vitality in several categories)

3.4.2. Computer-assisted vitality assessment by means of laser data

Is it possible to assess the sycamore maples´ vitality by means of laser data? Do the results confirm the assertions of the visual tree control in terms of vitality?

To this day, the visual assessment of vitality has been the norm, a subjective and time- and work- intensive method, especially for large stocks. Remote sensing methods have been extensively proven to bear the potential of solving these problems by providing accurate, spatially explicit, and detailed information on tree health. For the assessment of tree vitality with Airborne Laser Scanning, structural information that can directly be linked to tree health is needed.

Previous studies have, f.e., shown that the total cross-sectional area of living branches is strongly correlated with foliage mass (Ilomäki et al., 2003; Kantola & Mkel, 2004; Vanninen et al., 1996). Longuetaud et al. (2006) reported that a statistically significant indicator for tree vitality is the total cross-sectional area of branches, height-diameter at breast height (DBH) ratio (i.e., height/DBH), f.e. More specifically, Lehtonen et al. (2020) and Hu et al. (2020) found leaf biomass of Scots pine to be proportional to the stem cross-sectional area at the crown base. However, in both cases, the relationship was influenced by other factors, such as age, site type, and temperature. Some other studies, which have been dedicated to this topic, are Pretzsch (2019), Wallner, Seidel (2018), Seidel & Annighöfer et al. (2019), Seidel & Ehbrecht et al. (2019), Longuetaud et al. (2006), Alonzo et al. (2014), Binkley et al. (2013) and Shrestha & Wynne (2012).

4.1. Statistics and comparison of the different methods

4.1.1. Comparison of the different methods used for this survey of the sycamore maple population at "Großer Ahornboden"

According to the orthophoto interpretation, the total number of all point features amounts to 2864 elements in the LPA; the number of the point features added is 187. By means of laser data the number of unclassified point features ("p") could be reduced to 59. The number of vital sycamore maples was corrected to 2303, the number of dead sycamore maples to 633, and the number of coniferous trees to 49. After the first complete field inspection, the 2022 tree cadastre consisted of 3202 point features. The rest of 59 unclassified point features could be assigned to intact ("i"), dead ("z"), other tree species ("N/L"), or never existed ("n"). According to a second complete follow-up visit and renewed analysis of trees registered as dead on-site, further 89 formerly existing trees were added (Table 15).

Table 15: *Comparison of methods used to create the 2022 tree cadastre. The number of features assigned to one of tree status classes increased from orthophoto interpretation to laser data analysis to field surveys; at the same time, the number of features to be verified decreased and was reduced to zero after field surveys. The numbers shown relate to the LPA.*

		Method								**Total**
		Orthophoto interpretation		**Laser data interpretation**		**Field survey**		**Review of dead trees**		
Frequencies		**Absolute**	**Relative**	**Absolute**	**Relative**	**Absolute**	**Relative**	**Absolute**	**Relative**	**Absolute**
Tree status	**i**	1901	66,4%	2303	75,6%	2441[8]	76,2%	2438[8]	74,1%	---
	z/zz	409	14,3%	633	20,8%	645	20,2%	734	22,3%	---
	p	544	19%	59	1,9%	0	0%	0	0%	---
	N	2	0,07%	49	1,6%	65	2%	66	2%	---
	L	0	0%	0	0%	50	1,6%	52	1,6%	---
	n	8	0,3%	1	0%	1	0%	8	0%	---
Trees added		187	---	181	---	156	---	89	---	613
Total		2864	100%	3045	100%	3202	100%	3291	100%	---

4.1.2. The comparability of the different measurement methods used to determine crown parameters and tree heights

The correlation between the tree height measurements in the field and tree heights derived from laser data results in a Pearson correlation coefficient of r=0,794 (N=192). Pearson correlation coefficients of crown width measurements (N=186, r=0,897) and crown height measurements (N=192, r=0,794) were even slightly higher (Table 16&17).

[8] *Trees registered as vital ("i") + extensive areas of regeneration ("Jp")*

Table 16: *Basic statistics of tree-physiological parameters (BHD_Feld – diameter at breast height in cm; KB – Crown width (German Kronenbreite) in m; KH - crown height (German: Kronenhöhe); BH – tree height (German: Baumhöhe); _Feld – derived from field survey; g_Las – measured in laser point cloud). Source: Author, STATISTICA.*

	DBH	Crown width		Crown height	Tree height	
	BHD_Feld	**KB_Feld**	**KBg_Las**	**LHg_Las**	**BH_Feld**	**BHg_Las**
Mean	52,14	7,4	7,5	9,7	12,8	12,5
Max	127	17,2	18	19	23	22
Min	7	0,5	0,5	1,7	1,2	1
Range	120	16,7	17,5	17,3	21,8	21
SD	25,6	3,1	3,1	3,5	4,2	2,5
N =	188	188	215	215	205	238

Table 17*: Output table STATISTICA: Correlation of the paired samples; pairs are formed by the same tree parameters measured once in the field and once by laser data.*

		N	Correlation	Sig.
Paaren 1	KH522_Feld & KHg_LAS	192	,794	,000
Paaren 2	BH522_Feld & BHg_LAS	195	,926	,000
Paaren 3	KB522_Feld & KBg_LAS	186	,897	,000

In this master thesis, the Bland-Altman analysis was additionally used to analyse the agreement between the tree height measurements collected in the field and tree heights manually derived from laser data (Figure 16). For tree heights, the data points are clustered around the line of equality and differences are therefore visually difficult to record and the Bland-Altman plot is more informative. The Bland-Altman Analysis is based on a comparison of the differences between the measurements with two different methods and is widely used in medical sciences and other scientific disciplines (Abu-Arafeh et al., 2016; Kalra, 2017).

In terms of tree height measurements, no obvious trend is recognisable between the differences and the averages. The lower and upper "limits of agreement" (LoA) according to Bland and Altman (1986) are defined as the mean differences of ± 1.96SD. The level of agreement are estimates for the sample trees. Confidence intervals for the assessment of the precision of the calculated LoA were calculated with SD = 1,61249 and $\bar{e}$ = -0.253, the SE of $\bar{e}(SD/\sqrt{n},)$ is 0.115 and the SE of $(\bar{e} \pm 1.96SD)$ is $(SD * \sqrt{3/n.})$ 0.12 (Altman and Bland, 1983). With n = 195 we have 194 degrees of freedom and $t_{194} = 1.96$ at 95% probability level (for n >30). Therefore, the 95% confidence interval for the bias is (-0,253 – 1.96×0.115) = -0.4784 m to (-0,253 – 1.96×0.115) = -00,0276 m. The 95% confidence interval for the lower LoA is (-3,413 – 1,96 × 0.12) = -3,6482 m to (-3,413 + 1.96×0.12) = -3,1778 m. The 95% confidence interval for the upper LoA is (2,908 – 1,96 × 0.12) = 2,6728 m to (2,908 + 1,96 × 0.12) = 3,1432 m. Values of the LoA are within the confidence interval. The LoA have a range of 6,32m which is slightly higher than the benchmark range of 6m (+/- 3m). This seems reasonable, as literature reports about prediction errors up to 3- 8m (+/- 1,5 to 4m) (Kiraly & Brolly, 2007). The benchmark cut-off number of acceptance/rejection was set to 5% of total data outside the LoA. For the height measurement the Bland-Altman plot indicates that five data points (*Probe_ID* 4, 33, 44, 54, 82) are outside the LoA, which equals a share of approximately 2,56%. 97,44% of the differences are within the LoA. The number of "outliers" is less than 5% and the agreement between the distinct types of measurement can be assumed.

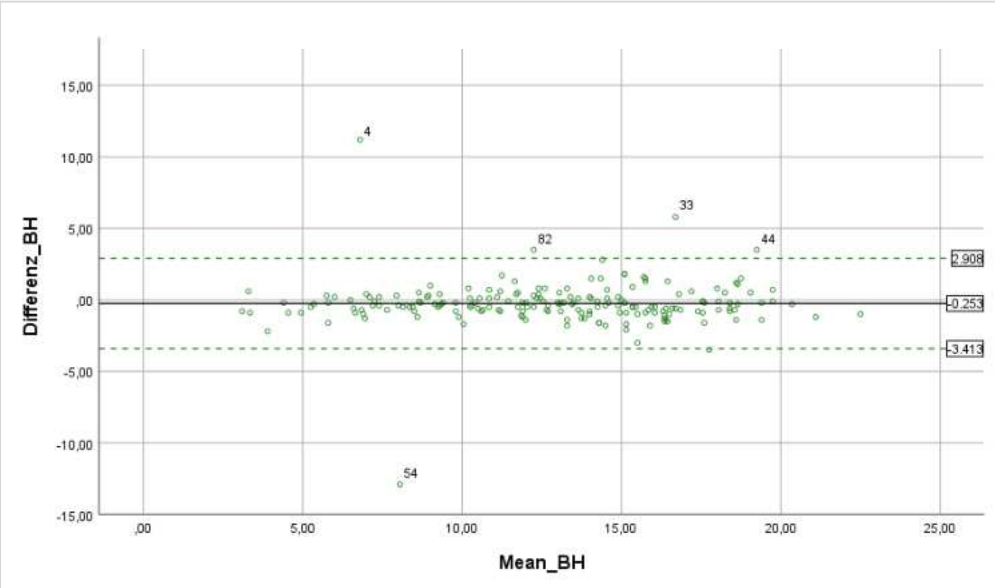


Figure 16: *Scatter plot with the comparison of the measurement methods using the Bland-Altman plot. On the x-axis, the mean value of the tree height measurements(Mean_BH) per sample element is plotted (BHg_Las, BH_Feld). On the y-axis, the differences between the tree heights measured minus the tree heights recorded during field work (Differenz_BH). The dashed lines are calculated according to "MEAN +/- 1,96*standard deviation". Tree height measurements of the sample trees with the IDs 4, 33, 44, 54, and 83 deviate strongly from the mean value. Source: STATISTICA*

4.1.3. Structural parameters and tree-physiological characteristics of the sycamore maples at "Großer Ahornboden"

Figure 17B shows the distribution of the measured tree heights in absolute values along with the probability density distribution. The data (n=205) seems to be normally distributed around the mean of 12,8m. Thus, the mean height is about 1,5 metres above the average height (Czell, 1966). According to the DBH class distributions that are shown in figure 17 A, the mean of the measurements (n=188) is approximately 52 cm. The distribution is slightly right skewed. The tree thickness distribution shows a strong overhang of the vlasses 20 to 55 cm.

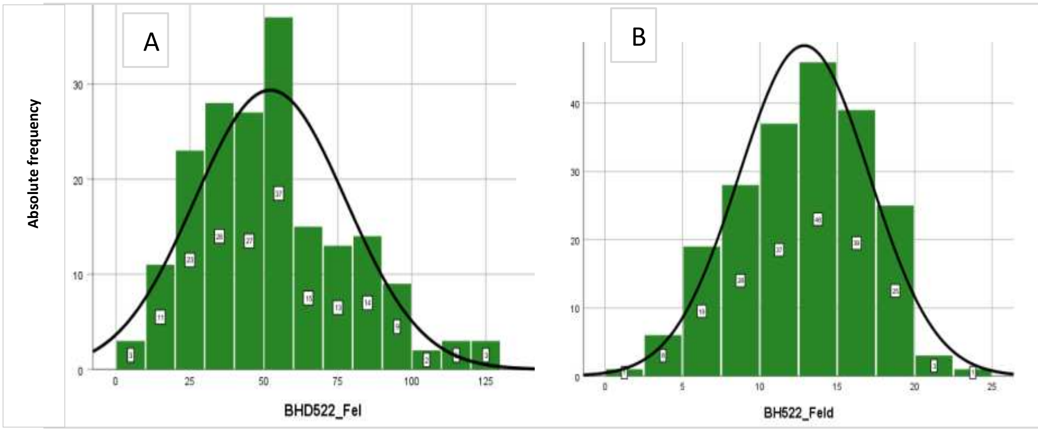


Figure 17*: Absolute frequencies of DBH (BHD522_Fel) measurements (N=188; M=52,14; SD=25,5) and tree height (BH522_Feld) measurements (N=205; M=12,8; SD=4,2) in the field in May 2022. Source: STATISTICA.*

Tree height and DBH were approximately normally distributed for young and middle-aged trees, but not for old trees, as assessed by the Shapiro-Wilk-Test, $p < .05$. Crown height and crown width were approximately normally distributed for all age-classes, as assessed by the Shapiro-Wilk test, $p > .05$. Der Levene test is not significant for any of the parameters measured. Homogeneity of variances can not be assumed. No ANOVA can be performend to compare the groups. The Kruskal-Wallis test was applied. The height growth of trees differed between the three age groups (N=248, Kruskal-Wallis H(3)=55,187, p=0,000). Similarly, the Kruskal-Wallis test indicated a significant difference of the DBH (N=248, Kruskal-Wallis H(3)=45,07433, p=0,000), and crown width (N=248, Kruskal-Wallis H(3)=32,5877, p=0,000). The parameters DBH and tree height, as well as crown width and crown height seem to be positively correlated (Figure 18). The scattering of the point cloud increases with increasing tree heights. Diagrams and tables referred to in this paragraph, which are not shown in the text, can be found in the Appendix I/Chapter 4.

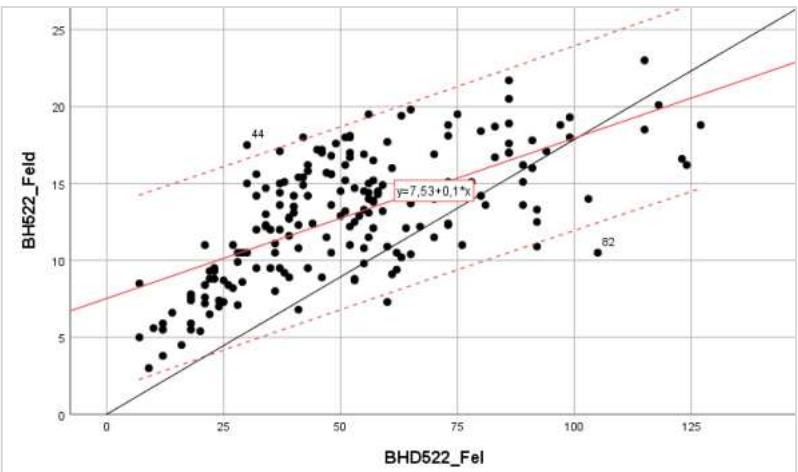


Figure 18: *The scatter plot shows the correlation between DBH (BHD522_Fel) and tree height measurements (BH522_Feld) conducted in the field in May 2022 (R^2 Linear = 0,441; y=7,53 + 0,1). A linear regression seems not to fit the data. Source: STATISTICA.*

4.2. Sycamore maple population at “Großer Ahornboden”

4.2.1. The tree cadastre of the sycamore maple population in 2022

General overview (1st volume)

The tree cadastre (1st volume – before the review of dead trees) for the landscape protection area “Großer Ahornboden” consists of a total of 3202 point features (Figure 19 & 20A/B, Appendix I/4.2.3.). The author supplemented the 2001 tree cadastre by 524 point features. According to the tree cadastre, there are 2430 vital sycamore maples (i) at “Großer Ahornboden” in 2022. Just under 3% (n=71) demonstrably originate from replanting. At 11 other locations, young emerging sycamore maples were found. There are further 115 vital trees at “Großer Ahornboden“, but they can be assigned to other tree species. They are 50 coniferous trees and 65 deciduous trees. One point feature was categorised with „never existed“. The category of dead sycamore maples was split into trees that died between 1953 and 2001 (304 trees) and sycamore maples that died between 2001 and 2022 (341 trees) (Figure 19).

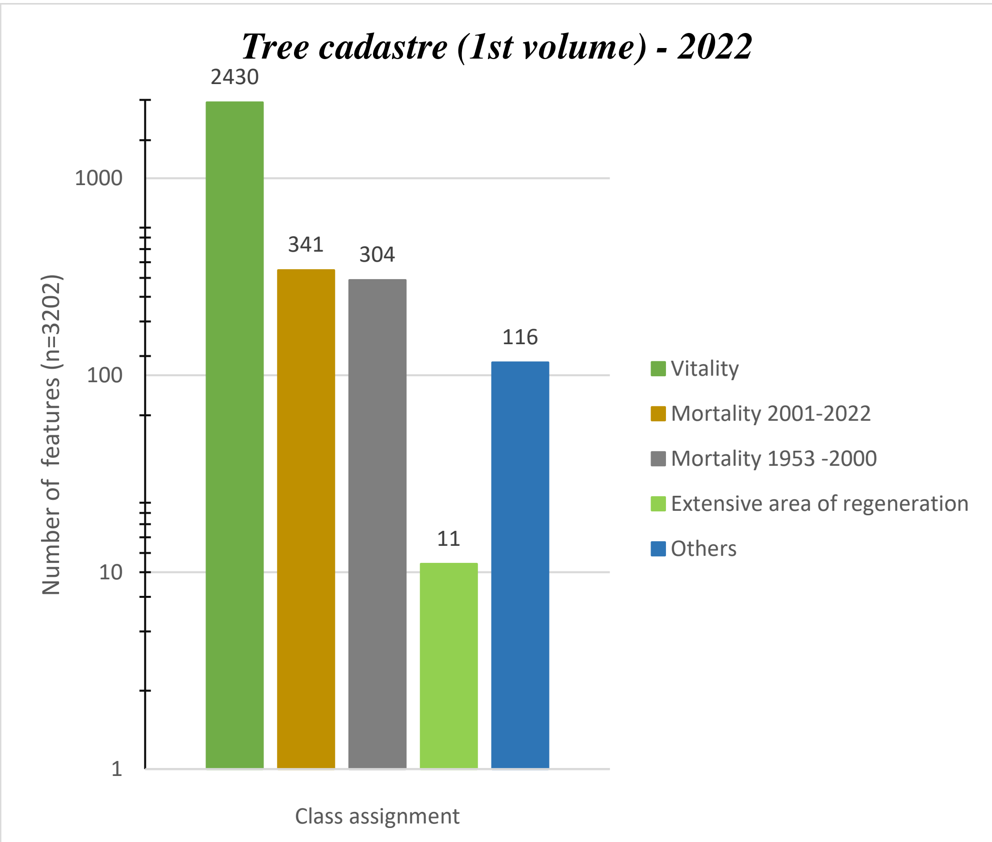


Figure 19: *The 2022 tree cadastre for the LPA consists of 3202 features which are allocated to the classes: 1) Vital sycamore maple (n=2430), 2) extensive areas of regeneration (n=11), 3) elements not classified as sycamore maples (n=115), 4) mortal trees (n=645(period 1953-2001: n=304; period 2001-2022: n=341)). Source: Author.*

Figure 20 and 20a: *See page 47/48.*

At “Großer Ahornboden”, 60% (n=1506) of the sycamore maples are old. Young trees make up a share of 30% (n=738) and middle-aged trees hold the smallest share of only 5% (n=121). The age of 65 trees is not registered (Figure 21).

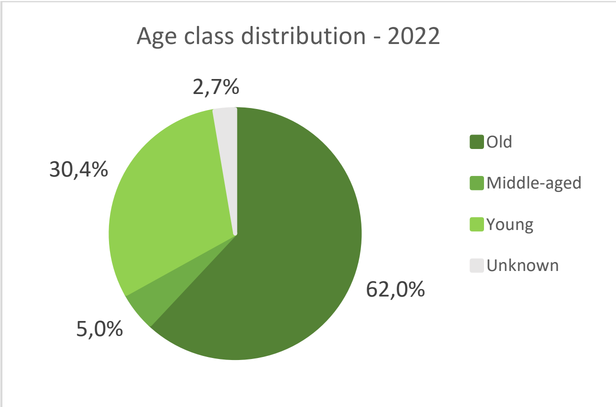


Figure 21: *Age class distribution of the sycamore maple population in 2022: 1506 old trees, 121 middle-aged trees and 738 young trees. The age of 65 trees is unknown. Source: Author.*

On the valley floor, there are 272 more elements outside the defined measure areas of the LPA “Großer Ahornboden”. Therefore, the 237 vital sycamore maples, 14 coniferous trees, nine dead trees, one deciduous tree, and eleven trees with unknown status were not considered further in the calculations. The point features are stored separately (Figure 10).

Differentiation of the 2022 tree cadastre according to the measure areas

Numbers referred to in this paragraph, can be found in the Appendix I/4.2.3., Table III.

Measure area 1 (Figure 22 & 23a) includes two areas where the sycamore maples stand densely. 2022, almost 41% of the sycamore maples were in measure area 1. The mean population density is 14 trees/ha and thus about twice as high as on measure area 2 and about three times as high as on measure area 3. From 2001 to 2022, 186 sycamore maples died in this part of the study area, which correspond to 54,5% of all sycamore maples that died during this period at “Großer Ahornboden“, and to 15,8% of the sycamore maple population in 2001 (n=1176). During the same period, replanting accounted for 71 trees, which make up for 7,2% of the vital sycamore maples (n=990). The overall balance is negative because the population decreased by 115 trees, which corresponds to an annual reduction of five sycamore maples since 2001. The age structure diagram shows that in measure area 1 old trees are dominant and have a share of more than three quarters of the population there. The number of young and middle-aged trees is the smallest of all measure areas.

A good of 30% of the total sycamore maple population stands in *measure area 2 (Figure 22 & 23b)*. The mean population density is six trees/ha and thus less than half of that of measure area 1, it ranges, however, approximately in the middle of all areas. 2001-2022, 82 of 843 sycamore maples died in this area, which corresponds to 10%. In terms of all mortalities of the sycamore maples between 2001 and 2022, the share is 15%. Here, the annual mortality rate is four. Like in measure area 1 old trees are dominating.

Measure area 3 (Figure 22 & 23c) consists of about 17% of the total sycamore maple population at "Großer Ahornboden". The mean population density is five trees/ha and similar to that of measure area 2. 2001 to 2022, 29 sycamore maples died here, that is 6,5% of the population in 2001. The annual mortality rate has been just over one tree over the past twenty years. In contrast to area 1 and area 2, the ratio between young and old trees is balanced. As in the other areas, middle-aged trees are underrepresented.

In the *exception area (Figure 22 & 23d)*, there is only just under one tree/ha. 14,2% (n=44) of the 309 sycamore maples alive in 2001 died between 2001 and 2022. Just under 20% of all trees in the exception area must be assigned to other tree species than sycamore maples. There are significantly more young sycamore maples than old ones. The number of young and middle-aged sycamore maples accounts for almost 75% of the tree population, a reverse picture of that of measure area 1.

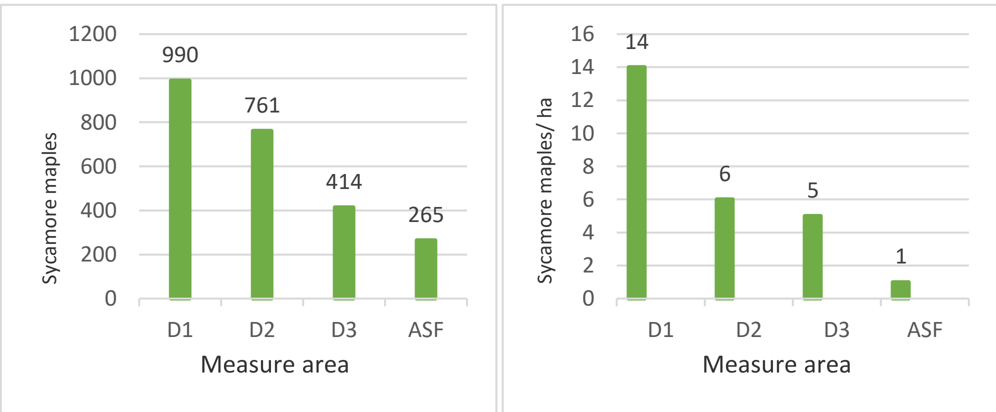


Figure 22: *The left diagram shows the number of vital sycamore maples in each measure unit (D1=measure unit 1, D2=measure unit 2, D3=measure unit 3,, ASF=exclusion area). In measure unit 1 and 2 are about three quarter of the population. The bars in the right diagram represent the number of trees per hectare in each measure unit. The average tree density per hectare is the highest in measure unit 1 and the lowest in the exclusion area. Source: Author.*

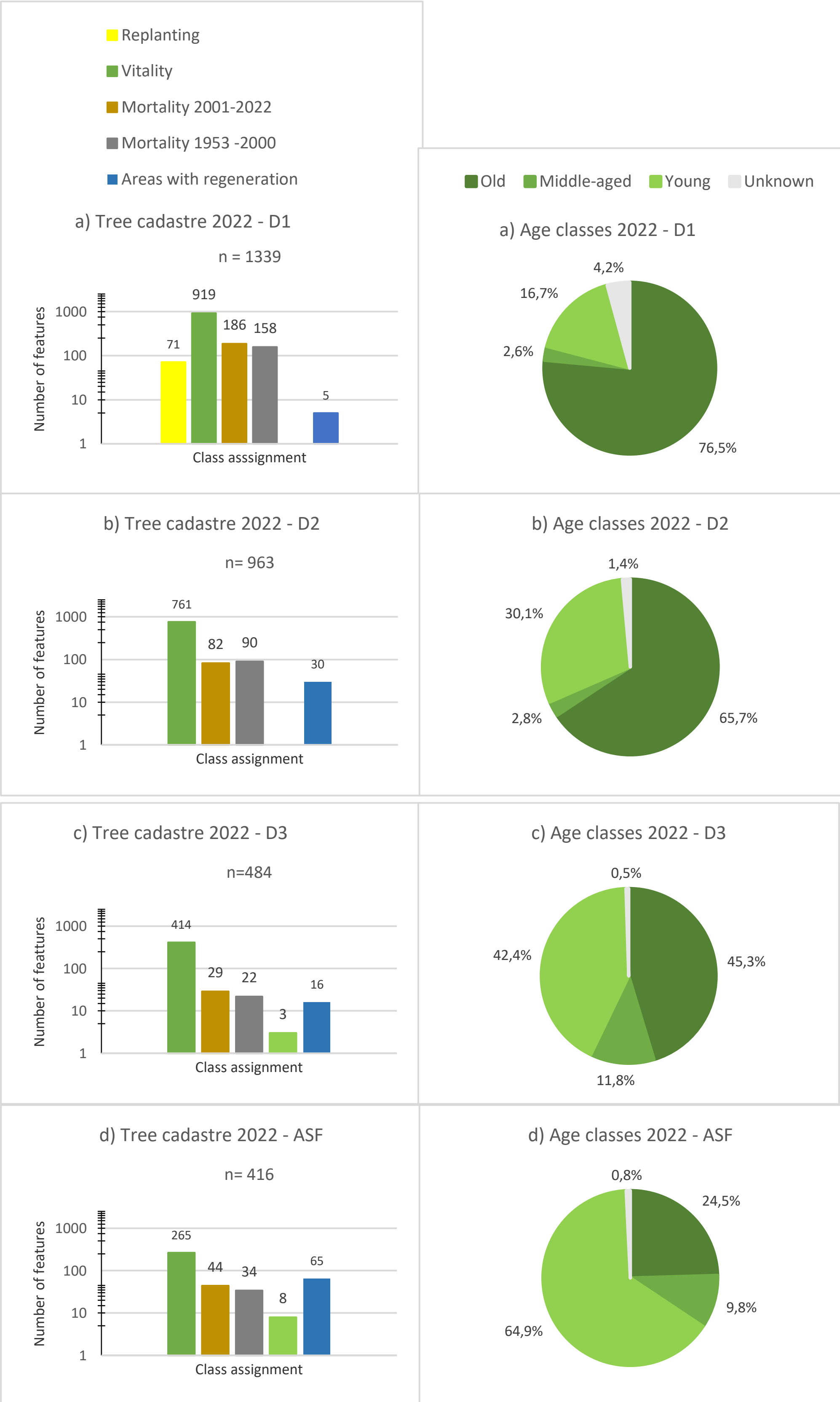


Figure 23: *The 2022 tree cadastre consists of 3202 point features (Figure 19). The left column shows the allocation of these point features to the different measure areas: D1 (n=1339), D2 (n= 963), D3 (n=484), ASF (n=416). The right column visualizes the age class distribution of the sycamore maples per management unit. Source: Author.*

4.2.2. Changes in population size and age structure of the sycamore maple population between 2001 and 2022

General overview

The reference data (3.2.3.) of 2001 states 2240 vital sycamore maples and 1991 vital trees in 2022 (Figure 24; Table 18; Appendix I/Figure IV). Obviously, between 2001 to 2022, the number of sycamore maples decreased by 249 trees which corresponds to a reduction of 11%. 1953[91], there were 2530 sycamore maples at "Großer Ahornboden", 11,5% (n=290) of these died beween 1953 to 2001. 2001 to 2022, 14,2% (n=319) of the 2001 population (n=2240) sycamore maples have died. 2001 to 2022, the mean annual mortality rate was 14,5 sycamore maples at „Großer Ahornboden". During the reference period 1953-2001, the mean annual mortality rate was about 6,2 trees. Consequently, the mean mortalitiy rate more than doubled.

Table 18: *Composition of the 2001 and 2022 tree cadastre. The table contains information about the number of features per class. Source: Author based on the MMP.*

Tree status Year	i	z	zz	n	N	L	Total number of features
2001	2240	290	n.a.	71	47	30	2678
2022	1991	319	290	1	47	30	2678

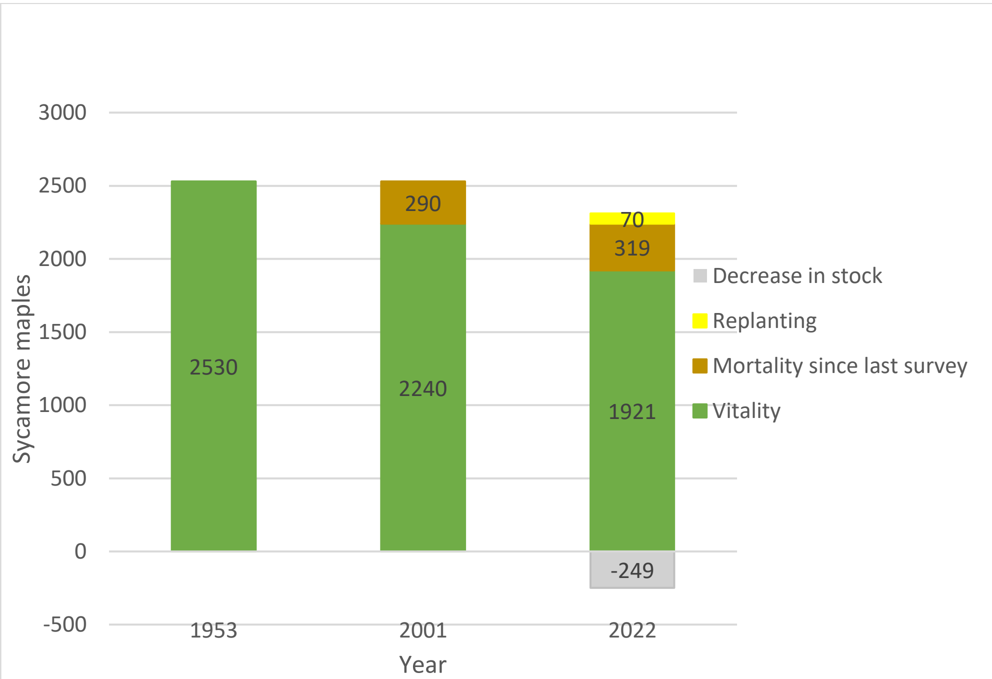


Figure 24: *The sycamore maple population at "Großer Ahornboden" 1953, 2001, 2022. Stock sizes are based on the reference population (3.2.3.). For the period 2001-2022 only 70 replantings are visualised. Planting no. 45/10 (ID 8327) was added later.*

[9] *Population stock* $_{1953}$ *= 2240 + 290*

A comparison of the age distribution diagrams of 2001 and 2022 reveals no significant changes. Both in 2001 and 2022, old sycamore maples dominate the study population. Young and middle-aged trees together make up one third of the population (Figure 25).

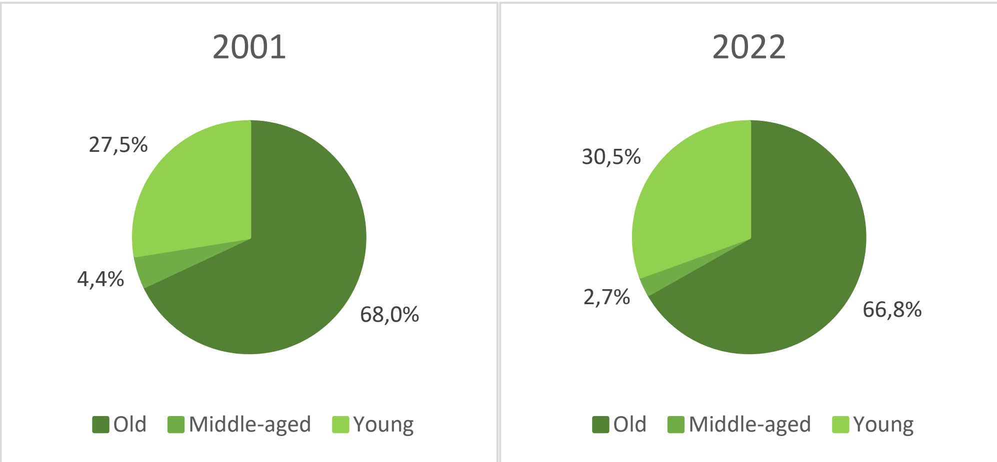


Figure 25: *Age structure of the sycamore population 2001 (left) and 2022 (right) based on the reference data. Source: Author.*

Differentiation according to measure areas

The overall balance of the population in *measure area 1 (Figure 26a, Appendix I/Table V)* is negative. The total population decreased by 111 trees. The tree mortality of young and middle-aged trees is rather low, whereas mortality rates in the oldest age class are high (n=150). Replanting lifted the number of young and middle-aged tree from 134 to 178. 2001, this age classes made up just under 15% of the total population, in 2022 already more than 20% of it.

In *measure area 2 (Figure 26b, Appendix I/Table VI)* the sycamore maple population shrank by 74 trees, which means a reduction of the population of 2001 of about 10%. The mortalities are evenly distributed to all age classes. The age classification structure remains about the same.

In *measure area 3 (Figure 26c, Appendix I/Table VII),* the population was reduced only slightly from 352 to 326 trees, that is about 7%.

In the *exception area (Figure 26d, Appendix I/Table VIII)* young and middle-aged tree are still dominating in 2022. In total, the population shrank from 139 trees in 2001 by 37 trees (appr. 20%). 32 mortalities were young and middle-aged trees; thus, this age class was reduced by 22%. Five old sycamore maples (4%) died on this area. 2001 to 2022, the mortalities of young trees corresponded approximately to 86% of the total mortality rate between 2001-2022. The rate of young tree to the total population is about one fourth. The mortality of young sycamore maples in the exception area is above average.

Figure 26*: The changes of the sycamore maple population in each management unit (D1, D2, D3, ASF) in comparison of the periods 1953-2001 and 2001-2022 (left). Relative age class distribution of young, middle-aged and old trees of the years 2001 and 2022 (middle and right). Source: Author.*

4.2.3. A separate analysis of the eliminated stock and registered dead trees results in the 2nd volume of the tree cadastre 2022

The eliminated stock and registered dead trees

According to a separate follow-up and renewed analysis of trees registered as dead according to the 2022 tree cadastre in order to detect trees which may have died unnaturally, the eliminated stock consists of 734 point features (Table 20).

A total of 52 still standing but dead trees (*BZ2_Feld*: "DS") and 50 rootstocks were recorded. These 102 features are remnants of naturally died-off trees. There were 116 rootstocks with straight cuts indicating sawed-off trees. It can be assumed that many of these trees were cut down in 2011 (Table 19A). A large part of these dead wood objects showed a high degree of decomposition, or the stump was hidden under a moss cover, which sometimes made a reliable determination of the tree species difficult. According to the author, probably four elements of the cut trees were coniferous trees, eight elements were deciduous trees. Further 24 elements registered as dead also were other tree species than *Acer pseudoplatanus* (Table 19 B). The tree cadastre also includes 26 indications of trees on locations where no tree or remnants be found. But near these locations, there were indirect indicators of removed stumps on five locations and 21 other conspicuous ground elevations or depressions (Table 19 A). For 21% (156 of 734) of the point features classified as dead, by means of the orthophotos the author cannot make a definite statement whether there ever existed a tree. In addition, during field inspection indicators of dead trees were searched for in vain on 30 of these locations (Table 20).

Figure 27*: Dead wood at "Großer Ahornboden". Source: Author.*

Table 19: *Information on trees, finally recorded as dead and may not have died naturally.*

Abbreviations: BZ22=*acronym of a column in the 2022 tree cadastre, where the tree condition in 2022 is registered; the used attributes for dead trees are*

A) Recorded evidence of tree mortality in *BZ2_Feld* (*BZ22* = z OR *BZ22 = zz*)						B) Questionable if it had been a sycamore maple (*ART_Feld*)		C) Added (89 features)	
2011	***Entf***	***DS***	***WS***	***n.a.***	***Sonst***	***N?***	***L? Buche?***	***BZ22 = z***	***BZ22 = zz***
117	5	52	50	70	21	28	8	426-341= 85	308-304= 4

Table 20*: Registered dead trees grouped by time of death before (zz) and after (z) 2001.*

Registered dead trees grouped by time of death before (zz) and after (z) 2001								**All dead trees (734 features)**			
BZ22 = z (426 features)				***BZ22 = zz (308 features)***				***BZ22 = z OR BZ22 = zz***			
Z_test		***BZ2_Feld***		***Z_test***		***BZ2_Feld***		***Z_test***		***BZ2_Feld***	
Verifiziert im Feld	138	2011	94	Verifiziert im Feld	22	2011	4	Verifiziert im Feld	160	2011	98
		Entf	1			Entf	0			Entf	1
		DS	15			DS	2			DS	17
		WS	20			WS	8			WS	28
		n.a.	2			n.a.	1			n.a.	3
		Sonst.	2			Sonst	7			Sonst.	9
		<NULL>	4			<NULL>	0				4
Verifiziert	204	2011	16	Verifiziert	214	2011	2	Verifiziert	418	2011	18
		Entf	4			Entf	0			Entf.	4
		DS	34			DS	1			DS	35
		WS	12			WS	10			WS	22
		n.a.	17			n.a.	18			n.a.	35
		Sonst	3			Sonst	6			Sonst.	9
		<NULL>	117			<NULL>	177			<NULL>	294
Existenz fraglich	84	n.a.	27	Existenz fraglich	72	n.a.	3	Existenz fraglich	156	n.a.	30
		Sonst	3			Sonst	0			Sonst.	3
		<NULL>	53			<NULL>	69			<NULL>	123

The reviewed 2022 tree cadastre (2nd volume)

The number of point features of the 2022 tree cadastre presented in chapter 4.2.1. was extended by 89 formerly existing trees which may have died unnaturally (Table 19). This addition has no effect on the reference population (4.2.2.), because all point features which were added within the framework of this master thesis are not included (Figure 10). Neither does it affect the feature classes of the vital trees of the 2022 tree cadastre (4.2.1)[10].

The reviewed tree cadastre for the landscape protection area "Großer Ahornboden" consists of a total of 3291 point features (Figure 27b; Annex I/4.2.4.). The author supplemented the 2001 tree cadastre by 613 point features. According to the tree cadastre, there are 2427 vital sycamore maples (i) at "Großer Ahornboden" in 2022. Just under 3% of theses (n=71) demonstrably originate from replanting. At 11 locations, young emerging sycamore maples were found. There are further 118 vital trees at "Großer Ahornboden", but they can be assigned to other tree species. They are 66 coniferous trees and 52 deciduous trees. One point feature was categorised with „never existed". The category of dead sycamore maples was split into trees that died

[10] The class of vital trees consists of sycamore maples, deciduous trees and coniferous trees. 2022 tree cadastre (1st volume with 3202 elements): 2430i + 50L + 65 N = 2545; 2022 tree cadastre (2nd volume with 3291 elements): 2472i + 52L + 66N = 2545

between 1953 and 2001 (308 trees) and sycamore maples that died between 2001 and 2022 (426 trees).

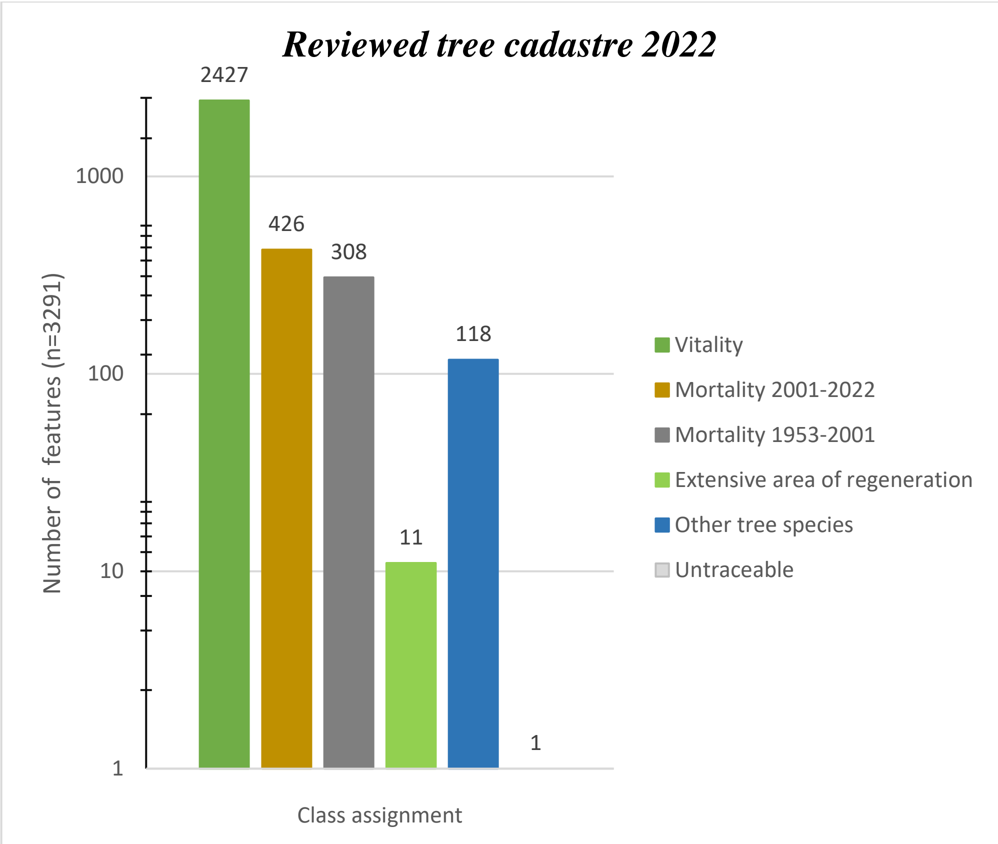


Figure 27b: *The reviewed 2022 tree cadastre for the LPA consists of 3291 features which are allocated to the classes: 1) Vital sycamore maples (n=2427); 2) extensive areas of regeneration (n=11); 3) elements not classified as sycamore maples (n=118); 4) mortal trees (n=645 (period 1953-2001: n=308; period 2001-2022: n=426)). Source: Author.*


Das Landschaftsschutzgebiet "Großer Ahornboden" mit seinem Baumbestand im Jahr 2022
Anzahl der Elemente je Objektklasse - Dringlichkeitsfläche 2
Anzahl (n=966)
759
93
84
20
9
1
i
zz
z
L
N
n
Klassenbezeichnung im Baumkataster 2022
Anzahl der Elemente je Objektklasse - Dringlichkeitsfläche 3
Anzahl (n=485)
i
z
zz
L
N
Jp
Klassenbezeichnung im Baumkataster 2022
Anzahl der Elemente je Objektklasse - Dringlichkeitsfläche 1
Anzahl (n=1.424)
988
269
160
4
3
i
z
zz
N
L
Klassenbezeichnung im Baumkataster 2022
Anzahl der Elemente je Objektklasse - Ausschlussflächen
Anzahl (n=416)
265
45
43
34
21
8
i
N
z
zz
L
Jp
Klassenbezeichnung im Baumkataster 2022
Anzahl der Elemente je Objektklasse - Baumkataster 2022
Anzahl je Klasse (N=3291)
2.427
426
308
66
52
11
1
i
z
zz
N
L
Jp
n
BZ22
Legende: BZ22 (Spaltenname in der Attributtabelle)=Baumzustand 2022; i=vital; z=Mortalität 2001-2022; zz=Mortalität 1953-2000; N=Nadelbaum; L=Laubbaum; Jp=Bereich natürlicher Regerneration; n=nicht vorhanden.
Objektklassen - Baumkataster 2022
Natürliche Regeneration des Bergahornbestandes (Jp)
Laubbaum (L)
Nadelbaum (N)
Vitaler Bergahorn (i)
Nicht nachvollziehbar (n)
Mortalität eines Baumes im Zeitraum 2001-2022 (z)
Mortalität eines Baumes im Zeitraum 1953-2001 (zz)
N
W
E
S
0
0,19
0,38
0,75 Kilometers

Jungbäume und registrierte Neupflanzungen (Spaltenname im Baumkataster: PFLANZUNGEN) sowie zusätzliche Vermerke zu vitalen und abgestorbenen Bäumen (Spaltenname im Baumkataster: BZ2_Feld), Stand 2022

4.3. Vitality of the sycamore maple trees at “Großer Ahornboden”

4.3.1. Vitality assessment of the two hundred sample sycamore maples and research into correlations between tree age and habitat characteristics on field data

Vitalitity of the two hundred sample trees

The vitality values calcualted ranged from -0,75 to 3,2. The mean vitality for all trees was calculated 1,37. The vitality analysis of the sample trees establishes that 52 of the surveyed trees were assigned to the class of healthy trees. The largest proportion of the trees (n=116) has level 2. Only 8,5% (n=17 trees) are weakened or seriously weakened according to the evaluation scheme used in this analysis (Figure 28).

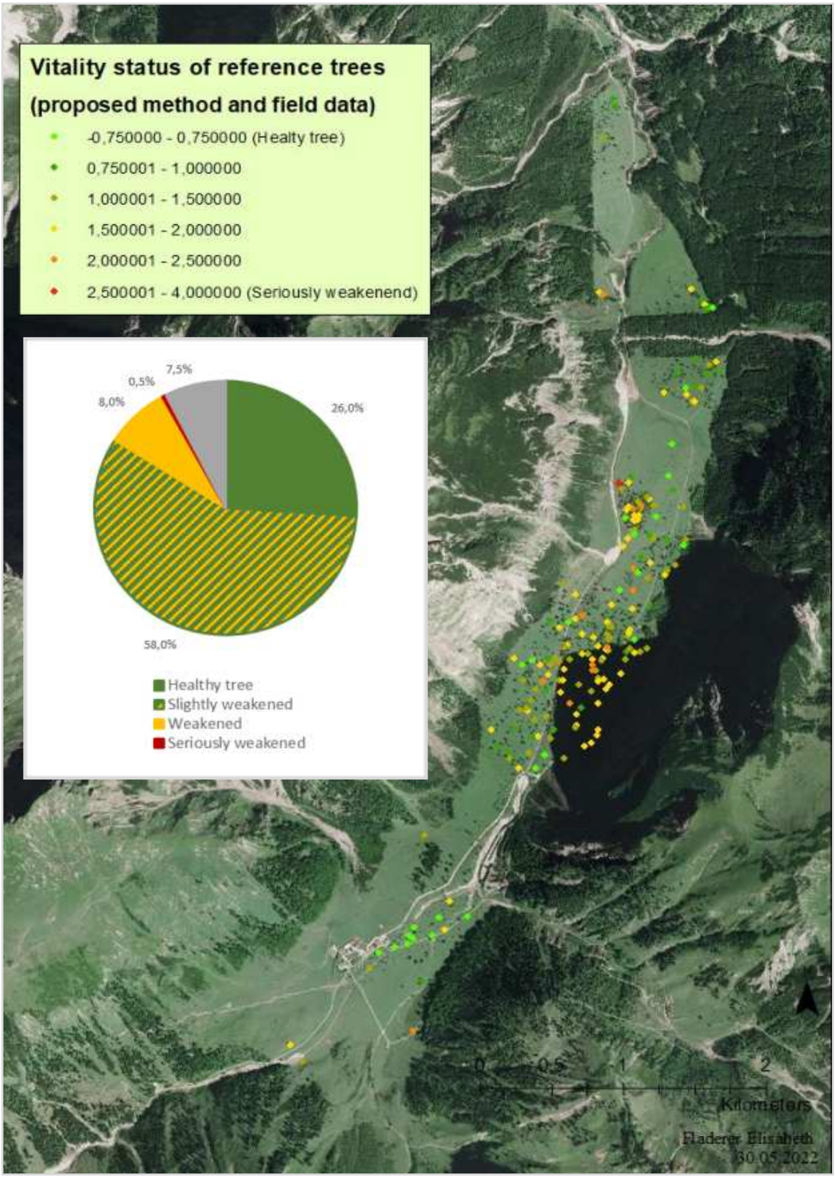


Figure 28: *Number of sample trees assigned to each vitality class and visualisation of the spatial distribution of the trees and calculated vitality values at “Großer Ahornboden”. The total number of trees included is 200. Source: Author. Orthophoto Land Tirol.*

The correlation between tree age and vitality

Vitality decreased with increasing age. Compared to younger trees, older sycamore maples show a significantly lower vitality , $t(185) = -6,88$; $p = 0,000$; $d = -0,61$ (Figure 29). The mean vitality in age class "younger" (n=46, SD=0,48) was 0,9, which corresponds to healthy trees. For trees in age class "older" (n=141, SD=0.48) the mean vitality was 1,5. In the category of younger trees, 62,2% (n=28) of the trees were classified as healthy, while only 10,8% (n=14) of the older trees were estimated healthy. Vitality status 2 (slightly weakened) contains 101 trees (77,7%) of older trees and 15 trees (33,3%) of younger trees. Only 4,4 % of the younger trees (n=2) belong to the class of stressed trees. The proportion of older trees was 10,8 % (n=14) in this class. None of the young trees and one of the older trees (0,8%) was assigned to the class of seriously weakened (Figure 30).

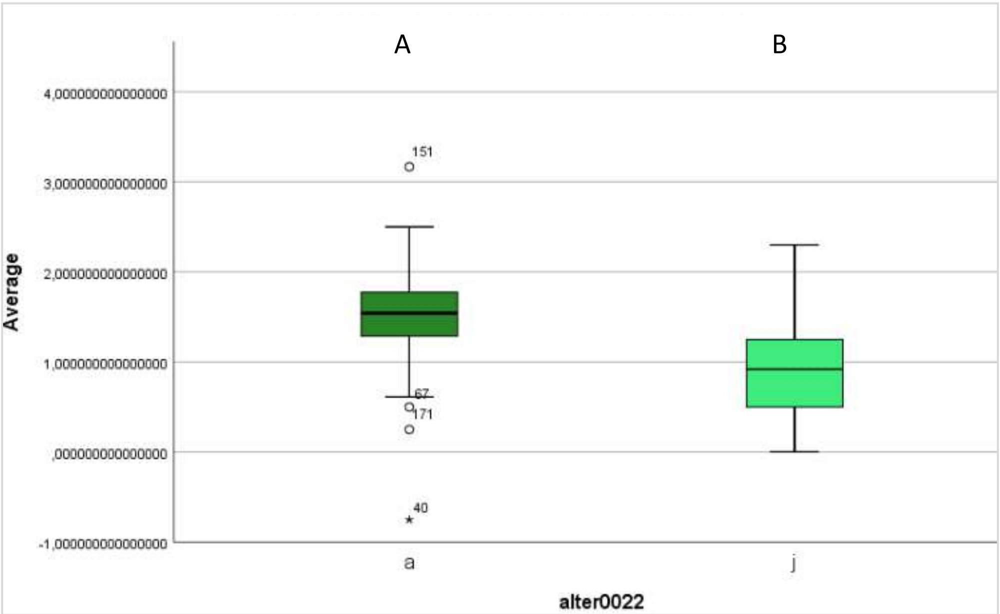


Figure 29*: Boxplot of asessed vitalities (range: -1 to 4) of the surveyed sycamore maple (Acer pseudoplatanus) trees in the two groups (n=141 for older trees(a); n=46 for younger trees(j)). The different letters indicate significant differences (α=0.05). Source: Author. STATISTICA.*

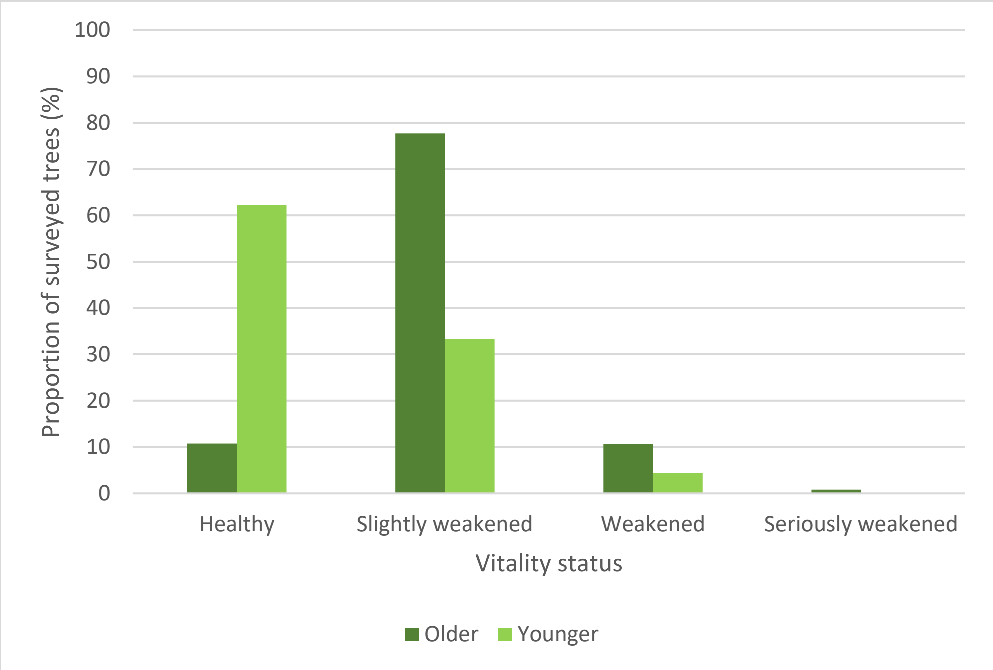


Figure 30: *Vitality status of the surveyed younger (n=45) and older (n=130) sycamore maple trees. For each age category the proportionate quantities of the surveyed trees were assigned to the four vitality classes.*

4.3.2. Vitality assessment by means of laser data

Because of various reasons (5.2.), the author did, in consultation with Karwendel Nature Park, not pursue the announced research questions further.

Chapter 5 - Discussion and outlook

5.1. The historically grown structures of the landscape protection area “Großer Ahornboden“ depend on the conservation of its ancient trees and natural or artificial rejuvenation

5.1.1. Sycamore maple population, mortalities and rejuvenation

Assessment of the population

In the framework of this master thesis, I counted 2427 vital sycamore maples at „Großer Ahornboden“. In addition, there are 11 further areas with extensive natural regeneration, and thus the number of young trees tends to be underestimated when considering only the mere numbers. However, the total number of sycamore maples has decreased in the period from 2001 to 2022 with some flux. High mortality rates, especially in the oldest generation, nullified the influx by replanting and natural regeneration. Between 1953 and 2001, the mean annual mortality rate of sycamore maples in the study area was calculated to be 6 trees based on the reference population, which is two less than estimated in the MMP. For the years 2001 to 2022, the annual rate was calculated to be fourteen trees, which means that the rate has more than doubled. Data on natural mortality rates of sycamore maple populations from other sites is extremely limited, especially regarding ancient trees and wood pastures. Most information available is restricted to silvicultural practices (Aas, 2009; Ambrazevičius, 2006; Hein et al., 2009; Pasta et al., 2016; Roloff & Schmidt, 2009; Sedlar et al., 2021). However, according to the literature available, which reports about a yearly loss between 0.5% and 1%-2% per annum for beech and oak (Bengtsson & Bengtsson, 2011; Drobyshev et al., 2008; Kirby, 2015), the sycamore maples´ mortality rates at “Großer Ahornboden” between 2001 and 2022 still seem to be about normal for ancient trees.

Mortalities in the sycamore maple population can be split into the classes of irregular mortalities and age-related (regular) mortalities. The results of this master thesis suggest that a regular mortality is currently dominant, which the MMP had also predicted. However, many ancient trees have been observed to be affected by various defects. The frequency of severely damaged crowns and stems suggests that one or more events have affected the sycamore maples. Czell (1966) already states in his investigation about “Großer Ahornboden” that trees with an intact treetop are the exception. Therefore, it is difficult to distinguish the dominant driver of the individual tree mortality.

The “impaired vitality in their canopy development” (Tappeiner, 2007b) of the sycamore maples in relation to grazing was also intensively investigated into. An obvious idea, as the “Großer Ahornboden“ has been used as alpine pasture for many centuries and is still designated mainly as such (Agrarmarkt Austria). Schreiner (2004) presumes that an agricultural use not adapted to the location is reflected in (less) vitality and less mycorrhizal abundance on the sycamore maples. It must be mentioned, however, that the ideal stocking density and stock type for wooded pastures is still unclear and requires further research (Forbes et al., 2005). Tappeiner (2007) notices an increasing management intensity (LU/ha) of the pastures since 1950. Moreover, the supplementary feeding of hay and concentrates, and atmospheric deposition have been breaking up the closed nutrient cycle. Between 1952 and 2006, nitrogen input increased by 13.7 kg/ha (Tappeiner, 2007). This thesis does not further pursue this topic, because the mineral nitrogen content or the total content of nitrogen of intensively managed fields does not differ significantly from that of extensively managed fields (Tappeiner, 2007). Therefore, the increase of nitrogen input by alpine farming since 1950 into the area “Großer Ahornboden” should not have had any decisive effect on the vitality of the sycamore maples. Aas (2009, S. 8) even maintains that sycamore maples profit “from changes in location such as eutrophication”. Although the changes in the nutrient cycle by alpine pasturing does not have an influence on the sycamore maples´ vitality, the pasturing of “Großer Ahornboden“ very well has a mechanical impact on the vegetation. Grazing animals rub themselves at the sycamore maples´ trunks and cause damages there, „young trees being more susceptible to damage“ (Tappeiner, 2007a) and consequently are more likely to die than older trees. This may be, because they have a smaller circumference so that a certain proportion of bark damaged or removed represents sooner a higher risk. It should be mentioned in passing that the rubbing also removes lichens and bryophytes up to a stem height of 1.5m (Tappeiner, 2007a), among these possibly also rare species like *Tayloria rudolphiana*. During my field inspections, among the two hundred sample trees, I detected twelve sycamore maples with above-ground roots and nine sycamore maples with damages to superficial roots. Intensive cattle grazing probably also results in damages to the fine root system of the sycamore maples (Kutschera & Haselwanter, 2000; Wairiu et al., 1993). Especially in groundwater-influenced, wet areas, damages must be expected because in these areas the sycamore maple´s shallow root system is very pronounced. Root damage by cattle grazing not only impairs tree vitality (FUST-Tirol, 2002), these primary injuries facilitate secondary damage by fungal infestation (Tappeiner, 2007a).

Fungal infections are an influential factor and may contribute to tree mortality considering how many living and dying trees are infested by fungal pathogens. Despite the knowledge about this

correlation, in the framework of this master thesis it was not possible to determine how many trees at “Großer Ahornboden” have died since 2001 due to fungal infestation. Apart from only two sycamore maples on which the author detected the fruiting bodies of the fungal pathogen of red pustule disease (*Nectria cinnabarina*) , no data are available about which trees were also infested before they died, and which became fungal hosts only afterwards.
Sycamore maple is often described as a species that well adapts to current and also to predicted future climatic conditions in western Europe, where elevated temperatures and reduced precipitation must be expected (Kölling & Zimmermann, 2007; Neophytou et al., 2016). Thus, its vulnerability to climate change, at least at “Großer Ahornboden”, should be minor and the mortality rate of its population is not expected to change much by climate change.
As discussed in 2.3.2. the sycamore maple has an intensive heart sink root system which allows strong and deep rooting. Thanks to this characteristic the ancient trees thrives on the gravelled areas. They root in fine-grained sediments although they are buried by debris-flow gravel. In line with this, an overlay of all trees recorded dead at Großer Ahornboden shows no conspicuousness in terms of a denser mortality cluster where soil conditions are poor or where Engergrundbach left its streambed. Peter Zangerle (2007) even noted in his studies on the influence of over-graveling events on a high mountain forest ecosystems of the Karwendel that sycamore maples “presumably due to the strong competition from spruce and mountain pine (Pinus mugo) [cannot] emerge“ outside overgravelled areas.

Ancient trees and dead wood

Historically, the value of ancient trees has often not been recognised, and mostly the value assessment of trees concentrated on a flawless appearance, sparkling vitality, and the economic timber value. This attitude has experienced a profound cultural shift towards the insight that an ancient tree has values beyond money. Today, they are indicators of a sustainable forest management and are revered (Zapponi et al., 2017). The great fascination, strong appeal and particular charisma the LPA “Großer Ahornboden” to a large extent excerts from the large-diameter trunks of living or dead sycamore maples (Nilsson et al., 2002) against the picturesque mountain backdrop.
Targeted replanting is important. A young tree, however, cannot fulfil the diverse and complex functions of a veteran tree, or as ecologist Oliver Rackham says, “even thousand 100-year-old oaks are not a substitute for one 500-year-old oak”. Sycamore maples take many years to develop microhabitats like cavities in branch forks or the stem. I observed a correlation between the sycamore maple´s age, the DBH, and the number of microhabitats, while other authors report an increase of microhabitat structures unattached to an increasing DBH (Barkman, 1969;

Michel & Winter, 2009; Vuidot et al., 2011). Apart from the tree age and the DBH, a reduced vitality also seems to have a positive impact on the structural diversity (Vuidot et al., 2011). Furthermore, the installation of nest boxes at “Großer Ahornboden” has artificially created additional microhabitats, which reduces the competition for nesting sites among cavity-nesting birds such as the Pied Flycatcher (*Ficedula hypoleuca*).

To secure a large overlap of life spans, the degradation and loss of ancient trees must be avoided, existing veterans´ lives must be prolonged to give younger trees time to grow up. Also, because natural regeneration is scarce in the area (2.3.1.), the conservation of old trees represents an important pillar for securing the production of genetically valuable saplings. Many sites face shortages of suitable regeneration material, which often is a problem for successful active restoration and regeneration (Cernansky, 2018; Löf et al., 2019). The number of threatened and endangered forest tree species is globally resulting in the responsibility for an increased genetic conservation (Jacobs et al., 2013; Jacobs et al., 2015; Potter & Hargrove, 2012).

Dead wood is another important component of temperate forests (Bauhus et al., 2018; Hararuk et al., 2020). Standing dead trees, fallen logs and large branches and stumps form major structural features of ecological importance of the wooded pastures at “Großer Ahornboden”. It is assumed that a complete removal of dead wood from a woodland would result in the loss of up to 20% of the species (Read, 2000).

Old and dead wood continuity in the medium and long term is regarded secured at “Großer Ahornboden“, because of the age structure and the interdiction to remove dead wood from there. Probably, microhabitats and special structures will increase further with more sycamore maples getting old.

Regeneration

To maintain the indisputably valuable “Großer Ahornboden“, in the long term it will not suffice to maintain the old stock of sycamore maples, but new plantings are necessary.

Already in the middle of the 19th century, people reacted to a declining sycamore maple population with replanting and hereby obviously focused on the area that today is assigned as exclusion area. The total number of these plantings is not conclusively clarified. To compensate for replanting failures and mortalities of ancient trees, the MMP demanded fourteen sycamores maple plantings a year, but only 71 plantings have been documented since 2001. This means that the proposed measures have not been implemented to safeguard stock, and today new plantings are of utter importance.

Young trees should be planted before the ancient ones are lost to guarantee for a range of age classes and to prevent that today´s problem of an overaged population must be faced again in

hundred years (Figure 31). However, “Großer Ahornboden” does not need sycamore maple plantings every year. Read (2001) suggests regular gaps of about ten years between the planting of cohorts. The number of plantings must allow for failures because not every young tree that establishes itself or is planted will survive through several centuries to become an old tree.
On the plus side, one can note that the measures of the MMP seem to be successful. The aim of reducing the failure rate of replanting from 40% (9 trees/a) in 1962 to 25% in 2001 (6 trees/a) was exceeded by far. 2001-2022, only 61 young plants have failed to grow (3 trees/a), and these were planted before 2001. All new plantings since 2001 have thrived, and in general all sycamore maples planted are in a good condition. According to my observations, the main obstacles to a healthy development of the young sycamore maples are competitive accompanying growth and secondary tree species in the fences and, above all, browsing. Although young sycamore maples can survive the browsing of young shoots and buds (Ammer, 1996; Hein et al., 2009; Höllerl & Mosandl, 2009), their height growth can become disturbed permanently. Accordingly, in the first years after replanting, new trees must be closely monitored to start appropriate protection measures in time. Fencing is generally effective against browsing. However, browsing animals can put their heads through the wire netting. Although it is labour-intensive and costly, it might be an effective measure to reinforce the fencing around individual trees with smaller gauge mesh. The browsing impact could also be reduced by reducing the populations of game (by hunting) or increasing the forest landscape carrying capacity (more food for the game) or combining these two approaches. However, fencing is the most targeted and reliable option. Furthermore, replanting at “Großer Ahornboden” must be in accordance with its unique landscape. Especially the typical structures of stocked and unstocked areas at “Großer Ahornboden” must be maintained. Young trees must not be planted too close to veterans so that they do not grow up to interfere with the older ones. They should be of a similar genetic origin to those already on site, either by using planting material from Hinterriß or by natural regeneration of sycamore maples, which I observed at a few places.

Figure 31*: Best practice example of a planting to maintain the typical structures of stocked and unstocked areas at "Großer Ahornboden". First, the young tree is planted not too close to the ancient tree. Second,it is of a similar genetic origin and the browsing impact is reduced by fencing. Third, the young sycampore maple was planted before the ancient one is lost. Source: Author.*

Ecologically relevant observations and management aspects

To ensure the best outcome for vulnerable biodiversity (wildlife dependent on dead or decaying wood, saproxylic fauna, *Tayloria rudolphiana*, f.e.) new planting or tree establishment proposals should not only consider the maintenance of the typical landscape structure. To reduce the risk of fragmentation or isolation and to create appropriate habitat conditions, connectivity metrics instead of density targets should be the driving target. Therefore, a range of agreed threshholds are required. For example, the probability of occurrence of rare species *Tayloria rudolphiana* decreases with the number of trees being further away than fifty metres from a focal tree (Kiebacher, 2017). Also, a dynamic mosaic of trees, grass and shrub habitats are much richer in biodiversity than pure sycamore maple stands.

Therefore, some single native tree species should grow among the sycamore maple population and flowering shrubs should be included at the edge of the measure are. According to Czell (1966), a share of 10% mountain elms (*Ulmus scabra*), beech (*Fagus sylvatica),* downy birches (*Betula pubescents*), and rowan (*Sorbus aucuparia*) is appropriate. Ancient and other veteran trees can also be found outside the wooded pasture of Großer Ahornboden. They are important biodiversity stepping-stones and provide long-term natural capital and centuries of ecosystem services.

This thesis is not intended as a species appraisal or a treatise on the ecology at "Großer Ahornboden". Nevertheless, an assessment procedure for both habitat and vitality of sycamore maples has been created which is different to most tree control sheets that focus either on existing damage symptoms or on the assessment of the ecology of trees.

There is hardly another being with the structural complexity and biomass ancient trees have accumulated over the centuries (Blicharska & Mikusiński, 2014). Thus, they provide habitats for numerous species. Some of the species of fungi, bats, birds, lichens and insects associated with ancient and hollowing trees are endangered, such as *Tayloria rudolphiana* and the long horn beetle *Ropalopus ungaricus* (Kašák & Foit, 2018; Kiebacher, 2016a; Ranius & Jansson, 2000). But also, vertebrates like the Pied Flycatcher are important for a wholesome ecosystem. The presence of the rare and endangered Hungarian bark beetle (*Ropalopus ungaricus*) has so far not been proven at "Großer Ahornboden". However, during field inspection, the author detected damages like those depicted by Kašák & Foit (2008). After contacting one of the authors, it was confirmed that „probably one damage is caused by "goath moth" (*Cossus cossus*), but part of the galleries very probably belongs to *Ropalopus ungaricus* [Figure 32]."

In the field work for their study (Kašák & Foit, 2018), the authors also detected few *Acer pseudoplatanus* trees which were colonized by both species, but these trees were deleted from the dataset later (Kašák, 2022). There are only old records about the distribution of this long horn beetle in Tyrol and knowledge "about the recent distribution of Ropalopus ungaricus in Austria would be beneficial" (Kašák, 2022).

Figure 32: *Sycamore maple with insect damages: Circle 1 – Probably a part of the gallery belongs to* Ropalopus ungaricus*; Circle 2 – Probalbly caused by "goath moth"* (Cossus cossus)*. Source: Photo by author, comments in red by Kašák, 2022.*

Epiphytic bryophytes and lichen communities at “Großer Ahornboden“ have been studies intensively. Bryophytes and lichens belong to different taxonomic groups (Green & Lange, 1994), and they can be encountered on nearly every tree at “Großer Ahornboden”. The extent of their populations and the composition of the taxonomic groups differ, however. According to my observations in the field at “Großer Ahornboden”, sycamore maples of high vitality are rather covered with lichens and those of reduced vitality with bryophytes. When bryophytes and lichens covered the trees in roughly equal proportions, their state of vitality was balanced, too (Figure 33).

Apart from the correlation of coverage and vitality, I further observed a correlation between tree age and coverage (Figure 34). Younger sycamore maples show a higher rate of lichens cover, older trees are more likely to be covered by bryophytes. This observation is confirmed if one compares the proportion of epiphytic flora of bryophytes and lichens with the age structure of the total population. Clearly more than half of the sample trees were covered with bryophytes as the dominant taxa and in 2022, old trees accounted for two thirds of the total population at “Großer Ahornboden”. For young sycamore maples, a quantitatively corresponding statement applies. How come? First, older sycamore maples tend to have a rougher bark, a larger diameter (Ulyshen, 2011) and more damages, so the phenological tree age of these trees may be the decisive factor (Fritz et al., 2009). Bark fissures are positively correlated with bryophyte growth, which is not true for lichens (Kiebacher, 2017). Second, the differences in coverage could be explained by the light condition within the trees which is influenced by tree architecture, stand density and sun-light exposition. While bryophytes are likely to benefit from more shady and humid microclimates, lichens tend to colonise in brighter and more open conditions (Sales et al., 2016). In the areas with a loose stand structure at “Großer Ahornboden”, light availability also correlates with tree age. The crowns of young trees tend to be more light- and air-permeable.

Thus, it is an interesting fact that less vital sycamore maples have a more transparent crown, and consequently the light penetration through crowns is higher, too, but still their lichens cover is smaller. Other factors important for epiphyte distribution are bark pH, chemistry, host tree species and temperature (Fritz et al., 2009; Király et al., 2013; Spier et al., 2010).

This thesis did not consider these factors in more detail, but they may have been drivers behind the observed patterns. However, the stated patterns are empirical observations and the significance levels of age and vitality, e.g., on the epiphytic flora have not statistically been proved. So far, studies on epiphytes and lichen communities at “Großer Ahornboden“ are based on randomly selected trees. An interesting further research approach would be the systematic survey of the *Tayloria rudolphina* population and of the differences of the individual coverage types, and then try and find correlations to other factors. For example, at “Großer Ahornboden“ light conditions vary, some trees are in the shade until noon even in the summer, and the trees´ age has a broad range. Moreover, the presence of *Tayloria rudophiana* in Rißtal and at “Kleiner Ahornboden“ has been recorded but not been mapped for a long time (Kiebacher, 2022).

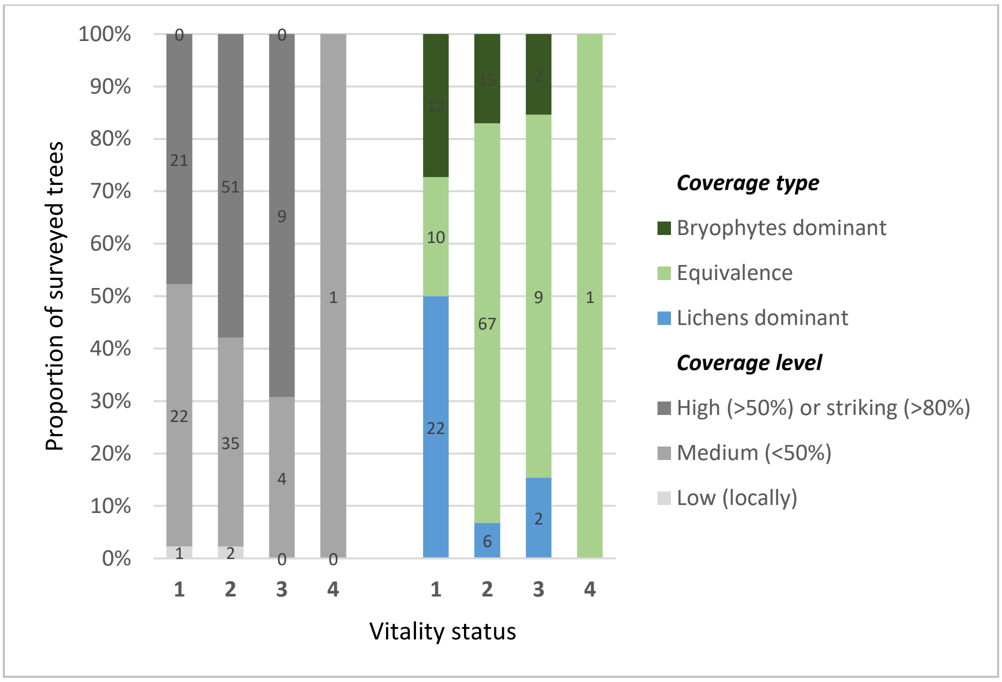


Figure 33: *Relationship between epiphytic coverage and vitality of sycamore maples at “Großer Ahornboden”. Source: Author.*
The proportion of trees with higher coverage levels increased with decreasing vitality (left). The category of healthy trees includes higher proportions of sycamore maples which have a dominant coverage with either lichens or bryophytes than the lower vitality classes 2-4. In the group of healthy trees 50% are principally covered by lichens and >34% especially by bryophytes. At lower vitality classes trees that are covered by bryophytes and lichens in roughly equal proportions is predominant. The relationship between vitality and a dominating lichen-coverage is non-linearly decreasing with decreasing vitality. The effect of vitality is stronger on lichens communities than on bryophytes. Class 4 contains only one tree. Therefore it may not be representative. Visually estimated coverage level (right). Source: Author.

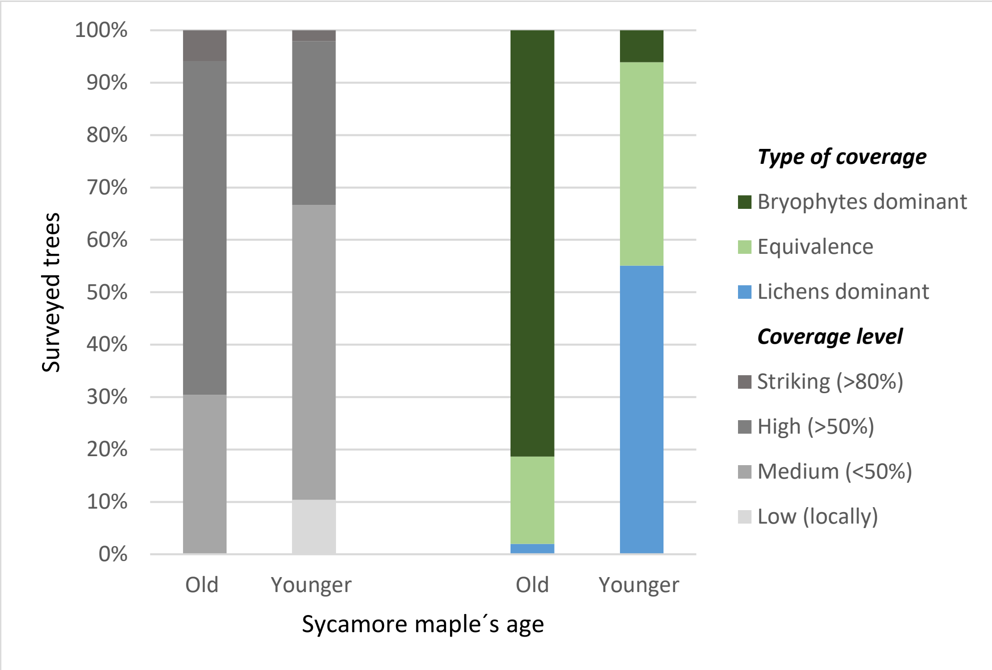


Figure 34: *Relationship between epiphytic coverage and sycamore maple´s age. Source: Author.*
Coverage levels of younger and of old trees differed. Younger trees were less covered with epiphytes than older trees. Approximately two third of the younger trees were assigned to coverage classes "low" or "medium"; about two third of older trees had highly or strikingly covered trunks, none showed a low coverage level (left). Older trees were covered mainly by bryophytes, while a covered by lichens is rarely determining. The proportion of younger trees dominantly covered by bryophytes was low. Lichens communities were dominant on younger sycamore maples (right). Fern, Tayloria rudolphiana, epiphytic young trees or flowering plants were only observed on old trees (additional information).

"Großer Ahornboden" is an important retreat not only for insects like the long horn beetle or plants like *Tayloria rudolphiana* but also for invertebrates. For the European Pied Flycatcher, for example, the single layer, loose tree population structure with many ancient sycamore maples, which offer numerous micro habitats, represents an almost ideal habitat (Naturpark Karwendel, 2013). Throughout its life, this migratory bird returns to its birthplace for breeding. *Ficedula hypoleucus* is assigned to threat category LC (least concern) of the "List of Austrian bird species" (Avifaunistische Kommission Österreich, 2021) whereas the Bavarian Red List already has it on the pre-warned list and Germany-wide it is classified as endangered (LfU, 2022). Its population at "Großer Ahornboden" already today plays a central role for the conservation of a viable European population. The presence of the Pied Flycatcher in the LPA is classified regionally as "very important" and as "significant" for its European population (Amt der Tiroler Landesregierung, Abt. Umweltschutz, 2015). Not only biocide use, the thinning of forests, and the decrease of cavity-rich old wood stock but also climate change contribute to a reduction of food and nesting sites and put a strain on native birds. The Pied Flycatcher is regarded as a model species to understand the impact of climate change on the populations of small migatory birds. Because spring in Europe now begins earlier, many of the scarce nesting sites are already occupied by non-migatory birds like the Great Tit. In addition, many insects have adapted their development cycles to the earlier onset of spring which leads to a mismatch between a high food supply for birds and the breeding period. Pied Flycatcher can be selected as Bird of the Year 2023 and thus has the chance both to draw attention to its need for protection and to the challenges of climate change (LBV, 2022).

The LPA “Großer Ahornboden“ has currently probably large enough for the conservation of viable populations of species groups specialised on the sycamore maple (Bergman, 2006; Forbes et al., 2005), but if such historic landscapes and species-rich habitats disappear we lose history, culture, wildlife and landscape beauty.

5.1.2. Cooccuring use, protection interests and potential conflicts

It is a great challenge, but also an enormous chance, to maintain and promote the economic viability of pastoralism, the high aesthetic and functional value of the landscape and the biotic communities in need of protection and conservation at the same time.

The use and protection interests at „Großer Ahornboden“ can come into conflict or cause trade-offs, therefore “the various interests of agriculture, tourism, and environmental protection should be discussed and integrated” (Schreiner, 2004). The COVID-19 lockdowns, f.e., have demonstrated the need for more open space, with current lack of accessible areas in urban communities contributing to over-use and damage of statutorily-protected sites by recreational pressure. Also, 2001 the landowners prevented replantings because they were afraid of losing to much of the pasture area.

The situation does not allow for simple solutions. The interest groups must consider each other´s arguments seriously and a cooperation between the disciplines can provide a win-win situation. It contributes to sustain the tree-related biological and cultural heritage at “Großer Ahornboden” and, at the same time it supports the economic drivers of the region - tourism and recreation - and the extensive grazing allows for cash-flow of income. On the one hand, alpine farming has an essential function for the preservation of the cultural landscape at “Großer Ahornboden“. It prevents scrub encroachment (Zapponi et al., 2017). On the other hand, Karwendel Nature Park, for example, has been contributing, too, by replanting and taking care of young maple trees. In principle, all those involved in the LPA of “Großer Ahornboden“ strive for a mutual positive attitude and appreciation. This is a great advantage, because a coordinated interdisciplinary use of land and a long-term planning will be necessary to maintain this fragile (Hertel, 2009) and unique grazing system and its sycamore maple population.

5.2. Calculated vitalities with the proposed estimation procedure

In the following, I would like to describe some difficulties of assessing nature and its complex processes correctly, using the example of sycamore maple vitality. By implementing a variety of vitality-related parameters, averaging, and assigning the trees to the four vitality classes, I tried to account for the complexity of nature and to make the vitality assessment less susceptible to subjectivity.

To create a reference data to countercheck the results of laser data analysis, for two hundred sycamore maples the trees´ vitality was assessed based on a set of recorded field data.

As a result, within the framework of this master thesis, an estimation procedure (3.5.1.) has been developed: First, various parameters related to tree vitality and tree health were collected for each of the two hundred sample trees. Second, an evaluation scheme was created. The single parameters were assigned to a value between -1 and 4. The higher the value, the stronger the indication for a reduced vitality or stressor. Third, the mean value of all single parameter values of each individual sample tree and thus its vitality value was calculated. Fourth, the calculated vitality values were divided into four classes. I assumed that the combination of the many different tree attributes allowed a comprehensive insight into the tree´s vitality, even if some values were missing.

Reviewing the data, I found that I had assigned the remark *Prüfe 23* to six of the two hundred sample trees, when collecting the vitality parameters for the vitality estimation scheme in the field. *Prüfe 23* means that the tree´s condition must be checked in 2023, because I assumed from its overall appearance on site it might be dead until then. Subsequently, I wondered whether the results of the proposed vitality estimation scheme for these six sycamore maples were coinciding with those clear field estimates, because then I could be quite sure that the results were resilient. The remark *Prüfe 23* should coincide with the calculated vitality value "4". Interestingly, none of the six trees was classified as seriously weakened ("4"). Four of the six trees were ranked slightly weakened and two trees as weakened. However, all trees were at least estimated less vital than the average old tree (Figure 35, Table 21).

A vitality estimation directly on site is not one-to-one comparable to the vitality value calculated with the proposed methodology. There will always be situations in which the human mind can make an assessment that better reflects reality than any standardized assessment procedure. In view of the unique tree personalities at "Großer Ahornboden", and here especially the veteran sycamore maples, any standardized assessment form can easily produce errors.

Are the calculated vitality values of the sample trees reliable and appropriate as reference data to countercheck the results of the laser data analysis?
In my opinion, the vitality of the sycamore maples at “Großer Ahornboden“ must be assessed holistically and individually in the field. Only then, the results are meaningful and resilient.

Table 21: *The table shows the six sample trees which were assigned with a remark to check the trees´ condition in 2023. All these trees belong to the old stock. The mean calculated vitality for all older trees was 1,5 ($mean_{older}$=1,5) - the vitality of all trees shown is below average. The column "Ranking" represents the ranking of tree vitality for the 200 sample trees. The least vital sample tree ranks 1. Source: Author.*

Probe_ID	Ahorn_ID	Remark - holistic visual inspection	Age class	Vitality level	Ranking
180	8102	Prüfe 23	older	1,6 (slightly weakened)	58
61	5182	Prüfe 23	older	2,0 (slightly weakened)	17
52	2127	Prüfe 23	older	1,8 (slightly weakened)	34
46	1658	Prüfe 23	older	2,1 (stressed)	14
116	583	Prüfe 23	older	2,5 (stressed)	3
119	347	Prüfe 23	older	1,75 (slightly weakened)	42

Figure 35: *From left to right: Ahorn_ID 1200, Probe_ID 171: Vitality level 1 (exact value = 0,25); (Ahorn_ID 521, Probe_ID 198: Vitality level 1 (exact value= 0,38); Ahorn_ID 583, Probe_ID 116: Vitality level 3 (exact value = 2,46); Ahorn_ID 1421; Probe_ID30: Vitality level 3 (exact value = 2,5). Source: Author.*

5.3. Biases of this master thesis as well as the respective strengths and weaknesses of field assessment, laser data analysis and orthophoto interpretation

Assessment of the tree population

This thesis focused on assessing the current population of the sycamore maples at “Großer Ahornboden“ and their vitality and on creating a clear and reusable tree cadastre with the information gained. Both, the methods of aerial photo interpretation, and the structure of the tree cadastre are based on those of the MMP to safeguard the comparability of the results of this thesis and the results of the reference period 1953 to 2001. The data base provided contains quantitative, qualitative, temporal, and spatial criteria on the sycamore maple population at

"Großer Ahornboden" and should allow conclusions to be drawn about possible patterns of changes.

The first unexpected difficulty arose regarding the quantity of sycamore maples. In literature, figures fluctuate (Figure 10, Table 22). Czell (1966) recorded 2444 trees in total: 2409 sycamore maples, ten beeches, six mountain elms, three spruces, and 264 dead trees. In retrospect, the total number of *Acer pseudoplatanus* must have been 2600 to 2700 trees at the beginning of the 19th century. Czell (1966), however, also mentioned a recorded number of 1285 sycamore maples from another survey in 1927 and explained the enormous difference by a smaller survey area. This is no satisfying explanation for the doubling of the number. The next survey was conducted during the creation of the MMP which recorded 2217 sycamore maples. By using the age development diagram of the MMP (p.25), the result of my calculation was 2080 sycamore maples in 1953. It is impossible to explain the inconsistent population size recorded by Czell (1966) and the MMP in retrospect. In the framework of this master thesis, 2427 sycamore maples were calculated, a number comparable to that of Czell (1966). The quantitatively higher number compared to that of the MMP can mainly be explained by the addition of point features in more densely stocked areas and the fact that sometimes two closely standing trees were mapped as one.

Table 22: *Discrepancies concerning the stock size of the sycamore maple population of "Großer Ahornboden".*

Year	**19th cent.**	**1927**	**1953**	**1966**	**2001**	**2022**
Source	***Czell***	***Czell***	***MMP***	***Czell***	***MMP***	***Fladerer***
Number	~2700	1285	2080	2409	2217	2427

For the survey, the strengths of laser data, orthophoto and field inspection were combined. During the evaluation of laser data and orthophotos, the author noted the following advantages: No changes in vegetation but fixed images, it allows viewing of the study area remote no matter the time and how often, no time-intensive orientation search, no travel time. The data analysis was also well-appropriate for determining solitary trees, strong crown thinning and for differentiating large from small tree crowns.

Orthophotos also make a visual time travel over decades possible to the effect that vitality changes can be retraced in retrospect (especially when changes have become conspicuous and shadow cast and tree crowns were easily recognisable), even though the continuous changes of the long-living sycamore maples often proceed imperceptibly slowly by human standards. Additionally, CIR aerial images often help to identify older coniferous trees by colour, laser data help to differentiate sycamore maples and coniferous trees by the crown shapes. Compared to aerial orthophotos, laser data is a better instrument to identify small trees hidden under the canopy of large trees and to identify the number of trees standing closely together. Furthermore, it is possible to position the points of the GIS programme at the base of the tree whereas the points for the aerial orthophoto analysis must be positioned in the middle of the crown, which makes the location of lopsided trees only inaccurately identifiable and complicates the orientation in the field.

Orthophotos and laser data, however, seem not to be reliable for tree species assessment if they are younger trees or deciduous tree species. Other potential errors when assessing the tree population by orthophoto analysis include: First, the omission of trees or dead wood located under a closed canopy cover or in the shadow cast and, second, poorly visible crown separation. Third, young trees or dead wood are easily overlooked or confused with shrub and thus must have a certain minimum size to be recognised. Tree stumps are rarely recognisable on orthophotos. Fourth, the distinction between a vital and a dead tree is rather difficult when the crown retrenchment is very advanced. Fifth, some point features were registered as vital in 2001 but I could not infer evidence for their existence from the orthophotos. In such a case, it is difficult to determine if a point feature is falsely set or if the point is out of place or where there was a vital tree in 2001 but none in 2022.

Despite all preparatory work, the terrestrial control effort was immense to assign all sycamore maples to the categories living or dead. For the 2022 survey of the sycamore maple population in the field, I first focused on an accurate mapping of all vital trees as well as the detection of coniferous and deciduous tree species.

The identification of dead wood and tree mortalities turned out to be particularly problematic as mistakes made were not possible to identify even with rework in the field. Due to the discrepancy of the figures regarding the population size described above, I tried to countercheck the registered mortalities for the period 2001 to 2022 with all trees registered vital for the period 1953 to 2001. I assumed that all point features not mapped as vital in 2022 should be able to be detected by a tree stamp, a standing dead tree, or any other remnants of a dead tree. Although the decay rates of logs show a high variability depending on tree species, temperature and precipitation (Hararuk et al., 2020; Sedlar et al., 2021), residence times of 27 years for *Fagus sylvatica* (Hararuk, 2020) to more than 170 years for old oaks (Read, 2000) have been reported. Nevertheless, evidence could not be found for all dead trees in the study area. Dead wood or stumps may have been removed or the point features set in the previous assessment did not coincide with the true location of the trees (Figure 36). At the same time, the long perseverance of dead wood makes it difficult to conclude from the signs of decay whether the tree died before or after 2001 (Figure 37). In addition, a few trees among those previously assessed dead, in

2022 have been found to be alive during field inspection (shoots at the tree base or at the top of dead standing wood, e.g.). Without remnants of dead trees however, there is no conclusive scientific evidence supporting my statement concerning losses within the sycamore population. Consequently, the statistics of mortalities must be analysed with some caution.

The assessment of orthophotos forms a solid basis for the survey of a tree population but will never be as accurate as a counting and mapping of trees on site (4.1.1.). This is especially true in those areas where trees are not solitary. During the creation of the MMP, there were field inspections, too. Therefore, one can assume that the sycamore maples recorded then represent the true status of the tree population in 2001 at "Großer Ahornboden", although I could not confirm all results of the 2001 tree cadastre in my evaluation of the orthophotos. Only in exceptional cases, where a clear contradiction was visible, I took the liberty of changing the 2001 tree register (Figure 38).

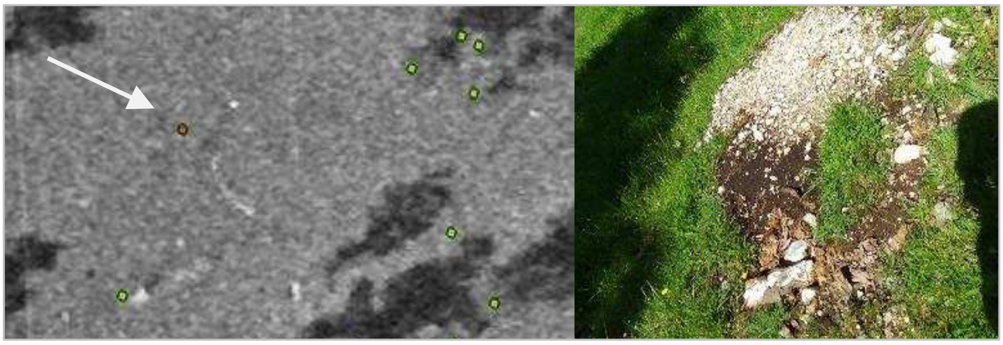


***Figure 36**: Difficulties in the verification of mortalities, example 1&2. Example 1 (left): Point out of place – The tree was registered as vital in the 2001 tree cadastre. At this location, no tree is visible in the orthophotos 1954 and 1974. I assigned the point feature to the tree shadow in south-eastern direction. The tree had died in the period 2001-2022 (green point- vital tree 2022; brown point – mortality after 2001). For other trees, the assignment was much more ambiguous. Example 2 (right): At some locations it seems as if stumps had been removed. Source: Orthophoto Land Tirol, Author.*

***Figure 37:** Difficulties in the verification of mortalities, example 3: The long perseverance of dead wood made it difficult in the field to conclude from the signs of deterioration whether the tree died before or after 2001. The dead trunk of sycamore maple ID 543 is visible on the orthophoto 2001 (left) as well as on the orthophoto 2019 (right). Source: Orthophoto Land Tirol.*

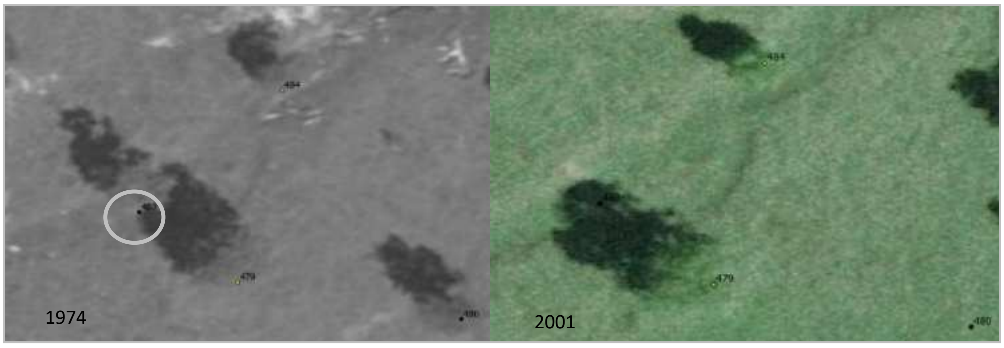


Figure 38: *Difficulties in the verification of mortalities, example 4: Tree status was adapted for the year 2001. Sycamore maple ID 483 was assigned as vital in 2001. I could not verify this observation –comparing the orthophotos 1974 and 2001 it is more reasonable that the tree had died before 2001. Source: Orthophoto Land Tirol.*

Even if exact quantitative statements are difficult to make, the visual comparison of the orthophotos of 1974, 2001, and 2019 proves a decreasing stand density. The crown widths within the old stand also have decreased, an observation that coincides with the calculated high number of mortalities of old sycamore maples. The young sycamore maples are developing well (Figure 39).

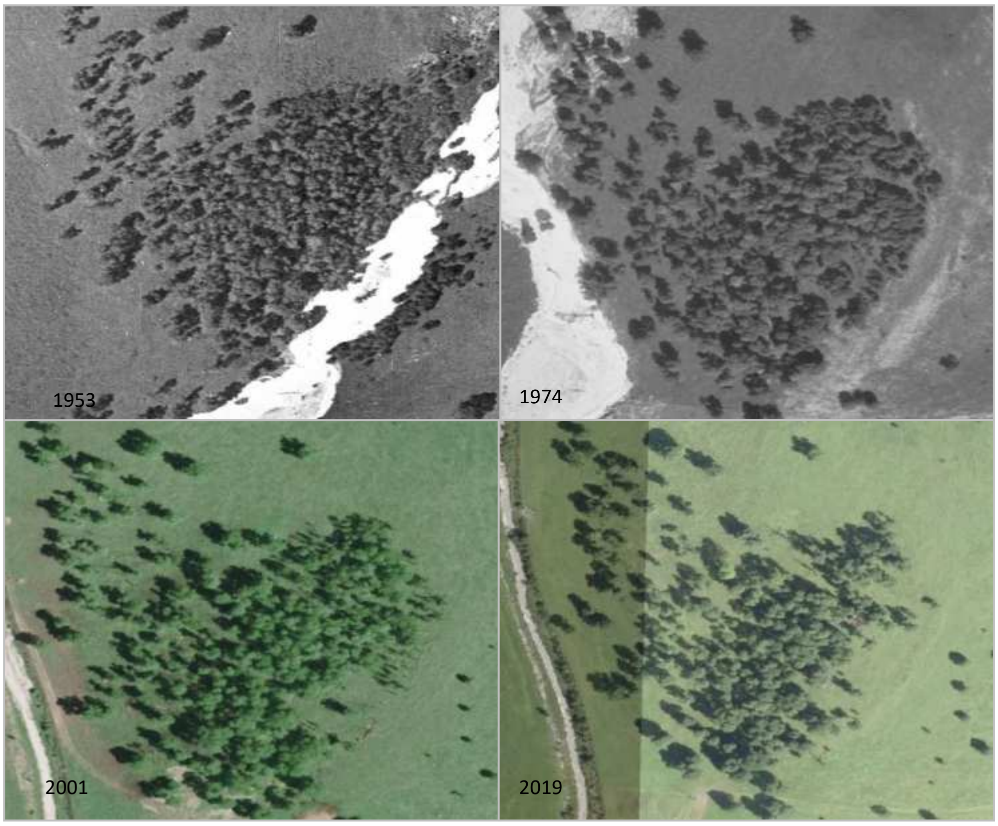


Figure 39: *Stand density and crown volumes of old sycamore maple trees decreased from 1953 to 2019. Source: Orthophoto Land Tirol.*

Estimation of the sycamore maples´ tree age

The distinction between age classes in the tree cadastre is a useful tool to identify age gaps arising from losses in the population. The more so as a sound knowledge about the age structure there is important for upcoming conservation interventions, for managing population sustainability, the conservation of habitat and dead wood continuity, and thus the reduction of losses of specialised species. An accurate and consistent statement about the sycamore maples´ age was a challenging task, no matter which method I used.

The MMP concluded from shadow cast to the appoximate tree age which was divided into the classes old, middle-aged, and young, which in turn correspond mostly to the size classes large, medium-sized, and small. Especially the distinction between young (respectively small) and middle-aged (respectively middle-sized), I found to be very subjective.

Therefore, for the sycamore maple population at "Großer Ahornboden", the definition of unambiguous criteria for age classification was lacking.

Methodologically, it would be conceivable to distinguish between sycamore maples that belong to the old stand and sycamore maples that have originated from replanting or regeneration efforts since the 1960s. The MMP and other studies use tree sizes such as crown width or DBH as indicators for tree age (Nascimbene et al., 2009). This can be misleading, as tree size and DBH are frequently not closely related to tree age (Boudreault et al., 2000). Several studies and tree assessment forms use the phenological age rather than tree height for age determination. The author applied this method in the field, too (Appendix II). Young, mature, and ancient trees can clearly be distinguished based on a few criteria such as flowering ability, bark condition, and branching pattern in combination with tree size and proportions. For example, in youth, sycamore maples grow strictly monopodial and acrotonic (Aas 2009, S. 8). At this stage, the tree grows up to two metres per year (Aas 2009,p. 8). From an age of thirty years, sycamore maples start to flower and form fruits, solitary trees already from an age of 15 years (Rohmeder, 1972). From this point, shoot growth is changing (Aas 2009,p.8) and due to regular branching, the typical appearance of old solitary sycamore maples develops. Also, the bark shows a distinctive feature. For many years, it is golden brown and smooth (Aas 2009,p. 9). Old sycamore maples get a scaly bark, which is the reason for its epithet `pseudo-platanus´ ("like a plane tree").

Vitality assessment and ecological parameters

The third method, apart from orthophoto and laser data analyses, was field inspection. In comparison to orthophoto and laser data analyses, the inspection on site was much more time-consuming. Not only measuring the tree crowns in two directions and the handling of the different devices turned out to be very time-intensive but also the registering of defects and ecological parameters. In addition to the walking time and the time to identify the right reference sycamore maple, the pure assessment time took about fifteen minutes. Nevertheless, during field assessment, information was gathered that neither orthophoto interpretation nor laser data analysis could provide, such as ecological or vitality-related parameters.

There have been long-lasting and ongoing discussions about the adequate definition and use of the two terms *vitality* and *tree health* in terms of vitality assessment. Often, foliage loss is used as the main parameter for assessing the health of trees (Allikmäe et al., 2017; Dobbertin et al., 2016; Gehrig, 2004; Tinner et al., 3013; Weihs, 2017a). This thesis has claimed to find further meaningful parameters. As a tree cannot verbally communicate its state of health, its outward appearance must serve. Starting from a conceptual ideal tree, defined as the best tree with full foliage that could grow at a particular site considering factors such as altitude, latitude, tree age, site conditions and social status, each deviation or abnormity then is an indicator of vitality loss. Genetic differences, however, of single tree individuals with the same degree of vitality can cause differences in phenology, growth curve, reproductive capacity, or resilience against pathogens (Dobbertin et al., 2016; Gehring, 2004) and the foliage condition is subject to natural fluctuations of unknown extent. Especially the factor of site conditions can lead to misjudgements of vitality. Ellenberg (1995) points out that “normal“ crown transparency varies very strongly from site to site, and a direct and large-scale comparison is misleading. On favourable sites, tree vitality is overestimated and vice versa. Also, age-related and stress-related changes must be distinguished correctly (Weihs, 2017b).

In the literature, visual and terrestrial methods to assess tree vitality are assumed to be appropriate if rough measures, even if they are subjective. Within the course of this master thesis the following specific issues in assessing tree vitality emerged:

First, the field work started early in spring when foliage shoots on the sycamore maples at “Großer Ahornboden” had not yet fully developed, which might have caused systematic observation errors. Nevertheless, I attempted to draw meaningful conclusions about crown transparency by making statements about later foliage quantity based on bud sprouting. Also, symptoms for leaf diseases and pathogens might not have developed sufficiently for detection and identification and not be registered. Second, a prolonged vegetation period was used as an indicator for a high tree vitality pl (Plietzsch, 2017). It can either be prolonged by an early budding in spring or late leaf shedding in autumn. The study period of this thesis did not include the leaf shedding period and had to be limited to the period of leaf budding and sprouting. Third, the assessment of a potential habitat or damage was limited to the directly visible environment, therefore, for example rotten spots inside the stem could not be considered in this master thesis. Fourth, parameters that are assumed to be related to tree vitality like observations on tree phenology, fructification, fungal or insect infestations may be more likely to be predicting a decreasing tree health than indicating a reduced vitality (Seidling, 2019).

Other influential facts are, that the author is no expert in tree assessment and that conventional tree assessment formulars did not reflect all attributes of the sycamore population. Accordingly, after each field excursion, I updated my assessment procedure and adapted it to the tree personalities at "Großer Ahornboden". This allowed a more exact recording of vitality and ecological characteristics. The drawback is, however, that the results for the sample trees that were examined in the beginning can be compared only with reservation to those of the last trees examined.

Supplementary, the measurement of the tree growth could have been a useful tool to assess tree condition, because it is closely linked to the tree age and vitality. However, *growth* can be measured on different parts of a tree. In the literature, mostly the breast height diameter (DBH) is used as growth indicator (Bachmann, 1999). So far, there are no comprehensive test series available for "Großer Ahornboden". Punctual or short-term measurement efforts are subject to the risk of being falsified by external factors like weather or nutrient fluctuations (Gehring, 2004). Only repeated and long-term growth measurements can be valuable and reliable elements to assess tree condition (Gehring, 2004). Basically, the increase of a tree diameter can be measured in retrospect, but then usually destructive methods are applied such as the removal of several stem slices or of cores (Bachmann, 1999). These methods were refrained from to avoid injuring or felling. According to the principle of allometric growth, growth parameters have a certain ratio to each other. These interrelations are species-specific, site-related, and different for each individual tree. For example, the ratio of height growth to diameter growth changes in relation to tree age or increasing nitrogen input (Bachmann, 1999). Non-competitive, less than ten-year-old sycamore maples show the greatest increment of diameter (Nagel, 1985). So far, in the literature, only few studies regarding the height growth of sycamore maples are available. There are clearly more about the more common European broadleaves oak and beech, which cannot be used as the growth curve of sycamore maples is different. Lessel (1950) graphically constructed first height growth curves using 77 trees. Further research on the height growth of sycamore maples was done by Hein et al. (2009) . For the future, a long-term study of the increment rates of the solitary sycamore maples at "Großer Ahornboden" could help to make statements about the associated vitality parameters.

Sample trees

The definition of strata and the systematic consideration of information known a priori were combined with the final and almost random selection of the individual sample trees, which was a compromise between several requirements. For a meaningful evaluation of the structural parameters and the vitality assessment, the reference data had to represent all age and height classes. A 100%-random selection of the reference trees would not have guaranteed that. Due to set selection criteria, the sample sycamore maples were not chosen entirely randomly in the population if also as randomly as possible.

The methods of selection used offer a representative picture of the sycamore maple population at "Großer Ahornboden" regarding spatial distribution (number of sycamore maples per measure area), disadvantageous environmental conditions in the exlusion areas, and the age structure. The selection of the sample trees is based on the results of the orthophoto interpretation (Orthophotos 2019), and thus does not entirely represent the population of 2022. A problem that could not be avoided. The small number of two hundred sample trees can be justified by the homogeneous environmental conditions in terms of topography, exposition, and climate at "Großer Ahornboden".

Chapter 6 – Conclusions

The sycamore maple wooded pastures at “Großer Ahornboden” are unique in terms of the diverse aesthetic, biological, and cultural values (Kirby, 2015) and “tell their own [hi]story“ (Kirby, 2015; Sonntag et al., 2019). They represent fragile ecosystems (Hartel et al., 2014) because they are intermediates between open pastures and closed-canopy forests. Precisely for this reason, it is important to keep an eye on the development of their sycamore maple population and to safeguard the existence and the integrity of this landscape and its multiple functions and values. The entire area of the Karwendel Nature Park enjoys legal protection. Thus, it is less vulnerable to the usual immanent threats that European landscapes face, for example, landscape and habitat fragmentation or the direct destruction of unique landscapes due to the construction of power plants, roads, and other large artificial structures. Also, eco torsos, damaged trees and dead wood are often removed in urban areas and near streets. All this is by and large not the case at “Großer Ahornboden” which, however, still faces certain problems.

Tree mortality as well as replanting or natural regeneration affect the landscape at “Großer Ahornboden” regarding the stand structure, stock size, and age class distribution, dead wood continuity and canopy gaps, e.g. Probably, the greatest threat to the ecological and aesthetic heritage of “Großer Ahornboden” are high mortality rates in combination with the absence of a next generation to replace dead ancient sycamore maples. Knowledge about population dynamics represents an important basis for the planning of a sensible and successful strategy to maintain the sycamore maple population at “Großer Ahornboden”. Considering the “unprecedented temporal scales (centuries)” (Lindenmayer et al., 2014) young trees need to become an ancient sycamore maples, the rejuvenation of the sycamore maple population should be addressed immediately. Therefore, management recommendations for wooded pastures often include the planting of new trees or the protection of natural regeneration to help close the generation gap (Bergmeier et al., 2010; Eriksson, 2008; Forbes et al., 2005). Conserving tree veterans is equally important (Lonsdale, 2013; Read, 2000).

The results of this master thesis are a sound scientific basis for a reissue of the MMP `Landscape Protection Area “Großer Ahornboden” in the Karwendel Alpine Park´ (Schreiner, 2004). In this context, the revision should help preservationists, polititians, scientists, farmers, and other stakeholders to take the necessary and appropriate measures.

Not only a cooperative relationship between the disciplines, especially agriculture, tourism, and nature conservation, plays a key role for a long-term preservation of the LPA, but also international cooperation holds great opportunities for “Großer Ahornboden” and other sycamore maple wooded pastures. Consequently, “(t)he preservation of open-grown trees […] should not just be target of single management plans" (Zapponi et al., 2017). Knowledge exchange about wooded pastures, sycamore maple population dynamics, conservation practices, importance and vulnerabilities, mortality rates, veteran habitats, (a)biotic factors would benefit all. Individual tree information forms a valuable basis for management planning and landscape conservation activities, such as biodiversity assessment, silviculture treatment, and tree growth modelling (Lichstein 2010). Regular surveys of sycamore maple wooded pastures with standardised assessment forms and methods would be supportive to increase the comparability of the results. The LPA “Großer Ahornboden” is already leading the way in terms of research, popularity, and conservation efforts. I am happy that with this master thesis I can make a small contribution to the preservation of the LPA “Großer Ahornboden” and its tree personalities, so that this unique landscape can continue to tell many stories in the future (Sonntag et al., 2019).

Figure 40: *LPA „Großer Ahornboden“ in August 2022. Source: Author.*

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Appendix 1

REGARDING ***CHAPTER 2:***

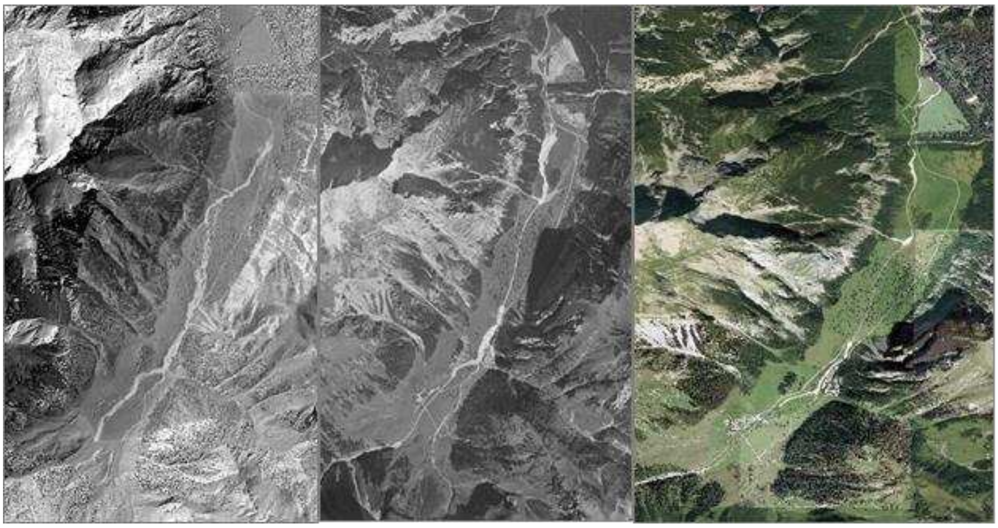


Figure XLI:*„Großer Ahornboden“ before and after the regulation of Engergrundbach. The course of the regulation is clearly visible between the sycamore maple groups on the valley floor (Orthophotos: Left: 1954, middle: 1974, right: 2019). Source: Orthophoto Land Tirol.*

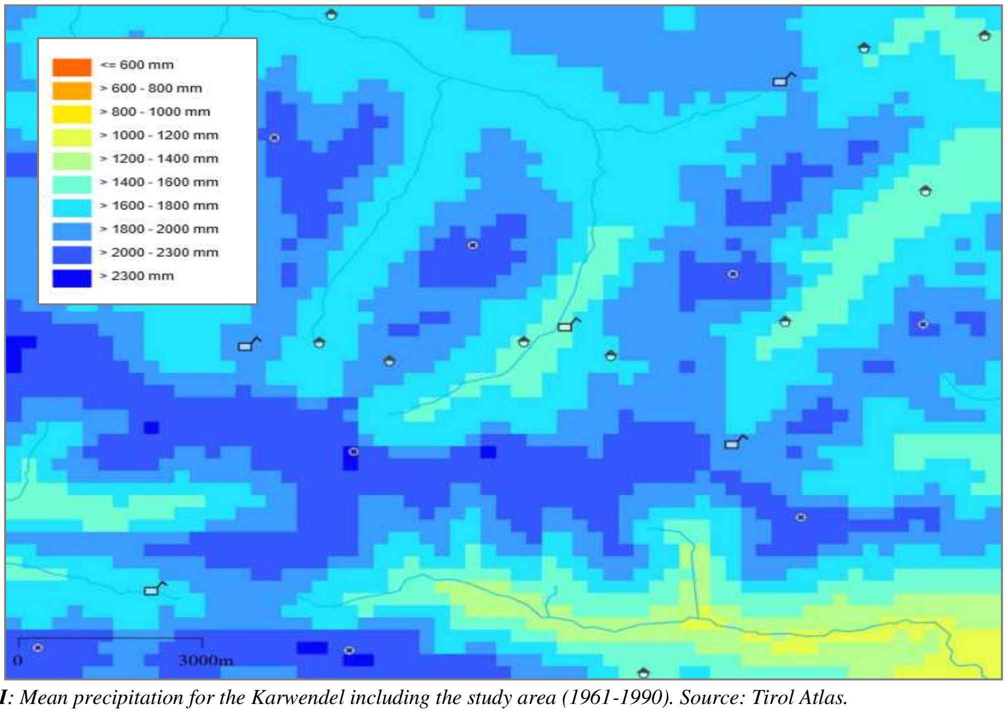


Figure XLII: *Mean precipitation for the Karwendel including the study area (1961-1990). Source: Tirol Atlas.*

REGARDING ***CHAPTER 3:***

Superordinate category	Parameters		
Defects & damages at the woody corpus	Bark missing (>/<4palms) Cave (>/<2palms) Fungal fruiting bodies Hollow stem Proliferation/Tuber Holes (>5mm) Lightning damage Crack (>/< 1m)	+	Location (trunk, root, base of tree, main branch)
Decay & disease symptoms	Crown damage Dead branches remaining within crown (in%) Rot on woody body (>2palms) Indications of disease		
Ecological condition & habitat potential	Type and extent of epiphytic growth Cave with debris Holes with drilling dust Insects and their preparatory stages Mammal´s burrow Woodpecker Others Dead wood		
Growth performance	Measurements (DBH, tree height, crown dimensions) Reiterative growth Ability to close defects/damage Fruiting/Failure to bloom Time of sprouting compared to that of population		
Tree environment	Crown competition Social position Site conditions		
Growth habit of crown	Crown architecture Crown symmetry Crown shape Crown class Crown transparency		

Table I: *The parameters used for vitality assessment of the sycamore maples at „Großer Ahornboden" considering ecological conditions and habitat characteristics. Source: Author.*

Superordinate category	Parameters	Assigned value
Defects/decay	Bark missing (> 4 palms)	3
	Bark missing (< 4 palms)	2
	Cave (> 2 palms)	3
	Cave (<2 palms)	2
	Fungal fruiting bodies	2
	Hollow stem	4
	Burl	2
	Holes > 5mm	2
	Lightning damage	4
	Crack (<1m)	2,5
	Crack (> 1m)	3,5
	Crown broken off	2.5
	Parts of crown missing	2
	Treetop missing	1.5
	Strong branch broken off	1.5
	Forked branch break	3
	Treetop died off	2
	1-15% Dead branches	1,5
	15-30 Dead branches	2
	30-50 Dead branches	3
	>50 Dead branches	4
	1-2 Rotten spots	2
	3-5 Rotten spots	2.5
	6-9 Rotten spots	3
	10 Rotten spots	3,5

Growth performance	Reiterative growth	Crown base	3
		Crown and crown base	3
		Crown	2
		No	-1
	Ability to close damage	Wound closure failed	2
		Ongoing wound closure	-1
		Wound completely closed	-1
	Fruiting /Failure to bloom (older trees)	Flowering (2021 or 2022)	-1
		No flowering	2
	Time of sprouting	Earlier than average	-1
		Later than average	2
External factors and habitus	Competition with neighbouring crowns	No	-1
		10% - 3.5 sides free	1
		20% - 3 sides free	1.5
		40% - 2 sides free	2
		60% - 1 side free	2.5
		80 % - crown top free	3
	Relation to neighbouring trees	Solitary	-1
		In group – dominant	1
		In group – even	1
		In group – dominated	2
	Crown shape	3:1 (slim)	2
		2:1 (oval)	1
		1:1 (spherical)	1
		1:2 (spreading)	-0.5
	Crown class	Long crown	1
		Medium	1
		Small	2
	Crown architecture	Top shoot, ascending branches	1
		No distinct top shoot, ascending branches and twigs	1
		Shank with treads	2
		Shank with branches	2.5
		Strong branches horizontal, twigs on crown coat	1
	Crown symmetry	Single crown	2
		Asymmetric	1.5
		Symmetric	1
	Crown transparency	Upper part	1.5
		Center	1.5
		Middle	1.5
		Lower part	1.5
		Equally sparse	1.5
		Equally dense	-0,5

Table II: *Vitality evaluation scheme. The assigned values range from -1 to 4. A value of -1 indicates a good tree vitality, whereas a value of 4 indicates a weakened tree.*

REGARDING **CHAPTER 4 – RESULTS:**

4.1. STATISTICS AND COMPARISON OF THE DIFFERENT METHODS

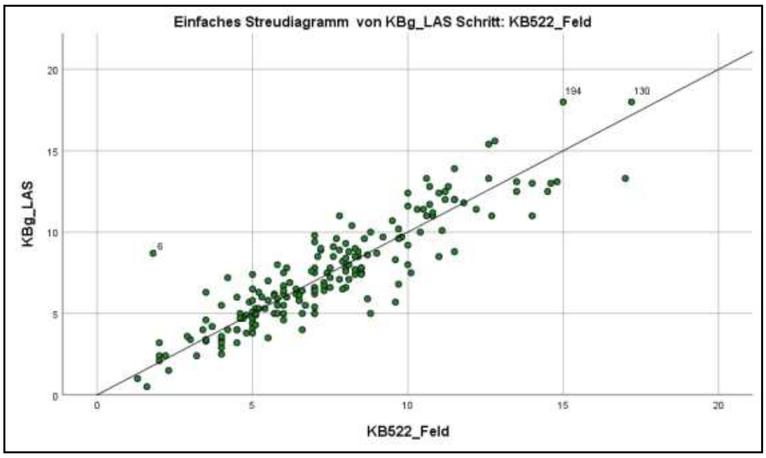
4.1.1. Correlation between measurements with different methods – tree parameter derived from laser data vs. field data

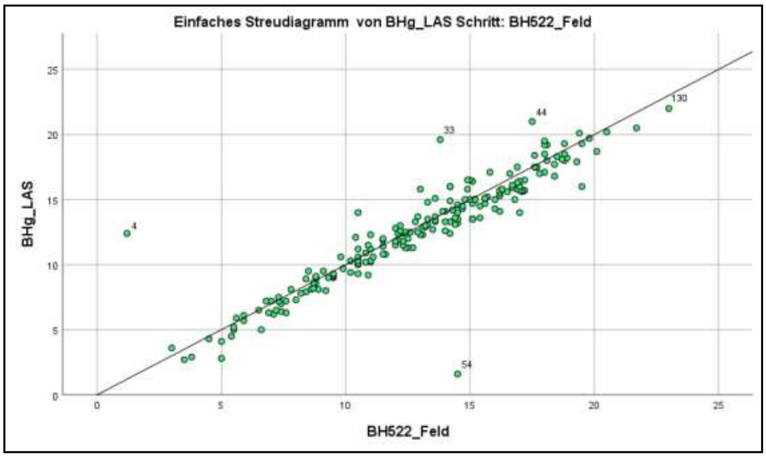
Statistics of paired sample trees

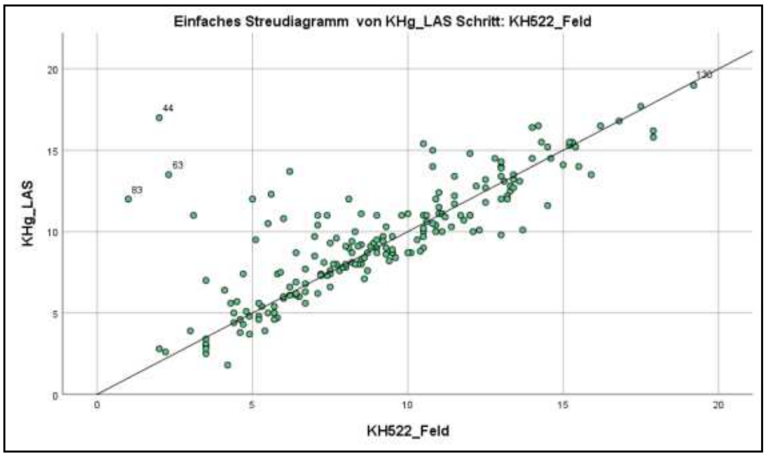
		Mean value	N	Standard deviation	Standard error of the mean
Paaren 1	**KH522_Feld**	**9,09322915722927**	192	3,664390125954251	,264454578204437
	KHg_LAS	**9,63906250024835**	192	3,557572145722394	,256745654499292
Paaren 2	**BH522_Feld**	**12,92512822517982**	195	4,164409146932748	,298219533170441
	BHg_LAS	**12,67230773400038**	195	4,215013967804392	,301843419662869
Paaren 3	**KB522_Feld**	**7,48010755162085**	186	3,095136938418387	,226946451307540
	KBg_LAS	**7,51075269073568**	186	3,241102990979876	,237649201557139

Correlations of paired sample trees

		N	Correlation	Sig.
Paaren 1	**KH522_Feld & KHg_LAS**	192	,794	,000
Paaren 2	**BH522_Feld & BHg_LAS**	195	,926	,000
Paaren 3	**KB522_Feld & KBg_LAS**	186	,897	,000







4.1.2. *Statistical analysis of structural tree parameters in total and within each age class*

Descriptive statistics

	N	Range	Minimum	Maximum	Mean value	Standard deviation	Variance
BHD522_Fel	188	120	7	127	52,14	25,555	653,076
KB522_Feld	188	16,700000762939	,500000000000	17,200000762939	7,44574470532702	3,120611692497135	9,738
KBg_LAS	215	17,500000000000	,500000000000	18,000000000000	7,46697674795639	3,148086148019118	9,910
BH522_Feld	205	21,799999952316	1,200000047684	23,000000000000	12,78634147760344	4,186885323743193	17,530
BHg_LAS	238	21,000000000000	1,000000000000	22,000000000000	12,48109248656186	4,457414520582381	19,869
KHg_LAS	215	17,299999952316	1,700000047684	19,000000000000	9,67255815018056	3,532140877696609	12,476
Gültige Werte (Listenweise)	171						

Shapiro-Wilk-Test

Tests for normal distribution

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	alter0022	Statistics	DF	Significance	Statistics	DF	Significance
BH522_Feld	a	,044	140	,200*	,980	140	,043
	j	,119	27	,200*	,965	27	,468
	m	,085	38	,200*	,967	38	,316
BHD522_Fel	a	,118	129	,000	,957	129	,000
	j	,165	22	,123	,944	22	,235
	m	,135	37	,086	,965	37	,285
KB522_Feld	a	,095	134	,005	,984	134	,117
	j	,166	21	,136	,950	21	,338
	m	,116	33	,200*	,971	33	,519
KH522_Feld	A	,049	136	,200*	,996	136	,980
	J	,114	23	,200*	,970	23	,699
	M	,109	36	,200*	,970	36	,413

*. Lower limit of real significance.
a. Significance correction according to Lilliefors.

Levene Test

Levene-Test auf Gleichheit der Fehlervarianzen Levene test for equality of error variance[a,b]

		Levene statistics	df1	df2	Sig.
KB522_Feld	Based on the mean value	3,273	2	185	,040
	Based on the median	3,335	2	185	,038
	Based on the median and with adapted df ??	3,335	2	169,766	,038
	Based on the trimmed mean	3,206	2	185	,043

Evaluates the null hypothesis that the error variance of the dependent variable is the same across groups.
a. Dependent variable: KB522_Feld
b. Design: Constant term + alter0022

Levene test for the equality of error variances a and b

		Levene statistics	df1	df2	Sig.
KH522_Feld	Based on the mean value	5,895	2	192	,003
	Based on the median	5,930	2	192	,003
	Based on the median and with adapted df ??	5,930	2	176,841	,003
	Based on the trimmed mean	5,934	2	192	,003

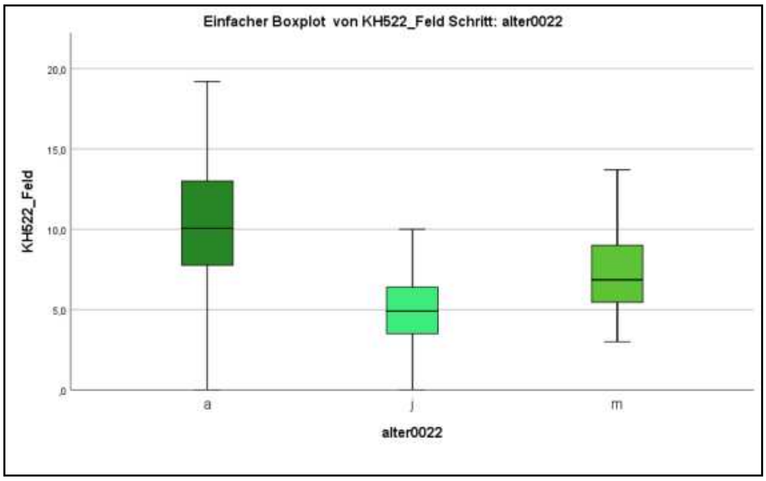
Evaluates the null hypothesis that the error variance of the dependent variable is the same across groups.
a. Dependent variable: KH522_Feld
b. Design: Constant term + alter0022

Kruskal-Wallis Test

	Null hypothesis	Test	Sig.
1	The distribution of BH522_Feld ist über die Kategorien von alter0022 identisch.	Kruskal-Wallis test for independent samples	,000
2	The distribution of KB522_Feld ist über die Kategorien von alter0022 identisch.	Kruskal-Wallis test for independent samples	,000
3	The distribution of KH522_Feld ist über die Kategorien von alter0022 identisch.	Kruskal-Wallis test for independent samples	,000

4.1.3. Statistical analysis – relationship between structural tree parameters and tree age

Crown height – tree age



Summary of the Kruskal-Wallis tests for independent samples

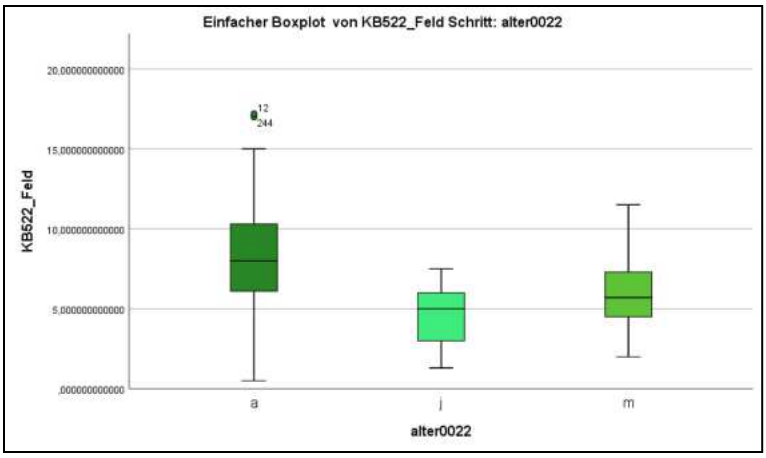
Total	197
Test statistics	49,806[a]
Freiheitsgrad Degree of freedom???	2
Asymptotic Sig. (Bilateral test)	,000

Pairwise comparisons of alter0022 – KH522_Feld

Sample 1-Sample 2	Test statistics	Standard error	Standard test statistics	Sig.	Corr. Sig.[a]
j-m	-35,416	14,841	-2,386	,017	,051
j-a	79,246	12,405	6,388	,000	,000
m-a	43,830	10,685	4,102	,000	,000

Each line tests the null hypothesis, that the sampling distribution of sample 1 and sample 2 are equal.
Asymptotic significances (two-sided tests) are shown.The significance level is ,05,
a. The Bonferroni correction adjusts the significance values for several tests.

Crown width – tree age



Summary of the Kruskal-Wallis test for independent samples

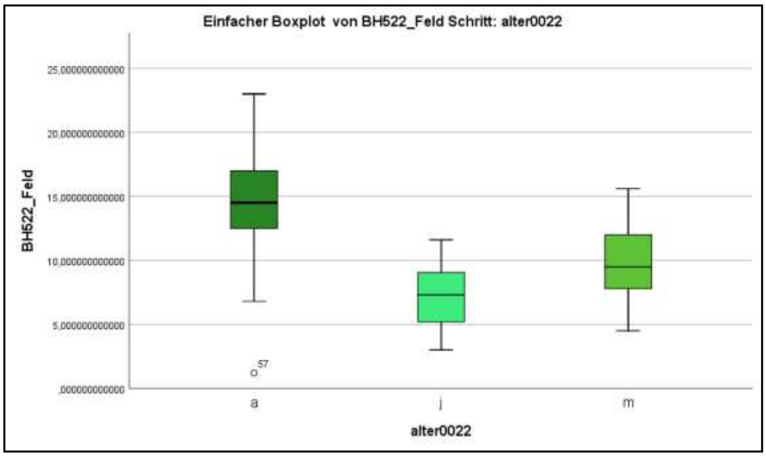
Total	197
Test statistics	43,279[a]
Degree of freedom	2
Asymptotic Sig. (Bilateral test)	,000

Pairwise comparisons of alter0022 – KB522_Feld

Sample 1 - Sample 2	Test statistics	Standard error	Standard test statistics	Sig.	Corr. Sig.[a]
j-m	-27,663	14,838	-1,864	,062	,187
j-a	71,738	12,403	5,784	,000	,000
m-a	44,075	10,683	4,126	,000	,000

Jede Zeile prüft die Nullhypothese, dass die Verteilungen in Stichprobe 1 und Stichprobe 2 gleich sind.Each line tests the null hypothesis, that the distribution of sample 1 and sample 2 are equal.
Asymptotische Signifikanzen (zweiseitige Tests) werden angezeigt.Das Signifikanzniveau ist ,05.
a. Signifikanzwerte werden von der Bonferroni-Korrektur für mehrere Tests angepasst.

Tree height – tree age



Summary of the Kruskal-Wallis test for independent samples

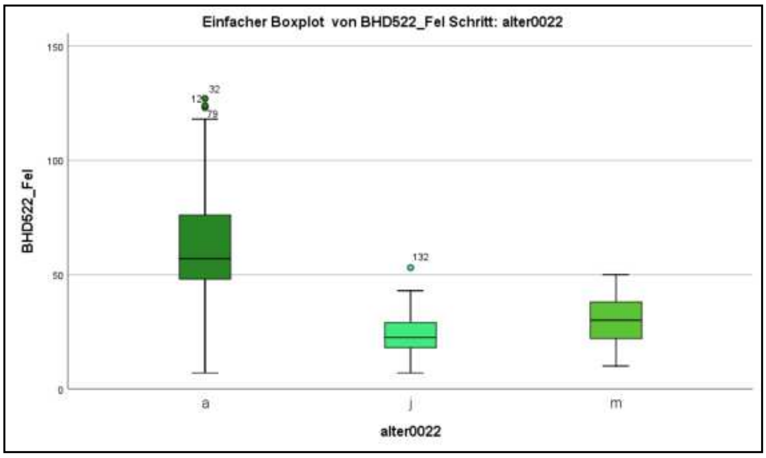
Total	197
Test statistics	85,112[a]
Degree of freedom	2
Asymptotic Sig. (Bilateral test)	,000

Pairwise comparison of alter0022 – BH522_Feld

Sample 1 - Sample 2	Test statistics	Standard error	Standard test statistics	Sig.	Corr. Sig.[a]
j-m	-34,241	14,841	-2,307	,021	,063
j-a	98,678	12,405	7,954	,000	,000
m-a	64,437	10,685	6,031	,000	,000

Jede Zeile prüft die Nullhypothese, dass die Verteilungen in Stichprobe 1 und Stichprobe 2 gleich sind.
Asymptotische Signifikanzen (zweiseitige Tests) werden angezeigt.Das Signifikanzniveau ist ,05.
a. Signifikanzwerte werden von der Bonferroni-Korrektur für mehrere Tests angepasst.

Diameter at breast hight - age



4.1.4. Statistical analysis - relationships between tree age and vitality

Group statistics

	alter0022	N	Mean value	Standard deviation	Standard error of the mean
Average	j	46	,944944246574681	,483974718898165	,071358179283862
	a	141	1,506428835152239	,479214318205828	,040357125867962

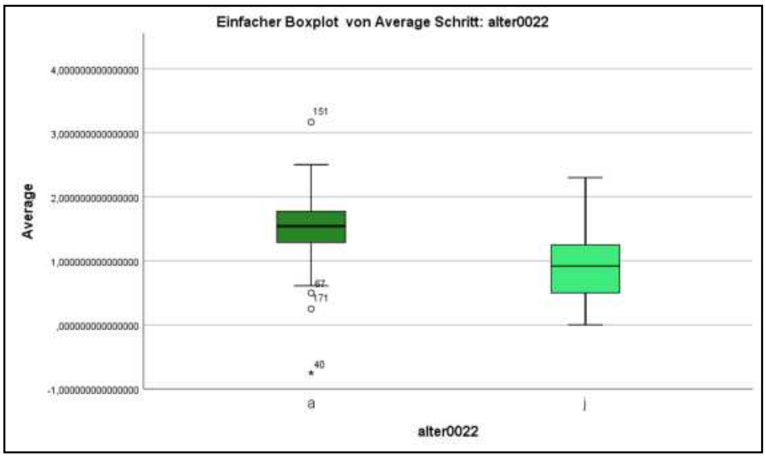
Tests of normal distribution of vitality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	alter0022	Statistics	df	Significance	Statistics	df	Significance
Average	a	,097	141	,002	,955	141	,000
	j	,085	46	,200*	,963	46	,152

*. A lower limit of the real significance.
a. Significance correction according to Lilliefors.

Test of independent samples

		Levene test equality of variance		t-test for mean value equality					95% Konfidenzintervall der Differenz	
		F	Sig.	T	df	Sig. (Bilateral)	Medium difference	Standard for standard error	Lower value	Oberer Wert
Average	Variances are equal	,384	,536	-6,884	185	,000	-,5614845885	,081566940172509	-,722405553448244	-,400563623706872
	Variances are not equal			-6,849	75,895	,000	-,56148458857	,081979798481274	-,724765161173349	-,398204015981767



4.2. SYC*AMORE MAPLE POPULATION AT “GROßER AHORNBODEN”*

4.2.1. Tree population in 2001 according to the MMP adopted in 2005

MMP, Abbildung 19 (vital in 2001)	
ALTER53/ALTER00	**No. of objects**
neu/mittel	11
alt/alt	1309
alt/jung	14
alt/absterbend	191
mittel/alt	7
mittel/mittel	109
jung/jung	50
jung/mittel	25
neu/jung	501
Gesamt	**2217 / 2218 (MMP, S. 24)**

MMP, Abbildung 19 (Mortalität 1953-2001)	
ALTER53/ALTER00	**No. of objects**
jung/tot	19
mittel/tot	10
alt / tot	346
Total	**375**

MMP	
Neupflanzungen 1962-2002	**No. of objects**
Vitale Neupflanzungen (1962-2002)	530 (MMP) / 512 (Abbildung 19)
Abgestorbene Neupflanzungen	310 (MMP) / 328 (NR: 840 – 512)
Total	**840 (MMP)**

4.2.2. The tree cadastre of the sycamore maple population at “Großer Ahornboden“ according to Ahorn_GDB

Relevant registered attribute	**No. of objects**
Gebiet = Kleinen Ahornboden / Kleinkristental	120
Objekt beginnt mit B bzw. keine Ahorn_ID	15
Pflanzung_2004 bzw. ALTER00 = NULL	70
ALTER00 = j/m/a	2375
ALTER00 = z	382
Total	**2962**

4.2.3. The tree cadastre of the sycamore maple population at “Großer Ahornboden“ in 2022 (1st volume- 3202 elements)

BZ22	**No. of objects**
i	2430 (71 registrierte Pflanzungen nach 2001)
Jp	11
L/N	115 (L=50, N=65)
zz	304
z	341
n	1
Total	3202

TREE STATUS			MEASURE AREAS				COUNT
			D1	**D2**	**D3**	**ASF**	
Living sycamore maple trees 2022 (i)			**990**	**761**	**414**	**265**	**2430**
Age classes	***Old***	*0a/a0*	*641*	*449*	*172*	*57*	*1319*
		aa	*49*	*36*	*10*	*7*	*102*
		za	*65*	*13*	*2*	*1*	*81*
		ja	*2*	*2*	*0*	*0*	*4*
		Total	**757**	**500**	**184**	**65**	**1506**
	Middle	*am*	*1*	*3*	*6*	*0*	*10*
		jm	*4*	*10*	*11*	*0*	*25*
		0m/m0	*16*	*8*	*30*	*26*	*80*
		Mm	*0*	*0*	*1*	*0*	*1*
		zm	*5*	*0*	*0*	*0*	*5*
		Total	**26**	**21**	**48**	**26**	**121**
	Young	*0j/j0*	*90*	*220*	*169*	*170*	*649*
		jj	*2*	*5*	*2*	*2*	*11*
		mj	*0*	*0*	*1*	*0*	*1*
		zj	*1*	*1*	*0*	*0*	*2*
		nj	*72*	*3*	*0*	*0*	*75*
		Total	**165**	**229**	**172**	**172**	**738**
	Unknown	*n0*	*0*	*1*	*0*	*0*	*1*
		n.a.	*42*	*10*	*10*	*2*	*64*
		Total	**42**	**11**	**10**	**2**	**65**
Regeneration (Jp)			**0**	**0**	**3**	**8**	**11**
Mortality (z/zz)			**344**	**172**	**51**	**78**	**645**
	2001-2022	*z*	*186*	*82*	*29*	*44*	*341*
	1953-2001	*zz*	*158*	*90*	*22*	*34*	*304*
Other (L/N/n)			**5**	**30**	**16**	**65**	**116**
TOTAL			**1339**	**963**	**484**	**416**	**3202**

***Table III**: The sycamore maple cadastre „Großer Ahornboden" in 2022 – general overview and differentiation according to management units. Columnn "abbreviations": The first letter stands for the survey by the MMP, the second letter stands for the survey in the framework of the underlying master thesis [z- mortality, i-living tree, a-old tree, m-middle old tree, j-young tree, 0 – no data]. Source: Author.*

4.2.4. The reviewed tree cadastre of the sycamore maple population at "Großer Ahornboden" in 2022 (2nd volume- 3291 elements)

BZ22	**Anzahl der Objekte**
i	2427
Jp	11
L/N	118 (N=66, L=52)
zz	308
z	426
n	1
Gesamt	**3291**

Elemente (gesamt) je Maßnahmenfläche	**Anzahl der Objekte**
D1	1424
D2	966
D3	485
ASF	416
Gesamt	**3291**

Vitale Bergahornbäume je Maßnahmenfläche (BZ22=i)	**Anzahl der Objekte**
D1	988
D2	759
D3	415
ASF	265
Gesamt	**2427**

Dokumentierte Baummortalitäten je Maßnahmenfläche (z/zz)	**Anzahl**	**1953-2000 (zz)**	**2001-2022 (z)**
D1	429	160	269
D2	177	93	84
D3	51	21	30
ASF	77	34	43
Gesamt	734		

Zusatzinformationen Baummortalitäten		
		Anzahl
Hinweise auf nicht natürliches Absterben (BZ2_Feld)	*2011*	117
	DS	52
	WS	50
	Entf	5
	Sonst. (Mulde, Branspur?, Schnitt DS, sehr vermodert)	21
Keine Evidenz eines Baumes (BZ2_Feld)	*n.a. / n*	70
Fraglich, ob Bergahorn (Art_Feld)	*N?*	28
	Weide?	1
	Buche?	8
	N/L?	1

Sehr junge Ahornbäume (seit 2001)	**Anzahl**
Mit Nummer/Pflanzungen (z.B. 20/05)	71
Ohne Nummer (=???)	25
Gesamt	96

4.3. CHANGES BETWEEN 2001 TO 2022 – POPULATION SIZE AND AGE STRUCTURE OF THE SYCAMORE MAPLE POPULATION AT "GROßER AHORNBODEN".

4.3.1. Overview of the reference tree population

Attribute der registrierten Objekte	**Anzahl im entsprechenden Jahr**	
	2001	***2022***
i	2240	290
Jp	0	70
L/N	77	77
zz	---	290
z	290	319
n	71	1
Total	2678	2678

4.3.2. Calculation procedure of the reference population

Total population	MMP 2001	False positive/negative	**Reference tree population 2001**	**Reference tree population 2022**
a	1515	-20 L -21 N -1 +80	**1553**	**1330**
m	99	-11 N +5	**93**	**53**
j	613	-7 L -14 N +2	**594**	**608**
n	70	+1	**71**	**1**
z	381	-87 -3 L -1 N	**290**	**319**
Others	---	+30 L +47 N	**77**	**77**
zz	---	---	**0**	**290**
Total	**2678**	**---**	**2678**	**2678**

Table IV*: Changes between 2001 to 2022 – Total population. Source: Author.*

D1	MMP 2001	False positive/negative	**Reference population 2001**	**Reference population 2022**
a	754	-1 aL -2 aN +65 zi	**816**	**661**
m	33	+5zi	**38**	**21**
j	95	-1jN +2zi	**96**	**157**
z	226	-71 zi	**155**	**181**
n	70	---	**70**	**0**
zz	---	---	**n.a.**	**155**
Others	---	---	**3**	**3**
Total	1178	---	1178	1178

Table V: *Changes between 2001 to 2022 – D1. Source: Author.*

D2	MMP 2001	False positive/negative	**Reference population 2001**	**Reference population 2022**
a	522	-13 aL -5 aN +13 ai	**517**	**467**
m	9	---	**9**	**7**
j	224	-1 jL -4 jN +1 ji	**220**	**198**
z	98	-14 zi	**84**	**74**
zz	---	---	**0**	**84**
Other	---	---	**23**	**23**
Total	853	---	853	853

Table VI: *Changes between 2001 to 2022 – D2. Source: Author.*

D3	MMP 2001	False positive/negative	**Reference population 2001**	**Reference population 2022**
a	177	-4 aN -2 aL +1 zi	**172**	**159**
m	29	-1 mN	**28**	**24**
j	156	-4 jL	**152**	**143**
z	20	+1zi	**19**	**26**
zz	---	---	**0**	**19**
Other	---	---	**11**	**11**
Total	382	---	382	382

Table VII*: Changes between 2001 to 2022 – D3. Source: Author.*

ASF	MMP 2001	False positive/negative	**Reference population 2001**	**Reference population 2022**
a	62	-4 aL -11 aN +1 ai	48	43
m	28	-10 mN	18	1
j	138	-2 jL -9 jN	127	112
z	37	-1 zi -2 zL	34	37
zz		---	0	34
Other	0	---	38	38
Total	265	---	265	265

Table VIII: *Changes between 2001 to 2022 – ASF. Source: Author.*

4.4. THE VITALITY OF THE SYCAMORE MAPLE TREES AT "GROßER AHORNBODEN"

Subject/class	Variable	Total	Specification of variable	Total	Older	Younger
		Abs.		Abs.	Abs.	Abs.
DEFECTS[3] & DECAY	Defect - Trunk	102 (69 trees)	Bark missing (> 4 palms)	34	32	2
			Bark missing (< 4 palms)	50	33	17
	Defect – Stem base	22	Cave (> 2 palms)	18	18	0
			Cave (<2 palms)	27	25	2
			Fungal fruiting bodies	4	4	0
	Defect – superficial root	3	Hollow stem	8	8	0
			Bulbs	14	14	0
			Holes > 5mm	25	23	2
			Lightning damage	9	9	0
	Defect – Main branch	15	Crack (<1m)	3	3	0
			Crack (> 1m)	12	9	3
	Crown damage	78	Entire crown missing	3	3	0
			Part of crown missing	35	34	1
			Treetop missing	8	7	1
			1-2 main branches missing	30	26	4
			Forked branch break	1	1	0
	TOTAL	220[5]	---	281[5]	249	32
	Treetop died off	132	Yes	11	9	2
			No	121	--	--
	Dead branches	42	1-15 %	10	34	4
			15-30 %	38	35	3
			30-50 %	4	4	0
			>50 %	3	3	0
	Rotten spots >2HF	91	1-2	36	26	10
			3-5	36	32	4
			6-9	3	2	1
			10	16	16	0
	TOTAL	265	---	---	---	---
ECOLOGICAL CONDITIONS & HABITAT POTENTIAL	Observed epiphytic type of coverage	170 (150 trees)	Bryophytes/Lichens	33	30	13
			Lichens dominant	29	3	12
			Bryophytes dominant	88	87	1
			Flowering plant	2	2	0
			Tayloria rudolphiana	6	6	0
			Young tree	7	7	0
			Fern	5	5	0
	Cave with debris	13	>2 palms	8	8	0
			<2palms	5	5	0
	Holes with drilling dust	16	5mm	16	16	0
	Others	22	Woodpecker	2	2	0
			Insects	6	6	0
			Cobwebs under bark	~ all	---	---
			Larvae/caterpillar	8	8	0
			Mammal´s burrow	6	6	0
	TOTAL	221	---	---	---	---
GROWTH PERFORMANCE, REPRODUCTION &	Tree dimensions	200	DBH	---	---	---
			Tree height	---	---	---
			Crown dimensions	---	---	---
	Reiterative growth	110	Crown base	45	31	14
			Crown and crown base	45	44	1

REGENERATIVE CAPACITY			Single crown	12	12	0
			No	8	3	5
	Ability to close damage	66	Wound closure failed	41	32	9
			Ongoing wound healing process	16	9	7
			Wound completely closed	9	8	1
	Fruiting/Failure to bloom	119	Flowering (2021)[1]	102	71	31
			Flowering (2021&2022)[1]	7	7	
			No flowering observed[1]	10	9	1
	Time of sprouting	56	Earlier than average[1]	13	11	2
			Later than average[1]	43	30	13
	TOTAL	551	---	---	---	---
TREE ENVIRONMENT & HABITUS	Competitive crown	98	No	40	29	11
			10% - 3.5 sides free	19	18	1
			20% - 3 sides free	21	20	1
			40% - 2 sides free	13	13	0
			60% - 1 side free	4	3	1
			80 % - only crown top free	1	1	0
	Social position	186	Solitary	116	72	44
			In group - dominant	13	13	0
			In group - even	54	0	3
			In group - dominated	3	2	1
	TOTAL	284	---	---	---	---
	Crown shape (= crown width to crown hight) - visually estimated	149	3:1 (Slim)	34	30	4
			2:1 (Oval)	77	56	21
			1:1 (Spherical)	20	12	8
			1:2 (Spreading)	18	12	6
	Crown class (= crown height to tree height)	160	Long crown	126	92	34
			Medium	17	11	6
			Small/Short	17	16	1
	Crown architecture	155	5[6]	39	15	24
			2[6]	35	25	10
			3[6]	20	20	1
			6[6]	18	17	1
			1[6]	43	39	4
	Crown structure and symmetrie	180	Crown disintegrated	30	28	2
			Asymmetric	53	49	4
			Symmetric	97	57	40
	Crown transparency	140	Upper part	4	3	1
			Centre	7	7	0
			Middle	17	13	4
			Lower part	42	37	5
			Equally sparse	23	20	3
			Equally dense	47	23	24
	TOTAL	784	---	---	---	---

Table IX:*Asessed tree parameters - total population, younger & older trees*

*** Not all trees have been surveyed with all parameters, because with every iteration of field survey the parameters have been specified and more attributes were collected.*

[1]Applied with some reservation, because in early spring flowering had not yet started.

[3]The specification of defects refers to all of the four defect classifications. The defects of the trunk, the strong branches, the stem foot, and the roots were put together.

[4] In relation to the total of all parameters observed.

[5] The total of all damage locations and the total of all damages are different, because for each tree to damage locations with the corresponding damage was recorded. The third damage was recorded without its location.

[6]AppendixII/4. (Additional criteria for sample trees)

z	Probe_ID	STgNO_Feld	ASTg_Feld	STg1_Feld	KRg_Feld	Kform_Feld	KvOrt_Feld	GlDue_Feld	BlSt_Feld	KrKl_Feld	WS_Feld	KrBau_Feld	BAT_Feld	WH2_Feld	WH1_Feld	STg2_Feld	STg3_Feld	alter0022	Average	Vitality
606	1	2,50		2,50	1,50	1,00	1,50	1,00		1,00	3,00	1,00			2,00			a	1,7	2
607	2	2,00	2,00	3	2,00	1,00	1,50	1,00	-1,00	1,00		1,00	1,00		2,00			a	1,375	2
617	3	2,50	2,00	3	2,00	1,00	1,50	1,00		1,00	2,00	1,00						a	1,7	2
610	4	2,50		2	2,00	1,00	1,50	1,00		1,00	3,00	2,50	2,00		2,00	2,00		a	1,875	2
633	5	3,00		3	2,00	1,00	1,50	1,00	-1,00	1,00	3,00	1,00						a	1,55	2
677	6	2,50	2,00	3		1,00	1,50	1,00	-1,00	1,00	3,00	1,00				2		a	1,54545455	2
701	7		1,50			1,00	1,50	1,00	-1,00	1,00	2,00	1,00						a	1	1
706	8	2,50	3,00	2	2,00	1,00	1,50	1,00	-1,00	1,00	2,00	1,00		2,00		3		a	1,61538462	2
710	9			2		1,00	-0,50	1,00	-1,00	1,00	2,00	1,00	-1,00					a	0,61111111	1
718	10		2,00	2,00	1,50	1,00	-0,50	2,00	-1,00	1,00	3,00	1,00	-1,00			Mg	2	a	1,08333333	2
760	11	2,50	2,00	3	2,00	-0,50	1,50	1,00		1,00	3,00	1,00	2,00		2,00	1,50	2,0	a	1,71428571	2
782	12		1,50	3	2,00												2	a	2,125	3
803	13																	a	#DIV/0!	#DIV/0!
816	14	3,50	2,00	4		1,00	1,50	1,00	-1,00	1,00	3,00	2,00	2,00		2,00			a	1,83333333	2
852	15	2,50		2		1,00	1,50	1,00	-1,00	2,00		2,00			2,00	3,50		a	1,65	2
853	16			3		1,00		1,00	-1,00	1,00	3,00	1,00						a	1,28571429	2
919	17				2,50					1,00						3,50		a	2,33333333	3
926	18		1,50							2,00		2,00						a	1,83333333	2
949	19		2,00	3		1,00	1,50	1,00		1,00		1,00				2		a	1,5625	2
954	20			2		1,00	-0,50	1,00	-1,00	1,00	3,00	1,00	-1,00					a	0,72222222	1
988	21			2	1,50							1,00				2		a	1,625	2
1005	22			2,50	2,00		1,50		-1,00			1,00						a	1,2	2
1094	23			3,50		1,00	-0,50	2,00	-1,00	1,00		1,00		-1,00	-1,00	3,50		a	0,85	1
1107	24	2		3		1,00	1,50	1,00	-1,00	1,00		1,00					2	a	1,27777778	2
1122	25			2,00	1,50	1,00	1,50	1,00		1,00	3,00	1,00	2,00		-1,00			a	1,3	2
1331	26	2,00	2,00	2		2,00	1,50	1,00		1,00	3,00	1,00						a	1,72222222	2
1343	27	2		3		1,00		2,00	-1,00	1,00	3,00	1,00						a	1,5	2
1403	28		2,00			1,00		1,00	-1,00	1,00	3,00	2,00						a	1,28571429	2
1419	29		2,00	2		1,00	1,50		-1,00	1,00	3,00	1,00						a	1,3125	2
1421	30		4,00	2		2,00				2,00	3,00	2,50				2		a	2,5	3
1475	31						1,50	2,00										j	1,75	2
1481	32			2	1,50		1,50											a	1,66666667	2
1484	33																	a	#DIV/0!	#DIV/0!
1508	34	2,00	1,50	3	1,50	1,00	1,50	1,00	2,00	1,00	3,00	1,00	-1,00		2,00			a	1,5	2
1514	35				1,50							2,00						a	1,75	2
1539	36			3	2,50		1,50											a	2,33333333	3
1567	37	2	2,00	3	1,50	1,00	1,50	1,00	2,00	1,00	3,00	1,00	-1,00		2,00	2		a	1,57142857	2
1593	38	2		2			-0,50											a	1,16666667	2
1608	39			2			1,50											a	1,75	2
1532	40						-0,50		-1,00									a	-0,75	0

1619	41	2,00	2,00	2	1,50	2,00	1,50	1,00	-1,00	1,00	3,00	2,50						a	1,59090909	2
1622	42	2,00	2,00	2	1,50	2,00	1,50	1,00	2,00	1,00	3,00	2,50		2,00	-1,00	3		a	1,75	2
1644	43		1,50			2,00	-0,50	1,00	-1,00	1,00	3,00	1,00	-1,00					a	0,77777778	1
1646	44	2		3,50		1,00	1,50	1,00	2,00	2,00	3,00	2,50		2,00	2,00	2		a	2,04166667	3
980	45			2		1,00	-0,50	1,00	-1,00	1,00	-0,50	1,00						j	0,5	1
1658	46		3,00	2,00		2,00	1,50	1,00	2,00	2,00	3,00	2,50	2,00					a	2,1	3
1670	47						1,50											a	1,5	2
1753	48																	a	#DIV/0!	#DIV/0!
2111	49	3,00		2	2,00	-0,50	1,50	1,00		1,00	3,00	1,00			-1,00			a	1,3	2
2112	50	2,50	2,00	2	3,00	1,00	1,50	1,00	-1,00	1,00	3,00	1,00	1,00			2		a	1,53846154	2
2114	51	2	1,50	2		-0,50		1,00	-1,00	2,00	3,00	1,00	2,00					a	1,3	2
2127	52	2,50		3		1,00	1,50	1,00		1,00	3,00	1,00	2,00					a	1,77777778	2
2138	53		2,00		1,50	2,00	1,50	1,00	-1,00	1,00	3,00	2,00						a	1,44444444	2
2146	54	2,50		2	2,00	1,00		1,00	-1,00	1,00	3,00	1,00					2	a	1,45	2
2157	55	3,50		4		2,00		1,00		1,00	3,00	2,50	1,00			3,50		a	2,38888889	3
2232	56	2,50	2,00	3	1,50	1,00				2,00	3,00	2,00						a	2,125	3
2269	57					2,00		1,00		1,00		2,00						a	1,5	2
5142	58		4,00			2,00	1,50	2,00	2,00	2,00	3,00	2,50	2,00					a	2,33333333	3
5143	59	2,00	2,00	2,0		2,00	1,50	1,00	2,00	1,00	3,00	2,00	2,00					a	1,86363636	2
5170	60		1,50	3		2,00	1,50	1,00	-1,00	1,00	3,00	2,50	2,00	-1,00	-1,00	3,50		a	1,38461538	2
5182	61		3,00			2,00	1,50	1,00	2,00	1,00	3,00	2,50	2,00					a	2	2
2375	62																	a	#DIV/0!	#DIV/0!
5201	63					2,00	1,50	1,00	-1,00	1,00	3,00	2,50	2,00					a	1,5	2
868	64	2		2	2,50	-0,50	1,50	1,00		2,00	3,00	1,00					2	a	1,65	2
8087	65			2	2,00	-0,50												a	1,16666667	2
8205	66	3,50		4	2,00	2,00		1,00		1,00	3,00	2,50						a	2,375	3
8213	67					-0,50	1,50	1,00	-1,00	1,00		1,00						a	0,5	1
5251	68																	a	#DIV/0!	#DIV/0!
5252	69																	j	#DIV/0!	#DIV/0!
5289	70																	j	#DIV/0!	#DIV/0!
5290	71																	j	#DIV/0!	#DIV/0!
5291	72					1,00	-0,50	1,00		1,00		1,00						j	0,7	1
5295	73				2	1,00	1,50	1,00		1,00		1,00						j	1,25	2
795	74		1,50	2		1,00	-0,50	1,00	-1,00	1,00	-0,50	1,00	2,00					j	0,75	1
799	75		1,50							1,00								j	1,25	2
884	76	2,00		2		1,00	-0,50	1,00	keine Blüte 21/22	1,00	3,00	1,00			2,00			j	1,38888889	2
910	77	2,00	1,50						-1,00	1,00								j	0,875	1
1772	78	2		2														a	2	2
1020	79																	j	#DIV/0!	#DIV/0!
5095	80					1,00	1,50	1,00		1,00	3,00	1,00						j	1,41666667	2
5096	81	2,00				1,00		1,00		1,00		1,00	2,00					j	1,33333333	2
2073	82	2		4,00	1,50	1,00	-0,50	1,00		1,00	3,00	1,00						a	1,55555556	2
674	83	2,50		3	1,50	2,00	1,50	1,00		1,00	3,00	2,50			2,00	3,50		a	2,13636364	3
1218	84																	a	#DIV/0!	#DIV/0!

388	85					1,00	-0,50	1,00	-1,00	1,00	3,00	1,00	2,00					a	0,9375	1
390	86					1,00	-0,50	1,00	-1,00	1,00		1,00						j	0,41666667	1
401	87					1,00	-0,50	1,00	-1,00	1,00	3,00	1,00	2,00					j	0,9375	1
413	88					1,00				1,00		1,00						j	1	1
452	89			2	1,50	1,00	1,50	2,00	-1,00	1,00	3,00	1,00	2,00		-1,00			j	1,18181818	2
465	90	2,50		2	1,50	-0,50	1,50	1,00	-1,00	2,00	3,00	1,00	2,00	2,00		3,50		j	1,57692308	2
499	91	2,00		2		2,00	-0,50	1,00	-1,00	1,00	-0,50	1,00	2,00					j	0,9	1
514	92	3,00		2	1,50										2,00			j	2,125	3
548	93					2,00	-0,50	1,00	-1,00	1,00	-0,50	1,00	2,00					j	0,625	1
553	94	2,00		2		1,00	-0,50	1,00	-1,00	1,00	3,00	1,00	-1,00		2,00			j	0,95454545	1
554	95					2,00	-0,50	1,00	-1,00	1,00	3,00	1,00	2,00					j	1,0625	2
2120	96	2,00		2		2,00	-0,50	1,00		1,00	3,00	1,00	2,00		2,00			j	1,55	2
822	97		2,00	2		1,00	-0,50	1,00		1,00		1,00			-1,00			j	0,8125	1
867	98					1,00	-0,50	1,00	-1,00	1,00		1,00						j	0,41666667	1
7282	99					-0,50	1,50		-1,00	1,00		1,00						j	0,4	1
5097	100					-0,50	-0,50	1,00		1,00	3,00	1,00	2,00					j	1	1
5087	101				1,50	1,00	1,50	1,00	-1,00	1,00		1,00						j	0,85714286	1
5308	102	2,50		2		-0,50	1,50	1,00	-1,00	1,00		1,00			2,00			j	1,05555556	2
8060	103	2,50		3	2,00	2,00	-0,50	1,00		1,00	3,00	2,00				2,00		a	1,8	2
507	104	2,00		2		1,00	-0,50		-1,00	1,00	3,00	1,00	2,00		2,00			j	1,25	2
316	105	2,50	1,50	4	1,50	1,00	-0,50	1,00	-1,00	1,00	3,00	1,00	-1,00			3,50	2	a	1,39285714	2
326	106		1,50			1,00	1,50	1,00	-1,00	1,00		1,00						a	0,85714286	1
331	107	3,50	1,50	4,00		1,00	1,50	1,00	-1,00	1,00	-0,50	1,00	1,00		2,00	2,00	3	a	1,5	2
373	108	2,50	1,50	2	1,50	2,00	-0,50	1,00	-1,00	1,00	2,00	1,00	-1,00			2		a	1,07692308	2
378	109	3,50	2,00	3	2,00	-0,50		1,00	-1,00	1,00	3,00	1,00	1,00		2,00	2,00	2	a	1,57142857	2
391	110		2,00	2	1,50	2,00	1,50	1,00	-1,00	1,00		2,00						a	1,33333333	2
457	111	2,00	1,50	2	2,00	1,00	1,50	1,00	-1,00	1,00	3,00	1,00						a	1,36363636	2
470	112		1,50	2		-0,50	1,50	1,00	-1,00	2	3,00	1,00			2,00			a	1,25	2
478	113	2,50	1,50	2	1,50	1,00	-0,50	1,00	-1,00	1,00	3,00	1,00	2,00		2,00	2		a	1,35714286	2
509	114	3,50	1,50	4		1,00	1,50	1,00	-1,00	1,00	3,00	1,00				3		a	1,77272727	2
582	115		2,00		1,50	1,00	1,50	1,00	-1,00	1,00	3,00	1,00	2,00					a	1,3	2
583	116	10	1,50	3,50	2,00	2,00	1,50	2,00	-1,00	1,00	3,00	1,00				3		a	2,45833333	3
585	117	2,00		3	1,50	1,00	1,50	1,00		1,00		1,00						a	1,5	2
1445	118	2,50	1,50	3,50	1,50	1,00	1,50	1,00	-1,00	1,00	3,00	1,00	2,00		-1,00	2	3	a	1,5	2
347	119	2,00	1,50	3		1,00	1,50	1,00	2,00	1,00	3,00	1,00	2,00		2,00			a	1,75	2
1452	120		1,50	2		1,00	1,50	1,00	-1,00	1,00	-0,50	1,00	1,00		2,00			a	0,95454545	1
1985	121	3,50	2,00	4	2,00	-0,50		1,00		1,00		1,00			2,00	2,0		a	1,8	2
2006	122	2,50	2,00	2	2,00	2,00		1,00	-1,00	1,00		2,00			2,00			a	1,55	2
2021	123	2,50	2,00	3		1,00	1,50	1,00		1,00	3,00	1,00	2,00			Mg		a	1,8	2
2024	124	2	2,00	3	2,00	1,00		1,00		1,00	2,00	1,00						a	1,66666667	2
2035	125	2,50	2,00	3		-0,50		1,00	-1,00	2,00	2,00	2,50	2,00					a	1,55	2
2055	126	2,50		3,50	2,00	1,00	1,50	1,00		1,00	3,00	1,00	1,00			2,00		a	1,77272727	2
2061	127	2		3,50	1,50	1,00	1,50	1,00	-1,00	1,00	3,00	1,00				2	2	a	1,54166667	2
2097	128		2,00	2,00	2,00	1,00	1,50	1,00		1,00	3,00	1,00					2	a	1,65	2

2099	129	2,00	2,00	4,00		-0,50	-0,50	1,00	-1,00	1,00		1,00			2,00	2,00		a	1,18181818	2
2102	130	2,50	2,00	2,00		1,00	1,50	1,00	-1,00	1,00	3,00	1,00					2	a	1,45454545	2
2105	131	3,50		3,50	2,00	1,00	1,50	1,00	-1,00	1,00	2,00	1,00	-1,00	2,00	-1,00	3		a	1,32142857	2
2151	132	2,50		2	2,00	1,00	1,50	1,00		1,00	3,00	1,00	1,00					a	1,6	2
1961	133	2,50	2,00	2	1,50	1,00		1,00	-1,00	1,00	3,00	1,00					2	a	1,45454545	2
2291	134	2,50		3	2,00	2,00		2,00	-1,00	1,00	3,00	2,00				2,00		a	1,85	2
2318	135		1,50	2	1,50	1,00	-0,50	1,00	-1,00	1,00	3,00	1,00			-1,00			a	0,86363636	1
2324	136		1,50			1,00	1,50	1,00	-1,00	1,00	2,00	1,00						a	1	1
2376	137	2	1,50	3		2,00	1,50	1,00	-1,00	1,00	3,00	1,00	-1,00		2,00	2,00	2	a	1,42857143	2
2434	138					1,00	-0,50	1,00	-1,00	1,00		1,00	2,00					a	0,64285714	1
2435	139					1,00	-0,50	1,00	-1,00	1,00	2,00	1,00	2,00					a	0,8125	1
2437	140			2,50		1,00	-0,50	1,00	-1,00	1,00	3,00	2,00	1,00		-1,00	2,00		a	1	1
2441	141	2,50		2		2,00	1,50	1,00	-1,00	1,00	3,00	2,00	2,00					a	1,6	2
7446	142					2,00			-1,00	1,00	2,00	1,00						a	1	1
2466	143	2,50	2,00	3,50	1,50	2,00	1,50	1,00	-1,00	1,00	2,00	2,00	2,00		2,00	2,00		a	1,71428571	2
5038	144	2,50	2,00	4,00	2,00	1,00			-1,00	2,00		2,00			2,00			a	1,83333333	2
5040	145	2,50	2,00	4,00	2,00	2,00	1,50	1,00	-1,00	2,00		1,00			2,00			a	1,72727273	2
8173	146	3,50		3	1,50	2,00	1,50	1,00	-1,00	1,00	3,00	2,50	2,00		2,00	2		a	1,84615385	2
2509	147	3,50	3,00	2,0	1,50	2,00	1,50	2,00	-1,00	1,00	3,00	2,50	2,00		2,00	2,00	4,00	a	2,06666667	3
8187	148	2,00		2	1,50	1,00	1,50	1,00	-1,00	1,00	3,00	1,00						a	1,3	2
2062	149	2,50	2,00	4,00	2,00	-0,50	1,50	1,00		1,00	3,00	1,00			2,00			a	1,77272727	2
8209	150					2,00	1,50	1,00	-1,00	1,00	3,00	2,00						a	1,35714286	2
995	151	3,50		4												2,00		a	3,16666667	4
17	152	2		2		1,00	1,50	1,00		1,00		1,00			2,00			j	1,4375	2
35	153					1,00	-0,50		-1,00	1,00		1,00						j	0,3	1
41	154					1,00	-0,50		-1,00	1,00	3,00	1,00						j	0,75	1
53	155					1,00	0,00	1,00	-1,00	1,00		1,00						j	0,5	1
86	156	2,50		3	1,50	1,00	1,50		-1,00	1,00	3,00	1,00			2,00			j	1,55	2
93	157			2	1,50	1,00	-0,50	1,00	-1,00	1,00		1,00	2,00		-1,00			j	0,7	1
94	158		2,00			1,00	-0,50		-1,00	1,00	3,00	1,00			-1,00			j	0,6875	1
104	159			2		1,00	-0,50	1,00	-1,00	1,00		1,00			-1,00			j	0,4375	1
129	160					1,00	-0,50		-1,00	1,00		2,50						j	0,6	1
151	161		2,00			-0,50	-0,50	1,00	-1,00	1,00		1,00						j	0,42857143	1
1178	162	2,50		3,50	2,00		1,50									Mg	2,00	j	2,3	3
1666	163	2,00		2		1,00	-0,50	1,00	-1,00	1,00	3,00	1,00			-1,00	2,00		j	0,95454545	1
106	164			2		1,00			-1,00	1,00		1,00			-1,00			j	0,5	1
1322	165		1,50	2,00	2,00			2,00	-1,00	2,00						1,50		a	1,42857143	2
1217	166									1,00								a	1	1
983	167		1,50	2	1,50	1,00	1,50	1,00	-1,00	1,00	3,00	1,00	2,00		-1,00			a	1,125	2
1153	168						1,50											a	1,5	2
1189	169																	a	#DIV/0!	#DIV/0!
1191	170									1,00								a	1	1
1200	171						-0,50					1,00						a	0,25	1
1223	172																	a	#DIV/0!	#DIV/0!

1240	173			3,50	1,50		1,50			2,00					-1,00			a	1,5	2
1241	174		1,50				1,50					2,50						a	1,8333333 3	2
1273	175									1,00								a	1	1
1278	176			2								1,00						a	1,5	2
1283	177		1,50		2,00													a	1,75	2
1286	178		1,50										2,00		-1,00			a	0,8333333 3	1
1301	179									1,00								a	1	1
8102	180		1,50	2,00	2,00					1,00								a	1,625	2
1187	181																	a	#DIV/0!	#DIV/0!
1231	182		1,50	3			1,50											a	2	2
1023	183		1,50	2		-0,50			-1,00									j	0,5	1
989	184			3					-1,00									a	1	1
916	185									1,00								j	1	1
935	186	2,50		2			1,50											a	2	2
672	187	10	1,50	2	2,00	1,00	-0,50	1,00	-1,00	1,00	3,00	1,00	2,00	-1,00	-1,00	2	3	a	1,625	2
957	188		1,50	3	2,00	1,00	-0,50			1,00	3,00	2,00					2	a	1,6666666 7	2
871	189		1,50	2			1,50		-1,00	1,00								a	1	1
1029	190								-1,00			1,00						j	0	0
139	191	3,50	2,00	4		1,00			-1,00	2,00	3,00	1,00				2,0	2	a	1,95	2
2559	192	2,00		3,50		1,00	1,50		-1,00	1,00		1,00	2,00		-1,00			j	1,1111111 1	2
8006	193	2	4,00	3	1,50	1,00	-0,50	2,00	-1,00	1,00	3,00	1,00	2,00		2,00	3,50		a	1,75	2
1809	194		2,00	2		1,00	1,50	1,00		1,00		1,00				2,00	2	a	1,5	2
199	195	2		2	1,50	1,00	-0,50	1,00	-1,00	1,00		1,00			-1,00	2,00		a	0,8181818 2	1
309	196	10		4,00		1,00	1,50	1,00	-1,00	1,00	-0,50	1,00	-1,00		2,00	3	2,00	a	1,8461538 5	2
537	197	2,50	1,50	2	2,00	1,00	1,50	1,00	-1,00	1,00	3,00	1,00				3		a	1,5416666 7	2
521	198					1,00	1,50	1,00	-1,00	1,00	-0,50	1,00	-1,00					j	0,375	1
540	199	2		3	1,50	1,00	1,50	1,00	-1,00	1,00	3,00	2,00	2,00					a	1,5454545 5	2
1818	200	10	1,50	2	2,00	1,00	1,50	1,00	-1,00	1,00	3,00	1,00						a	2,0909090 9	3

Table X: *Excel sheet. Calculated votalities for the 200 sample trees.*

Vitality status	Absolute numbers			% per age class			% per vitality status and age class		
	Younger	***Older***	***Total***	***Younger***	***Older***	***Total***	***Younger***	***Older***	***Total***
1	28	14	42	62,2	10,8	---	66,7	33,3	100
2	15	101	116	33,3	77,7	---	12,9	87,1	100
3	2	14	16	4,5	10,8	---	12,5	87,5	100
4	0	1	1	0	0,7	---	0	100	100
Total	45	130	175	100	100	---	---	---	---

Table XI:*.Vitality status of older and younger sample trees – absolute and relative numbers.*

REGARDING CHAPTER 5 – DISCUSSION:

Vitality status	**Coverage level with epiphytes**			**Dominant type of epiphytic coverage**		
	Low	***Medium***	***High***	***Lichens***	***Bryophytes***	***Equal shares***
1	1	22	21	22	12	10
2	2	35	51	6	67	15
3	0	4	9	2	9	2
4	0	1	0	0	1	0
Total	3	62	81	30	89	27

Table XII: *Left: Relationship between vitality and epiphyte coverage on the trunks of old and young Sycamore maple trees. Right: Relative number of trees covered by lichens, bryophytes or both epiphyte types per vitality status.*

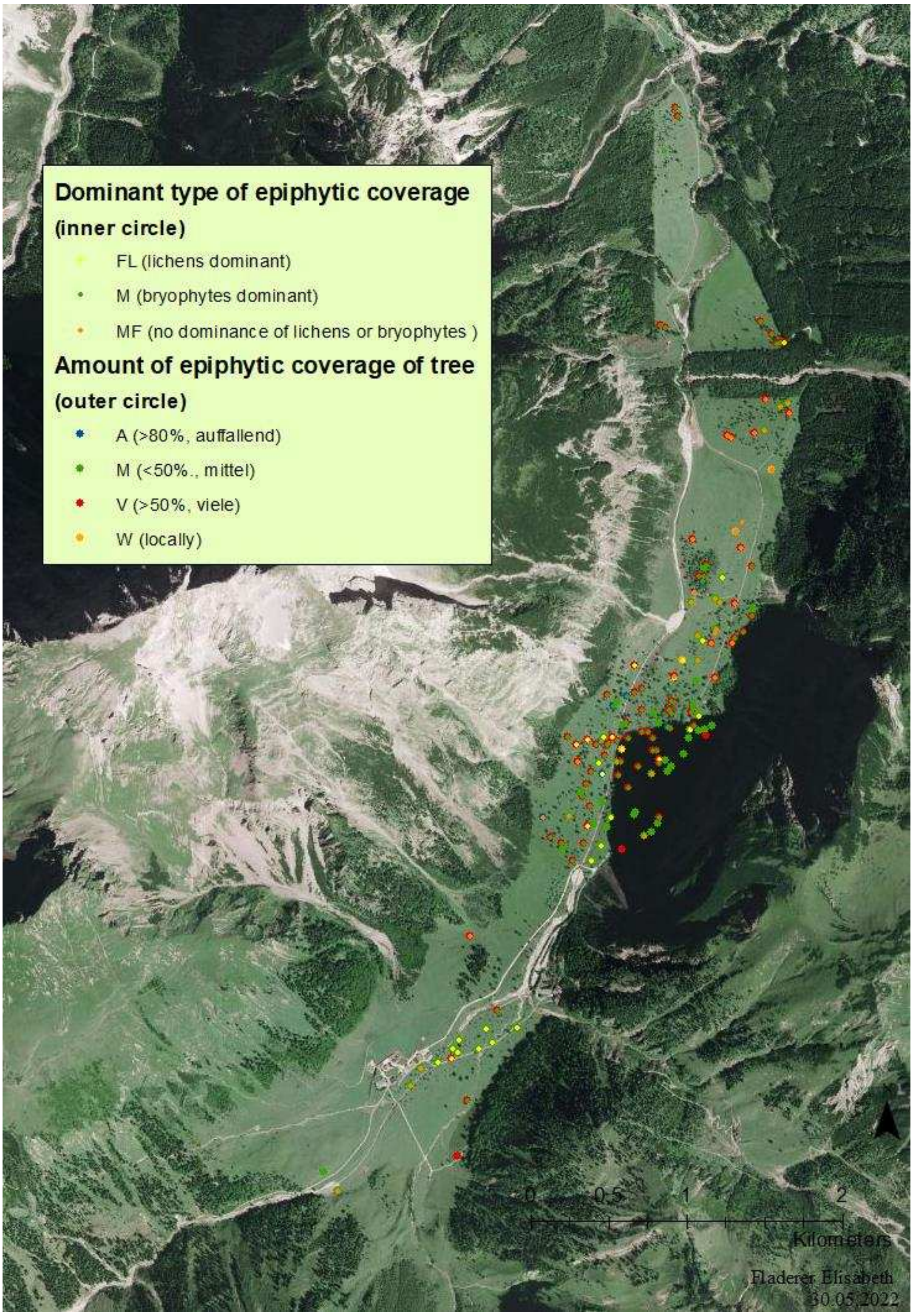


Figure XLIII*: Map shows the dominant type of epiphytic coverage as well as the amount of epiphytic coverage.*

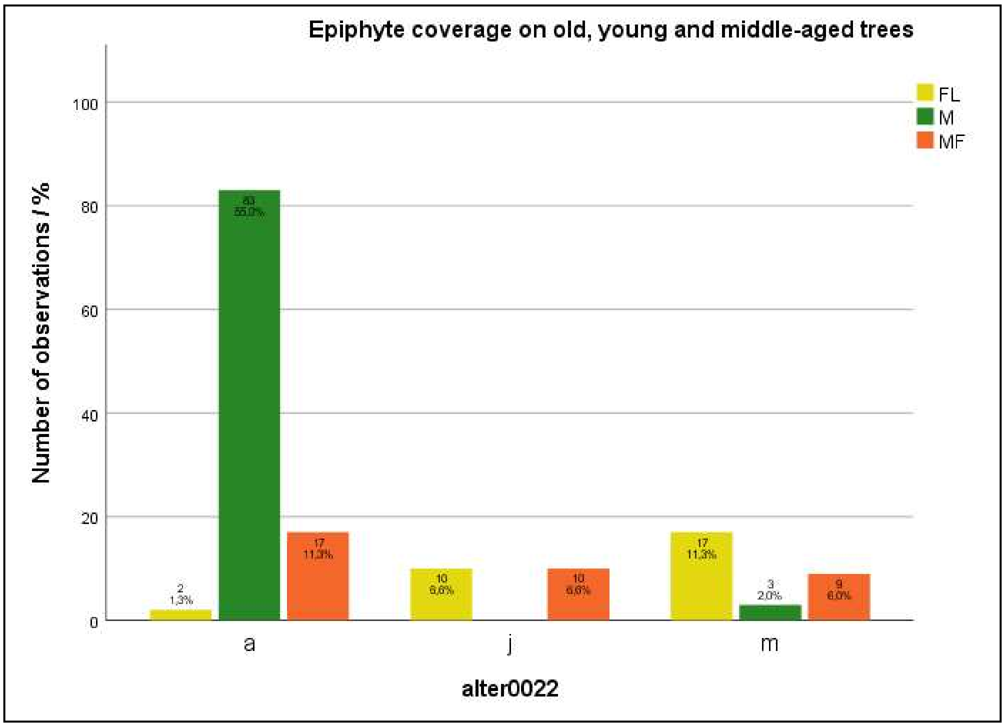


Figure XLIV.

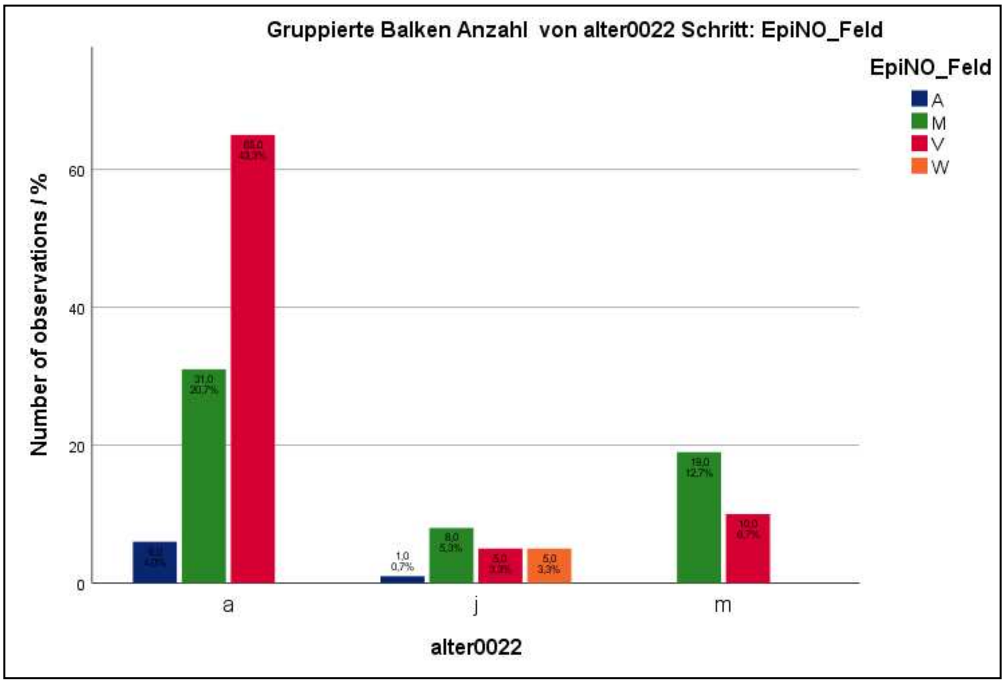


Figure XLV.

Appendix 2

Specific assessment sheet developed for and used in this master thesis to estimate the sycamore maples vitality at "Großer Ahornboden" considering ecological conditions and habitat characteristics

Fields estimated as specifically relevant for continued efforts to maintain and expand the tree cadastre:

Relevant information *(Name)*	**Description**
Tree ID *(Ahorn_ID)*	A unique record ID
Planting ID *(Pflanzung)*	Number and year of planting
Living status *(BZ22, BZ1_Feld)*	Weather the tree is dead or alive
Habitus *(BZ2_Feld)*	Facilitates orientation in the field
Tree side	Side name (Großer Ahornboden, …)
Category/Age class (*ALTER22*)	Young, veteran, ancient
Habitat/Veteran characteristics *(see pocket material "SICHERHEITSDEFEKTE UND KRANKHEIT(SHINWEISE) / BIODIVERSITÄT, HABITATE")*	Additional information about veteran characteristics of the tree
Measured girth of tree (cm) (*BHD_Feld, Umfang_Feld)*	Measured girth of tree (~ 1.3m)
Taxon *(ART_Feld)*	Taxonomic identity
Image *(Bbild_Feld)*	Possibility to upload an image of the tree
Date(*TAG_Feld)*	Date of the inventory
Person *(Pers_Feld)*	Person conducting the inventory
Additional notes *(Bfrei_Feld)*	Information which is related to the tree itself (Sign with dedication on the fence, e.g.);
Check *(BEMERKUNG)*	Observations that need to be checked in the near future (tree dying off, e.g.) or work that must be done (remove accompanying vegetation, repair fence, e.g.)
Vitality – young trees *(see pocket material "JUNGBAUM")*	Control work regarding the damage and habitus of plantings

Pocket material:

Erfassungs- und Bewertungsbogen für den Ahornbestand am Großen Ahornboden

Beurteilung des ästhetischen, ökologischen und kulturellen Wertes und der Vitalität

1. MATERIALLISTE

2. Tablet/Handy mit QField
3. Fernglas
4. Kluppe/Umfangmessband
5. Vertex mit Transponder
6. GPS – Ortungsgerät
7. Maßband (mind. 10m) zur Kalibrierung des Vertex
8. Meterstab (BHD -Messstelle, Transponderanbringung, Überprüfung von Dimensionen)
9. Markierkreide oder andere Markierungsinstrumente zur Vermeidung von Mehrfacherhebungen
10. Taschenmesser (Totholzbestimmung)
11. Bestimmungsbuch
12. Taschenrechner

1. DEFINITIONEN UND ABKÜRZUNGEN

Baumspitze: Höchster Trieb gilt beim Ahorn als Baumspitze; ein unbelaubter/unbenadelter Wipfel ist als Baumspitze zu definieren; ist die Krone abgebrochen, gilt die Bruchstelle als Baumspitze; hat sich eine Ersatzkrone gebildet, ist dort die Baumspitze zur Vermessung zu wählen; bei Zwieseln gilt die Spitze des höheren Teilstamms als Baumspitze.

BHD – Brusthöhendurchmesser: Durchmesser des Baumes auf 1,3m Höhe.

Kronenverlichtung: Lichtdurchlässigkeit der Baumkrone. Je höher die Kronentransparenz, desto mehr Licht dringt durch die Krone in tiefere Blattschichten und zum Boden (ROLOFF 2012).

Endtrieb eines Jungbaums: Zuletzt gebildeter Teil des Leittriebes. Seitentriebe können zu Leittrieben werden, wenn sie den Wachstumscharakter eines Astes verloren haben.

Krone: Setzt sich aus Ästen, Zweigen, Benadelung/Belaubung zusammen.

Kronenbreite: Horizontale Kronenausdehnung (FLL 2017).

Kronenhöhe/-länge: Abstand zwischen der Basis und der Spitze der Krone.

Leittrieb: Spross, der vom Stammfuß zum Gipfel die geringste Richtungsänderung zeigt und die höchste Spitze bildet.

MNF (Maßnahmenflächen): Im Managementplan 2005 definierte Flächen; nach Dringlichkeit und Aussichtserfolg der Anpflanzungen werden die Stufen 1-3 sowie Ausschlussflächen unterschieden.

Schaft: Verholzte Fortsetzung des Stammes innerhalb der grünen Krone; Hauptäste.

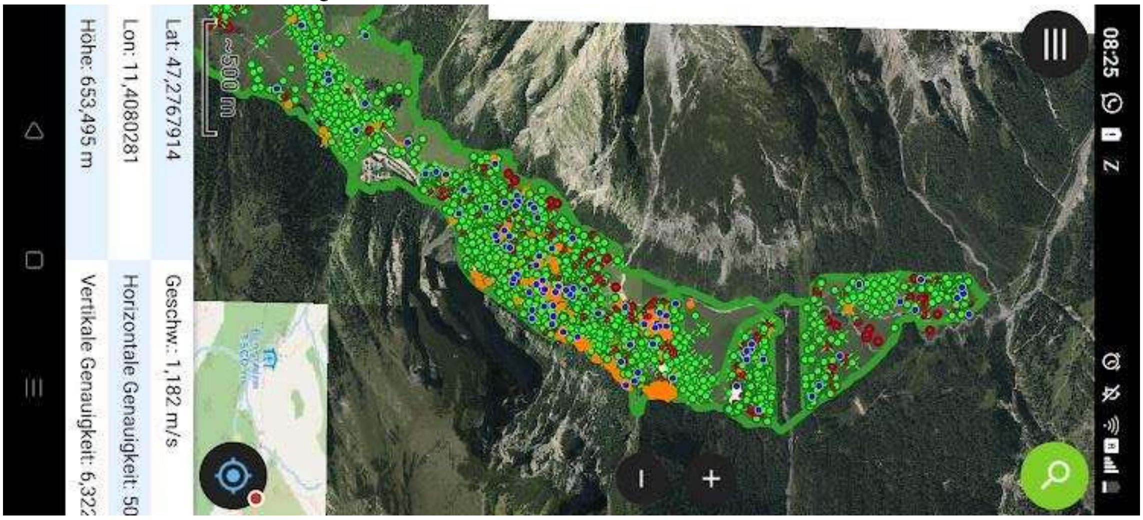
Sicherheitsdefekt: Beeinträchtigung oder Schädigung der Vitalität des Baumes; das langfristige Fortbestehen des Baumes kann dadurch gefährdet sein.

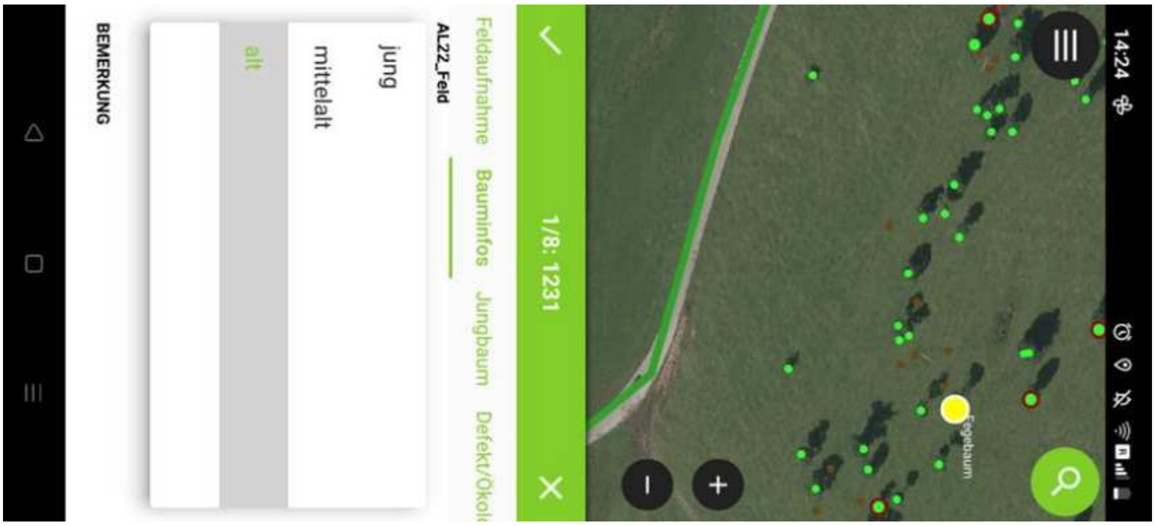
Stammfuß/Wurzelanlauf: Übergang von der Wurzel in den Stamm (FLL 2017); endet, wo der Baum seine „normale Dicke“ erreicht.

Starkast: Beim reifen Baum ein Ast, der einen Durchmesser von über 10cm hat (FLL 2017). Da bei alten Bäumen besonders große Starkäste beeindruckend wirken, sollen nur Starkäste mit einem Durchmesser von über 25cm bewertet werden. Bei Neupflanzungen sind die dominanten Äste als Starkäste zu verstehen.

Zwiesel: Gabelung eines Stammes; entsteht, wenn zwei verschiedene Wipfeltriebe konkurrieren und keiner der beiden die Vorherrschaft in der Krone übernimmt (ROLOFF 2012); Zwieselbildung wird beim Ahorn durch Verbiss begünstigt.

2. BENUTZERANSICHT IN QFIELD





3. INFORMATIONEN ZU BAUM UND FELDAUFNAHME - REITER UND AUSWAHLMÖGLICHKEITEN IN QFIELD

3.1. AUFBAU DER FOLGENDEN TABELLEN

Langform des Kürzels	Kürzel in QField	Kürzel der Attributt-abelle in QGIS	Auswahlmöglichkeiten bzw. Vorgabe in QField	Erklärungen (Zahlen werden unter der jeweiligen Tabelle erläutert)

3.2. NACHVOLLZIEHBARKEIT DER FELDAUFNAHME, REPRODUZIERBARKEIT BAUMBEURTEILUNG UND INFORMATIONEN ZU STANDORT UND ZAUN

FELDAUFNAHME und BAUMUMFELD				
Datum der aktuellen Feldaufnahme	**TAG_Feld**		*TTMMJJJJ*	
Startzeit der Messung	**UHR_Feld**		*HH:MM*	
Messperson	**PERS_Feld**		*Vorname, Nachname*	
Koordinaten	X_GIS			1
	Y_GIS			1
Anspracherichtung der visuellen Kronenbeurteilung	**VBR_Feld**		N, NO, O, SO, S, SW, W, NW	**2**

Standortinformationen	**STOR_Feld**	BU WR SN BB M Bfrei <Nul l>	Bachufer /Uferböschung Waldrand Staunässe Bachbett Maulwurfhügel/Mausgänge Bfrei_Feld <Null>	
Zaunzustand	**Zaun**	iZ dZ Zn <Nul l>	Intakter Zaun defekter Zaun Zaun notwendig <Null>	

1) Koordinaten der Bäume am Großen Ahornboden
   a. Die Koordinaten (X, Y) der Bäume werden vorgegeben (WGS84) und sind auf dem Datenerfassungsgerät in QField einsehbar.
   b. Sollte die Ortung mittels QField nicht möglich sein, sind die Probebäume über eine separate Einmessung zu gewinnen.

2) Ort der Baumbeurteilung und der Aufnahme des Baumbildes
   a. Die Distanz zur Messung der Baumhöhe bzw. der Beobachtungspunkt sollte in etwa eine Baumlänge betragen.
   b. Zur Einschätzung der Entwicklung des Blattverlustes und des allgemeinen Baumzustandes sollte die Krone immer aus der gleichen Richtung beurteilt werden. Dies kann durch Angabe der Entfernung des Beobachters zum Baum zusammen mit der Anspracherichtung gewährleistet werden.

3.3. BEREITS BEKANNTE ATTRIBUTE DES EINZELBAUMS UND ERHEBUNG ALLGEMEINER INFORMATIONEN ZU BAUMZUSTAND UND HABITUS

	Bauminfos			
Baumnummer im Baumkataster	**Ahorn_ID**		*XXXX [Zahl]*	*6000er nicht MNF* *8000er – Fladerer* *7000er- Doppel-ID*
Probebaumnummer	**PROBE_ID**			
Baumbild	**Bbild_Feld**		*Bilddatei*	*Foto von → TAG_Feld und → VBR_Feld*
Baumstatus	**BZ1_Feld**	i p z N L Jp	vital nicht gefunden Mortalität Nadelbaum Laubbaum Jungpflanzen / nat. Vermehrung	N,L → *ART_Feld* P → Orthophotos/Laserdaten gegenprüfen! **1**
Baumart	**ART_Feld**		*Freitext*	**2**
Zusatzinformationen zu BZ1_Feld	**BZ2_Feld**	Null DS WS ZWh ZWt 3S /4S LB DW WzOF TH SF K SW HW	Null Dürrständer } z Wurzelstock Zwiesel (in über 1.3m) Zwiesel 3-stämmig/4stämmig Liebende Bäume Drehwuchs Wurzen oberflächlächlich } i TH (liegend) Schiefer Baum Krummer Baum Sockelwuchs Hohlwurzel	z → *TH_Feld* i → 3)
Zersetzungsgrad Totholz	**TH_Feld**	TH Mo Mod Mu	Totholz Morschholz Moderholz Mulmholz	**4**
Geschätzte Altersstufe	**AL22_Feld**	a m j	Alt Mittelalt Jung	**5**
Freitext zum Baum	**Bfrei_Feld**	XXX	*Freitext*	***6***
Bei der Laserdaten- / Orthophotoanalyse festgestellte und zu überprüfende Attribute oder Eigenschaften	**BEMER-KUNG**	XXX	*Freitext*	***7***

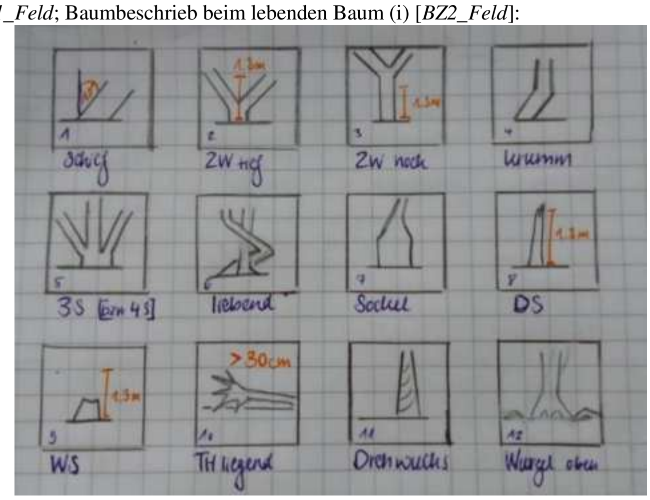
Baumalter 1953	**ALTER53**	<Null> , j, m, a	Jung, mittelalt, alt	
Baumalter 2001	**ALTER00**	<Null> , j, m, a	s.o.	
Baumgröße 1953	**GROESSE53**	<Null>, k,m,g	Groß, mittel, klein	
Baumgröße 2001	**GROESSE00**	<Null>, k,m,g	s.o.	
Zustand Erhebung Fladerer - Orthophoto	**BZ19_Ortho**	N i/i16 p z n 0	Nadelbaum Intakt/vital zu überprüfen Mortalität nicht vorhanden keine Information	
Gegenüberprüfung der als abgestorben vermerkten Bäume	**z_test**	Verifiziert Existenz fraglich Nie da		
Aufnahmejahre der Orthophotos - Identifikation Vitalität und der Mortalität	**z_test_anm**	XXXX i; XXXX z	Jahr des Orthophotos auf dem der Baum als vital zu erkennen ist; Jahr des Orthophotos auf dem der Baum als mortal identifiziert wurde	
Zustand Erhebung Fladerer - Laserdaten	**BZ_Las**		N z i p n 0	s.o.

1) Baumzustand [*BZ1_Feld*]:
   a. N/L und Probebaum (→ *Probe_ID*): Der nächstnahe Ahornbaum muss ersatzweise in den Kataster als Probebaum aufgenommen werden.

2) Baumart [Art_Feld]:
   a. Spezifikation bei Auswahl N bzw. L im Reiter BZ1_Feld
      i. Fichte
      ii. Buche
      iii. Bergulme
      iv. Birke
      v. Eberesche
      vi. Grauerle
      vii. Weide
      viii. …

   b. Ist der Baum ein Bergahorn, wird das Feld nicht ausgefüllt.

3) Spezifikation von *BZ1_Feld*; Baumbeschrieb beim lebenden Baum (i) [*BZ2_Feld*]:



4) Spezifikation von *BZ1_Feld*; Abbaustadium des Totholzes (z) *[TH_Feld]*:
   a. Totholz: Saftlos, fest, Messerklinge dringt in Faserrichtung nur sehr schwer ein.
   b. Morsch: Die Klinge dringt in Faserrichtung leicht ein, nicht aber quer.
   c. Moder: Weich, die Klinge dringt in jeder Richtung leicht ein.
   d. Mulm: Sehr locker oder pulverig, kaum noch zusammenhängend.

5) Alterseinschätzung *[Al_Feld]:*

Altersstufen	Anhaltspunkte
Jung	- Exploratives vegetatives Wachstum, streng hierarchisch aufgebaute Krone - Monopodiale und aktrotone Förderung - Goldene bis braune oder graue Rindenfärbung; glatt - Geringer BHD und Baumhöhe
Mittelalt	- Einsetzen der Blüte und Fruktuation - Schuppenborke bildet sich
Alter und Seneszenz	- "Baumpersönlichkeit"/ Habitatbaum - Schuppenborke - Eventuell Reduktion der Kronengröße durch das Absterben oder den Bruch von Zweigen und Ästen in der Oberkrone (Lonsdale, 2004; Rust & Roloff, 2002 - Großer Umfang - Seneszenz bedingte Reiteration (Reiterate bilden sich beim Ahorn im Kronenmantel)

6) Freitextfeld - Baum *[Bfrei_Feld]:*
Kommentarfeld für sonstige nennenswerte Informationen zum Baumstandort/Probefläche.

7) Freitextfeld

3.4. JUNGBAUM

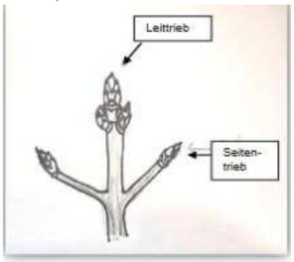
Gipfeltrieb	**GTj_Feld**	VB i	verbissen intakt null	**3**
Seitenrtieb	**STj_Feld**	I 30 50 100	intakt 5-30% 31-50% 51-100%	**3**
Bereits ausgetrieben?	**BAT_Feld**		→Zusatzinfos→AT_Feld	
Triebe duerr? Blätter oder Knospen braun?	**GiDue_Feld** **ASTg_Feld**		Ja = Leittrieb tot [in %] = Seitentriebe abgestorben	**4**
Knick oder entwurzelt?	**HabDe_frei**		„entwurzelt", „geknickt"	
Schädigung durch	**VbArt_Feld**	SW H M	Schalenwild Hase Maus	**3**
Baumzustand Jungbaum	**BZjun_Feld**	<Null> 1 2 3 4	Null Sehr guter Zustand Wenig geschwächt Geschwächt Stark geschwächt	**2**
Ist der Baum starker Konkurrenz ausgesetzt?	**BEMERKUNG**		*z.B „Buche entfernen"*	
Gibt es eim Schild am Zaun? Sind mehrere Ahornbäume im Zaun?	**Bfrei_Feld**		*z.B. [Baumpate] oder „ zum 80."* *2B, 3B,…*	**1**

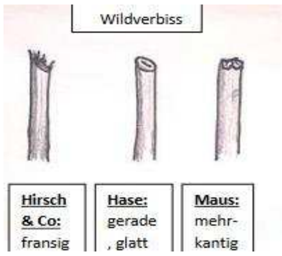
1) Freitext Baum *[Bfrei_Feld]:*
   a) Krankheiten und andere Defekte als Dürre, Verbiss, „entwurzelt", „geknickt" sind in → *Defekte/Ökologie* zu vermerken
   b) Zwieselbildung*: →Bauminfos → BZ2_Feld → Zwhoch/tief:* Neigt nach Verbiss des Leit- oder Ersatzleittriebes zur Zwieselbildung
   c) Buschartiger Wuchs: → *Zusatzinfos → Kbau_Feld→ Busch*

2) Baumzustand – Jungbaum (Schädigungsgrade Verbiss) *[BZjun_Feld]:*

Schädigungsgrad	Gipfelknospe / Leittrieb	Seitentriebe
1 = Keine	Nicht verbissen	Nicht verbissen
2 = Schwach	Nicht verbissen	30-50% verbissen
3 = Mittel	Verbissen oder Nicht verbissen	<50% verbissen >50% verbissen
4 = Stark	Verbissen	>50% verbissen

3) Und 4)





4) Gipfeldürre beim Jungbaum [*Gduer_Feld*]:
Die Gipfeldürre gibt einen Anhaltspunkt, weshalb der Schaft nicht mehr wächst, auch wenn er nicht verbissen worden ist (LFI4/2017)

3.5. INDIKATOREN ZUR BEURTEILUNG DER VITALITÄT UND VERMERK NATUSCHUTZRELEVANTER BAUMATTRIBUTE

3.5.1. SICHERHEITSDEFEKTE UND KRANKHEIT(SHINWEISE)

DEFEKTE/ÖKOLOGIE				
Schaden 1,2 Blattschäden	**Blg1_Feld** **Blg2_Feld**	TF BFpl Bfpe WF BG W F G <Null>	Teerfleckenkrankheit Ahornblattbräune – *Pleuroceras* Ahornblattbräune – *Pektrakia* Weißfleckigkeit Eingerollte Blätter Welke Fraßspuren Gallen/Pusteln <Null>	1
Ausmaß des Blattschadens	BlgNo_Feld	5 10 50 100 0	1-5 % 5-10% 11-50% 50-100% Kein Befall	2
Kronenschäden	**KRg_Feld**	K TK BS A ZW	Krone Teilkrone Baumspitze Starkast Zwieselabriss	
Orte der Stammschäden 1und 2?	**StgOrt1_Fe** **StgOrt2_Fe**	Stf St Wz A	Stammfuß Stamm/Schaft Wurzeln Starkast	3
Beschreibung der Schaden/Schadbilder 1, 2, 3	**STg1_Feld** **STg2_Feld** **Stg3_Feld**	L LmB SL Rg Rk Hg Hk MHg MHk HFk HFg RRK RPK HoSt PFK BL <Null>	Löcher >5mm Löcher (+ Bohrmehl) Spechtloch Risse <1m Risse >1m Höhlen < 2 HF Höhlen >2 HF Höhlen (+Mulm) < 2 HF Höhlen (+Mulm) >2 HF Holz frei 1 – 4 HF Holz frei > 4 HF Rußrindenkrankheit Rotpustelkrankheit Hohler Stamm Pilzfruchtkörper Blitzschaden/-rinne <Null>	4 Zusatzinfos → HabDe_frei
Wundholzbildung an Schäden 1 und 2?	**WH1_Feld** **WH2_Feld**	K Ü Üg <Null>	Kallus/Wulst Überwallung vollständig Überwallung gescheitert Null	**5**
Holzzersetzung?	**StgNo_Feld**	1, 2, 3,4, 5, >5	Anzahl der Defekte am Holzkörper mit Holzzersetzung > 1 HF bzw >15% des Baumumfanges	

1) Schadsymptome Blatt *[Blg1_Feld; Blg2_Feld]:*

Teerfleckenkrankheit / Ahornrunzelschorf (Rhytisma acerinum)	Schwarze, glänzende, teerfleckenartige, leicht erhabene Pusteln; oft mit hellem, gelblichem Rand; stark befallene Blätter verbräunen und fallen vorzeitig ab.	
Weißfleckenkrankheit (Cristulariella depraedans)	Rundliche, graue bis weiße Blattflecken, meistens mit einem dünnen, dunklen Rand an Ahornblättern; tritt bevorzugt an Blättern nieder hängender Zweige junger Bäume auf; unter der Lupe zeigen sich stecknadelförmige Makrokonidien	
Pleuroceras-Blattbräune (Pleuroceras pseudoplatani)	Auffallend bräunliche Blattflecken auf Ober- und Unterseite der Blätter; anfangs fingerartig auflösender Rand – später glattrandig; Blattunterseite durch schwärzliche Nekrosen an den; Infektion beginnt an Blattspreite	
Pektrakia-Blattbräune	Große ineinanderfließende, goldbraune bis dunkelnraine Flecken; oftmals mit konzentrischen Linien in den Flecken; Flecken sind elliptisch, rundlich oder unregelmäßig geformt	

2) Anzahl der Blätter mit Krankheitsbefall oder Schadsymptomen *[BLgNO_Feld]:*

Anteil der geschädigten Blätter	Anhaltspunkte
1-5 %	vereinzelt Blätter befallen
5-10%	Geringe Schädigung, beginnender Befall
11-50%	Befall deutlich sichtbar, es überwiegt aber der Eindruck unbefallenen Blätter
51-100%	Blattmasse stark beschädigt/befallen

3) Ort des Stammschadens *[StgOrt1_Feld, StgOrt2_Feld, StgOrt3_Feld]:*
   a. Stammfuß/Wurzelanlauf: Verdickter Übergang der Wurzel in den Stamm (FLL 2017). Bis dort, wo der Baum seine „normale Dicke erreicht
   b. Schaft: Verholzte Fortsetzung des Stammes innerhalb der grünen Krone, Hauptäste.

4) Schäden am Stamm *[Stg1_Feld, Stg2_Feld, Stg3_Feld]:*

Rotpustelkrankheit (*Nectria cinnabria*)	Kränkelnde Triebe, Welke, Rindennekrosen, rot gefärbte stecknadelkopfgroße Pusteln auf den Trieben im Winter und zeitigen Frühjahr
Rußrindenkrankheit (*Cryptostroma corticale*)	Welke, Blattverlust, absterbende Kronenteile, Rindenrisse, Schleimfluss am Stamm, verstärkt Wasserreiser im unteren Stammbereich; Aufplatzen und grobscholliges Abfallen von Rindenteilen

5) Wundholzbildung (CODIT-Prinzip)*[WH1_Feld, WH2_Feld]:*

Beurteilung des Wundverschlusses an den Stammschäden 1 & 2:

Links: Gescheiterte Überwallung = Phase 4 des CODIT-Prinzips konnte nicht erreicht werden, der Pilz hat sich im Inneren des Baumes ausgebreitet
Mitte: Kallusbildung / „Wulst" um Wunde = Phase 3 CODIT -Prinzip
Rechts: Überwallung vollständig = Phase 4

3.5.2. BIODIVERSITÄT, HABITATE

ÖKOLOGIE				
Epiphyten	**Epi_1** **Epi_2**	MI MF F M BP B TR F <Null>	Mistel Moose/Flechten Flechten (wenig Moose) Moose (wenig Flechten) Blütenpflanze Junger Baum *Tayloria Rudolphiana* Farn <Null>	**1**
Anzahl Epiphyten	**EpiNo_1**	W M V A	Wenig (lokal begrenzt) mittel (<50%) viele (>50%), auffallend (>80%)	
Habitate und Baumbewohner	**Hab1_Feld** **Hab2_Feld**	SN IN VN NK Am SM HB BS R K <Nul l>	Wohnung von Säugetier Nest von Insekt Nest von Vogel Nistkasen Ameisen Spinnmilbe Ungleicher Holzbohrer Blausieb Raupe Käfer <Null>	**2**
Freitext Defekte und Habitate/Arten	**DefHab_frei**	XX	Freitext	**3**
Bild von Defekten und Arten	**SD_Feld**		Bilddatei	

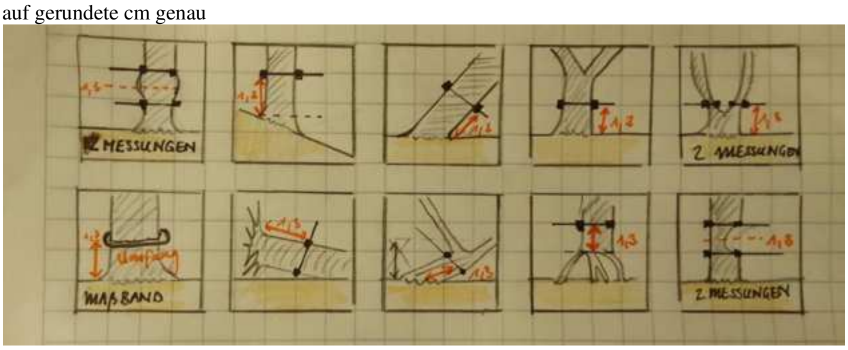
1 - Epiphyten: Es können maximal 2 verschiedene Epiphytenarten angegeben werden.
2 - Habitate: Es können maximal 2 Stichworte gewählt werden.
3 - Freitext zur Spezifikation der festgestellten Tier- bzw. Pflanzenart bzw. zur Beschreibung/Nennung weiterer Schäden am Baum.

3.6. MESSUNGEN – OBLIGATORISCH FÜR PROBEBÄUME
(BHD und Baumhöhe sind so weit möglich für alle Bäume zu erheben)

BHD	**BHD_Feld**	XX	**1**
Umfang	**Umfang_Feld**	XX	**1**
Kronenhöhe	**KH_Feld**	XX,X	**3**
Kronenbreite	**KB_Feld**	XX,X	**4**
Baumhöhe/Schafthöhe	**BH22_Feld**	XX,X	**5**

Gemessene Kronenhöhe – Laser	**gKH_Las**	*XX,X [Zahl in m]*	
Gemessene Kronenbreite - Laser	**gKB_Las**	*XX,X [Zahl in m]*	
Gemessene Baumhöhe -Laser	**gBH_Las**	*XX,X [Zahl in m]*	
Baumfoto Laseranalyse	**Foto_LAS**	XXXX.png	
Zu überprüfende Informationen und Anhaltspunkte (Laserdaten- und Orthophotoanalyse)	**Bemerkung**	*XXXX [Text]*	**1**

1) BHD (→Definition) *[BHD_Feld]:*
   a) Wird 2x gemessen. Ab einem BHD >60cm wird der Umfang gemessen.
   b) Ablesung auf gerundete cm genau



2) Kronenhöhe (→ Definition) *[KH_Feld]:*
- a) Erster grünen Ast, der noch im Zusammenhang mit der Krone steht, bis zur Baumspitze.
- b) Die Krone ist das "zusammenhängende Grün" der Nadel-/Blattmasse ohne Klebäste am Stamm.
- c) Der Kronenansatz wird durch die grüne Mantelfläche definiert und nicht der Astansatz am Stamm. Die untersten, spärlich benadelten/belaubten und langsam absterbenden Zweige sind nicht einzubeziehen.
- d) Bei einer einseitigen Krone gelten die untersten, grünen Äste der längeren Kronenhälfte als Kronenansatz

3) Kronenbreite (→ Definition) *[KB_Feld]:*
- a) Messung mit Vertex auf Dezimeter genau.
- b) Mittelwert aus 2 Messungen (orthogonal)

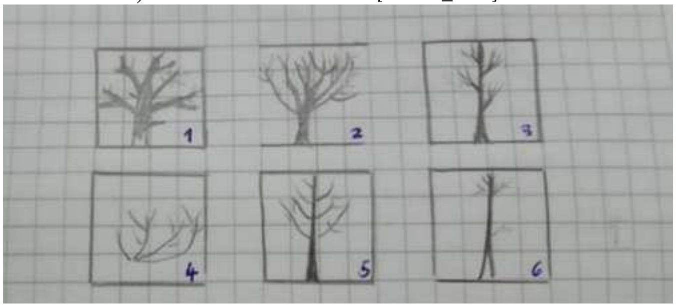
4) Baumhöhe/Schafthöhe (→ Definition) *[BH_Feld]:*
- a) Wird mit Vertex auf Dezimeter genau gemessen.
- b) Transponderhöhe (1.3m) bis Baumspitze (→Definition)

3.7. ZUSÄTZLICHE BEURTEILUNGSKRITERIEN - PROBEBAUM

Krone/Vitalität				
Soziale Stellung	**SOZ_Feld**	S Gh Gm Gu	Frei (solitär) Gruppe (herrschend) G gleich (mitherrschend) Gu (unterdrückt)	**6**
Konkurrenz	**Konku_Feld**	0% 10% 20% 40% 60% 80%	Keine Konkurrenz 3.5 Seiten frei 3 Seiten frei 2 Seiten frei 1 Seite frei Nur Kronendach frei	**7**
Allgemeiner Eindruck und Symmetrie	**KrZ_Feld**	Syn EK Asy	Eindruck einer Gesamtkrone, symmetrisch, harmonisches Bild) Zerfall in Einzelkronen/"lückig") Assymetrisch (z.B. durch das Feheln von 1-2 Starkästen)	
Kronenaufbau und - struktur	**KrBau_Feld**	kGT GT WA B TA S	Aufstrebende Äste und Zweige ohne klaren Gipfeltrieb Geradliniger Stamm geht in Schaft über, Äste und Zweige leicht aufsteigend Waagrechte Starkaste, Zweige außen Buschartig (4) Schaft mit Trittästen (3) Schaft mit pinselartigen Zweigen (6)	**1**
Kronenform	**Kform_Feld**	31 21 11 12	3:1 (Schlank/schmal) 2:1 (Eiförmig) 1:1 (Kugelförmig) 1:2 (Ausladend)	**2** Kronenbreite zu Kronenhöhe
Kronenklasse	**KrKl_Feld**	G M k	Langkronig (KH >1/2 BH) Mittelkronig (1/4 -1/2 BH) Kurzkronig (KH <1/4 BH)	Kronenlänge zu Baumhöhe
Kronenverlichtung	**KvOrt_Feld**	KVo KVm KVi KVu n KV Null	Kronentransparenz Oberes 1/3 Kronentransparenz Mitte (horizontal) Kronentransparenz innen Kronentransparenz Unteres 1/3 Keine Verlichtung/dichte Krone Gleichmäßig lichte Krone Null	
Gipfeldürre	**GiDue_Feld**	Null Ja Nein		GD = abgestorbener Wipfel
Totholzanteil der Krone	**ASTg_Feld**	0 15 30 50 95	Kein TH 1-15% 15-30% 31-50% >50%	
Wasserschosse	**WS_Feld**	KA KM K	Kronenansatz Kronenmantel Kronenmantel und Kronenansatz Null	

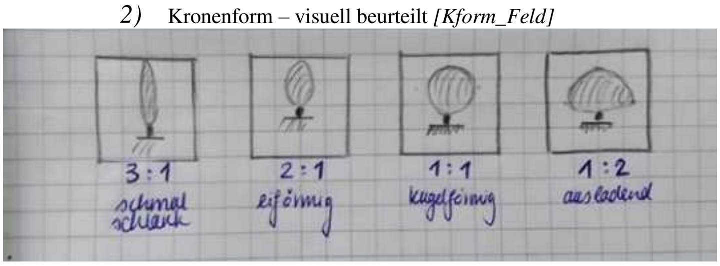
Blütenstände	**BlSt_Feld**	A Aj NULL	Alte Blütenstände 2021/ Blüte 2022 Alte Blütenstände und Blüte 21/22 Keine Blüte 21/22	**4**
Blattaustrieb	**BAT_Feld**	F M K	Ja, vollständig (früh) Ja, beginnend (mittel) Nein nur Knospen (spät)	

1) Aufbau der Baumkrone *[KrBau_Feld]:*



1. (Starke) waagerechte Äste, Zweige außen
2. Äste tendenziell aufstrebend, kein klarer Gipfeltrieb vom Stammkopf ausgehend
3. Schaft mit Trittästen und Feinzweigen
4. Busch/Strauch
5. Gipfeltrieb erkennbar, der sich vom Stammfuß bis zur Baumspitze durchsetzt
6. Schaft mit pinselartigen Zweigen

2) Kronenform – visuell beurteilt *[Kform_Feld]*



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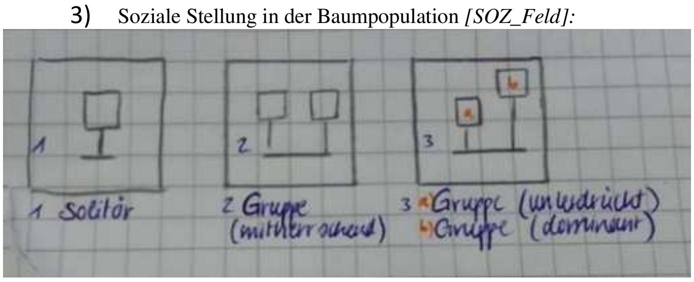
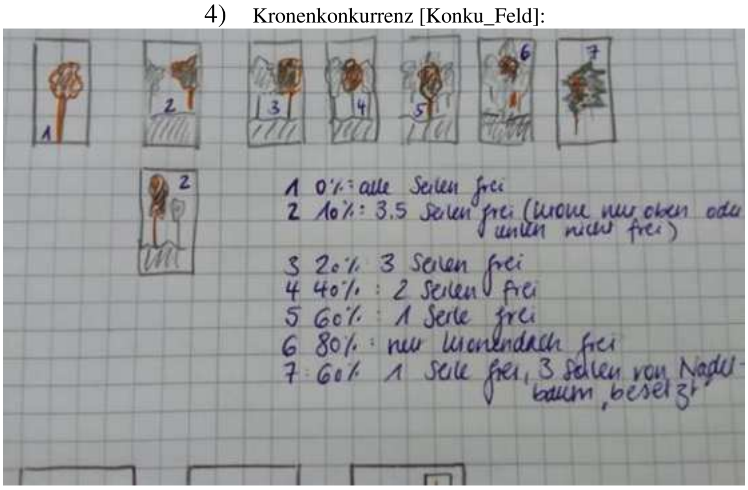
3) Soziale Stellung in der Baumpopulation *[SOZ_Feld]:*



4) Kronenkonkurrenz [Konku_Feld]:



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Anhang I: BEURTEILUNG DER BAUMVITALITÄT (URSPRÜNGLICH)

PROBEBAUM			
Indikator	**Feldname**	**Beschreibung**	**Auswahl**
Verteilung der Blattmasse und Kronenvolumen	**KV_Vit22**	Eindruck einer Gesamtkrone, Blätter sind am Ende der Äste konzentriert, keine Wasserreißer	1
		Krone weist einige Unregelmäßigkeiten auf (z.B. durch Absterben/Abbrechen von 1-2 Starkästen).	2
		Krone irregulär. Zerfall in mehrere Einzelkronen und/ oder epicormiv growth im Kroneninneren, Kronenteile abgestorben	3
		Kleine Krone, nur noch wenige Äste belaubt, eventuell Wasserreiser im Bereich des Kronenansatzes.	4
Blattverlust quantitativ Transparenz	**BV_Vit**	Dichte, gleichmäßige Belaubung (0-5% Blattverlust)	1
		Lockere Belaubung (5-50% Blattverlust)	2
		Spärlich belaubt (50-94%)	3
		Vollkommen entlaubt, „lebender Dürrständer" (95%),	4
Tote Zweige und Äste	**TH_Vit**	Keine abgestorbenen Zweige und Äste oder nur wenige Zweige im Kroneninneren (0-5% Totäste)	1
		Dürrasanteil <50%	2
		Dürrasanteil >50%, Aststummel	3
		Nur noch wenige lebende Äste oder Zweige verbleiben am Baum, „stehender Stamm" (96-100%),	4
Schädigung durch Pilz-oder Insektenbefall oder abiotische Schäden	**BLATT_Vit**	Keine Schäden erkennbar, gesunde Blatter	1
		Geringe Schädigung, beginnender Befall, vereinzelt Blätter befallen (0-10%)	2
		Befall deutlich sichtbar, es überwiegt aber der Eindruck unbefallenen Blätter 11-50%	3
		Blattmasse stark beschädigt/befallen (50-100%)	4
	ST_Vit	Keine Defekte oder Defekten und keine Hinweise auf holzzersetzende Pilze	1
		Bis zu 3 Sicherkeitsdefekte, kein Pilzbefall an den Wunden	2
		>3 Sicherheitsdefekte oder eine Wunde >1/4 DBH Tiefe/>10cm Durchmesser oder Wunde mit Anzeichen von holzzersetzenden Pilzen	3
		Sicherheitsdefekt mit Faulstelle/morsches Holz	4
Wundholzbildung und Wundverschluss	**WH_Vit**	Keine Schäden und folglich keine Wundholzbildung oder Wunde wurde komplett geschlossen	1
		Wunddurchmesser zwischen <15% des Baumumfanges bis max. 1 Handfläche	2
		MIT Wundholzbildung Wunde >1 Handfläche oder 2 Wunden <10cm Durchmesser, die weniger als eine Wundbreite entfernt sind	3
		OHNE Wundholzbildung, Wunde >10cm Durchmesser oder 2 Wunden <10cm Durchmesser, die weniger als eine Wundbreite entfernt sind	4