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Wood Pastures in the City

Combining Nature Conservation and Recreation in an Urban Landscape through Modern Woodland Grazing (Leipzig, Germany)

Master's Thesis

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Statutory Declaration

I declare that I have authored this thesis independently, that I have not used other than the declared sources, and that I have explicitly marked all material which has been quoted either literally or by content from the used source.

Berlin, 29.09.2016

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Abstract

Central Europe's potential natural vegetation is dominated by woodland which was presumably more open than it is today due to grazing by large herbivores. Modern extensive grazing concepts aim at keeping cultural landscapes open. At the same time, they pose a practical approach to restoring natural landscapes, whilst maintaining disadvantaged areas in ecologically and economically sound ways. In urban areas, there is a high demand for green space. Grazers can contribute to a sense of being close to nature here, whilst supporting self-regulating ecosystem mechanisms. A project in the city area of Leipzig, Germany, is dedicated to creating a self-sustaining wood pasture with sheep and goats against the backdrop of process protection. Since 2014, the grazers are kept on-site twice a year in rotational couplings. The present study analyses the effectiveness and ecological consequences of the current grazing regime in order to give recommendations for future grazing regimes. For the following seven tree species, browsing impacts, bite depths and tree vitality were investigated in 2015: *Betula pendula, Acer pseudoplatanus, Alnus glutinosa, Salix alba, Quercus robur, Rosa* spec. and *Salix caprea*. Additionally, tree height and site factors such as vegetation density, distance to the water and position were recorded. It was found that *S. caprea* was most popular among the grazers, whereas *B. pendula* was least grazed. Severe impacts on vitality were detected when the trees' cambium was affected, and more than half of the trees' circumference was browsed. Sallows were most affected in vitality, yet they show high abundances on-site, making an imminent extinction of the population unlikely. Sallows, oaks and roses were found to benefit from the current intermediate browsing pressure. Both browsing damage and bite depth decreased with tree height. Vegetation density and distance to the water influenced browsing behaviour. Yet those factors intercorrelated with tree species, asking for more specific research. The current grazing management under the given site conditions is considered realistic and ecologically sound. On a bigger scale, the project has the potential to act as a role model for urban land use. It helps revive a historical form of land use under the modern approach of process protection. A demand for long-term research on interactions between grazers and flora and fauna on-site could be spotted. Especially rare and invasive species pose an interesting research field in urban ecology that wood pastures could add a new perspective to. The current legislation still distinguishes between forest and pasture. Subsidies for ecosystems in-between are thus difficult to receive, diminishing their attractiveness for farmers and land owners. Adjustments on a legislative level, together with enhanced interlinking and accessibility of existing information, could open up new perspectives for urban area management.

Zusammenfassung

Mitteleuropas potentielle natürliche Vegetation ist eine Waldlandschaft, die zumindest in Teilen von großen Weidetieren offengehalten wurde. Moderne extensive Beweidungskonzepte zielen darauf ab, Kulturlandschaften offen zu halten. Gleichzeitig stellen sie einen praktischen Ansatz zur Wiederherstellung halboffener Landschaften dar, und können darüber hinaus einer ökologisch und ökonomisch sinnvollen Bewirtschaftung benachteiligter Gebiete dienen. Besonders in urbanen Gebieten gibt es einen hohen Grünflächenbedarf. Weidetiere können hier eine Naturnähe schaffen, und gleichzeitig selbstregulierende Ökosystemprozesse unterstützen. Ein Projekt im Stadtgebiet von Leipzig, Deutschland, widmet sich der Schaffung hudewaldähnlicher Strukturen durch Ziegen- und Schafbeweidung vor dem Hintergrund des Prozessschutzes. Seit 2014 werden die Weidetiere zweimal jährlich in Rotationskopplung auf der Fläche gehalten. Die vorliegende Studie analysiert das bestehende Beweidungsregime in Hinblick auf Effizienz und ökologische Folgen. Für folgende sieben Baumarten wurden 2015 Verbissschäden, Verbisstiefen und Baumvitalität aufgenommen: *Betula pendula, Acer pseudoplatanus, Alnus glutinosa, Salix alba, Quercus robur, Rosa* spec. und *Salix caprea*. Darüber hinaus wurden Baumhöhe und Standortfaktoren wie Ufernähe, Vegetationsdichte und Position aufgenommen. *S. caprea* war nachweislich am begehrtesten unter den Weidetieren, während *B. pendula* am wenigsten verbissen wurde. Starke Beeinträchtigungen der Vitalität konnten nur bei Verbissschäden, die mindestens 50% des Stammumfangs betrugen, und Verbisstiefen bis zum Kambium festgestellt werden. Weiden waren am stärksten beeinträchtigt, jedoch gleichzeitig in großer Abundanz vorhanden, sodass eine zukünftige Bestandsbedrohung als unwahrscheinlich eingestuft wird. Weiden, Eichen und Rosen profitieren vom aktuellen intermediären Beweidungsdruck. Sowohl Verbissschaden als auch –tiefe nahmen mit zunehmender Baumhöhe ab. Das aktuelle Beweidungsmanagement wird bei gegebenen Standortbedingungen als realistisch und ökologisch sinnvoll eingestuft. Vergleichbare Projekte können künftig helfen, Beweidungsregimes anzupassen und standortspezifische Empfehlungen zu formulieren. Forschungsbedarf besteht weiterhin bei Langzeitstudien zu Interaktionen zwischen Weidetieren und lokaler Flora und Fauna. Insbesondere seltene und invasive Arten stellen ein interessantes Feld innerhalb der Stadtökologie dar, wodurch Waldweiden hier eine Sonderstellung einnehmen können. Die gegenwärtige Gesetzgebung unterscheidet häufig noch zwischen Wald und Weide und bringt Waldweiden damit um ihre Attraktivität als primäre Landnutzung. Anpassungen der Agrarpolitik und verbesserte Vernetzung bestehender Projekte können neue Perspektiven im Stadtflächenmanagement eröffnen.

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1 Introduction

1.1 Motivation

There are several hypotheses of what Central Europe would look like without anthropogenic influence. The common assumption of large areas being covered by forests (e.g. WILMANNS 1973, ELLENBERG 1986) has been refuted repeatedly, for example by POTT & BURRICHTER (1983), BEUTLER (1992), GEISER (1992), BUNZEL-DRÜKE (1997), POTT & HÜPPE (1991) and BUNZEL-DRÜKE et al. (1999). Instead, half-open pastures created by large herbivores are being suggested as the dominant scenery then. Therefore, extensive grazing as a landscape conservation practise embodies a logical approach to consequently support natural ecosystems. With the appliance of historic livestock breeds, a contribution to both species conservation and cultural landscape heritage can be made (BERGMEIER et al. 2010). Grazed open forests tend to inhabit an increased number of red list species (RUPP 2013). In well-managed wood-pastures, both structural and biotic diversity in wood vegetation increase (e.g. RUPP 2013, BUNZEL-DRÜKE et al. 2008). Beside conservational interests, the fields of tourism, recreation and aesthetics push towards the maintenance of open landscapes (RUPP 2013). Extensively grazed woodlands provide a bucolic sense of wellbeing (ibid.). They therefore support both the goals of the German Federal Agency for Nature Conservation to preserve open cultural landscapes and those of the European Union for protecting biodiversity (DVL 2011). As a reappearing land management practise, wood pastures also embody "new" multi-use areas for research and education (SCHMID 2003).

With more than half of the world's population living in cities today (GRIMM et al. 2008), the demand for structures for recreation and wellbeing is constantly increasing. Green space clearly enhances human wellbeing (e.g. QIU et al. 2013). The necessity for green urban space alongside the benefits of wood-pastures offers new perspectives for grazing in cities.

Around the city of Leipzig, Germany, lignite mining over centuries led to large open areas, which are now subject to recultivation means. On the shoreline of a flooded mine in the southern city area, an extensive grazing project is being conducted since 2014. It is aimed to support biodiversity by maintaining open grassland patches among established trees and groups of trees. The lake is a popular local recreation area, and the project site is continuously frequented not only during swimming season. Through rotational grazing with sheep and goats during spring and autumn, persisting recreational use of the site has been assured. In its urban context, the

uniqueness of the project poses an interesting research subject. The question of whether conservational qualities in a recreational urban area can be preserved through a contemporary extensive grazing regime shall be addressed in the present study. The coexistence of humans and animals in the same location at different times raises questions on the compatibility of interests and demands. As year-round grazing is not possible, it remains unclear whether enough browsing pressure is being applied on-site. Also the question of how different trees react to the grazing conditions occurred.

1.2 State of Research

1.2.1 Wood Pastures and Extensive Grazing

Broadly speaking, wood pastures combine trees with non-tree vegetation (KIRBY & WATKINS 1998). RACKHAM (2000) defines them as systematically grazed landscapes with scattered trees and shrubs. BERGMEIER et al. (2010) furthermore convey the image of canopy-woodland patches with frequent glades (see Fig. 1).

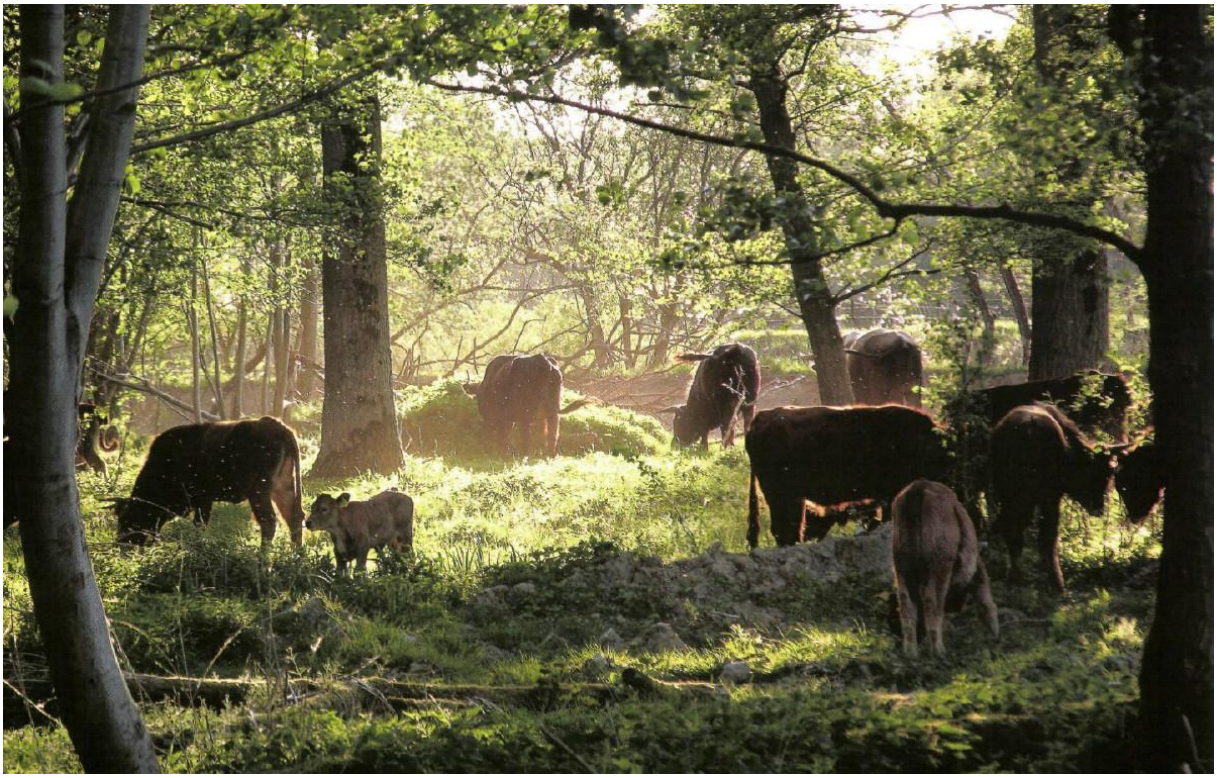

Fig. 1: Wood pasture grazed by cattle. M. Scharf

Wood-pastures are usually referred to as extensively grazed systems. The definition of "extensive" can be blurry, depending on the context. Economically, as LUICK (2002) defines the word, it refers to large-scale systems that mostly face problematic site factors and are therefore under

no intensive usage. As a new development, BERGMEIER et al. (2010) describe the abandoning of former intensely managed areas, so they can then turn into economically and ecologically more beneficial areas through grazing. Due to small nutrient input, these areas usually have little productivity and are therefore considered disadvantaged in agricultural policies. They are run in a capital-extensive way, with little work and infrastructure, no additional fertilisers and low stocking capacity (SCHMID 2003:4). Yet from a conservational point of view, extensive systems are considered high of value.

Livestock can be deer or farm animals, influencing the landscape through stepping, herbivory and manure (SCHMID 2003). In German literature, beside "*Hudewald*"/ "*Hutewald*" the term "*Waldweide*" (grazed woodland) is often used for wood pastures, usually in a historical context. Modern approaches involve grassland and are therefore referred to as "*strukturreiche Weiden*" (structurally rich pastures), "*halboffene Weiden*" (half-open pastures), "*ökologische Weideprojekte*" (ecological grazing projects), and "*Landschaftspflege mit Tieren*" (landscape conservation with animals, RUPP 2013). Other countries have regional names for the same type of landscape management, like *dehesas* (Spain) or *montados* (Portugal). In Central Europe, wood pastures are considered one of the rarest remnants of cultural heritage (LUICK & SCHULER 2008). With the areas of botany and zoology usually being strictly split in science as well as practice, grazers have often been completely excluded from conservation projects. However, a shift seems to have happened in the last decade. Projects involving large grazers on-site are popping up around Germany and Europe. A detailed overview on European *hudewald* landscapes is given by REDECKER et al. (2002), large wood-pastures in Germany have been compiled by GLASER and HAUKE (2004:125ff., Appendix 2).

1.2.2 Formation and Appearance

As expressed with the *megaherbivore theory*, landscapes similar to wood pastures were created by large herbivores over centuries, possibly millennia. The overkill hypothesis states that with the arrival of modern man 40,000 years ago, those mammals became extinct (e.g. MARTIN & WRIGHT 1967, REMMERT 1982, MARTIN & KLEIN 1984, MARTIN 1990, BEUTLER 1992, BUNZEL-DRÜKE 1997). Forest elephant and rhinoceros were hunted down before the end of the last ice age. Smaller herbivores like megaceros, cave bear and wild donkey survived only in small populations (BUNZEL-DRÜKE et al. 1999 & 2001). Other mammals like wild horse, elk, beaver, aurochs and bison determined the landscapes henceforth. The large bandwidth of animals with different food demands and habits led to a versatile landscape mosaic of open land, scrubland

and forests. With more species becoming extinct over time, the post-glacial natural landscape is hard to reconstruct today. Existing landscapes with large mammals like in Africa or South Asia can serve as models in that process (BUNZEL-DRÜKE et al. 1999). They show developments towards steppes and savannas. GEISER (1992) hence draws the conclusion that Central Europe's potential natural vegetation is park-like bush- and grassland with scattered trees.

Grazing animals are usually breeds low in demands that use available resources. Against the backdrop of process protection, natural dynamics evolve. BUNZEL-DRÜKE et al. (2008) describe how thorny bushes are being avoided by the animals and start to grow. Under their protection, saplings that would otherwise be eaten can evolve into bushes and trees (see Fig. 2). Whilst growing, the tree shades the thorny bushes around it and forces them back. When the old tree dies, it leaves grassland behind and the cycle can start again. Especially light-loving deciduous trees like oak and bushes like wild rose, blackthorn and whitethorn benefit from this process. It results in a landscape mosaic rich in structures and species. In spite of their strongly unique appearance and varying successional states, certain vegetation structures re-appear in grazed landscapes, like big old solitary veteran trees, open or partially open grown in a park-like surrounding (Fig. 3).

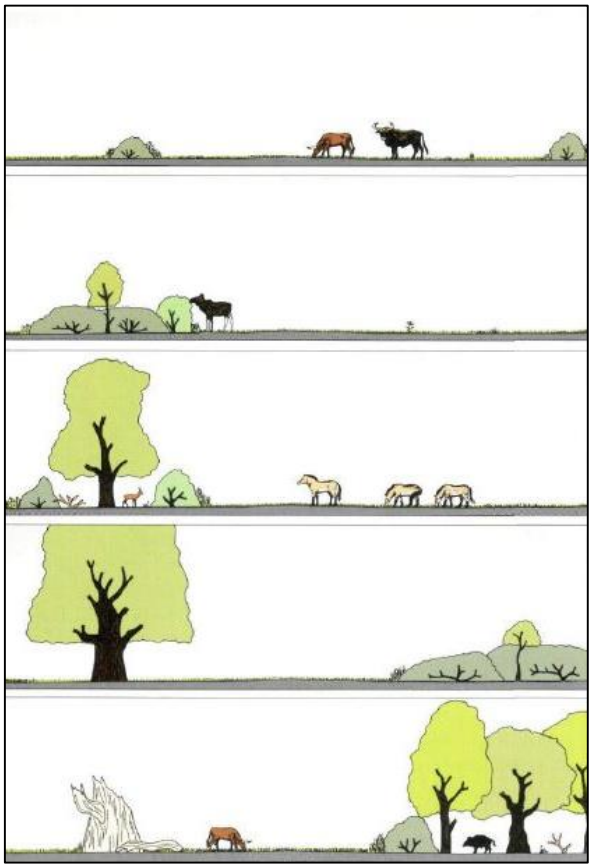

Fig. 2: Natural succession from open grassland to wood-pasture under the influence of large herbivores. Source: BUNZEL-DRÜKE et al. (2008).

1.2.3 History of Wood Pastures

According to ELLENBERG (1986), of all the historical forest usages, wood-pastures were those most significant in terms of persistence and broad impact. They might have even been the oldest agricultural form of livestock husbandry in Central Europe, starting between 4,000 and 11,000 years ago (MORGAN 1991, POTT & HÜPPE 1991, BUNZEL-DRÜKE et al. 1999, LUICK 2009, BERGMEIER et al. 2010). Especially during winter months, cattle, pigs, horses, geese, sheep and goats were kept in the woods. In the middle ages, wood-pastures throughout the whole year were widely spread. They often involved parts of the forest or were the main forest use (LUICK & SCHULER 2008). BERGMEIER et al. (2010) define *hudewald* as "pastoral woodland dominated by tall old-growth oaks, beech, hornbeam or other deciduous trees, often with pollarded or shredded, but not coppiced trees". Historically, grazed woodlands consisted of mainly beech and oak trees indeed. They were partly planted (KONOLD 2008), and the fructiferous trees were used for autumn fattening for livestock and winter fodder. In the 9th century, mainly pigs as the main source of fat and meat were driven into the woods to feed on acorns and beechnuts (e.g. POTT & HÜPPE 1991, LUICK 2009). Due to concerning damages to soil through trampling and plants through browsing, that habit was forbidden later on in many places. Goats were considered most harmful, hence a regulation in 1532 was announced asking the farmers to only have them when no other animals were affordable (GLASER & HAUKE 2004:126). At that time, wood pastures had their biggest extent in Central Europe (ibid.). In the following decades, the interests of grazing and wood production could not be united any more. The division between forest and pasture thereupon started successively in the 18th, and continued massively in the 19th century. Grazing rights were adapted and wood-pastures largely banned and pushed back by timber forests (SONNENBURG & GERKEN 2004, GLASER & HAUKE 2004, BUNZEL-DRÜKE et al. 2008, KONOLD 2008).

Grazing has been applied again as a conservational practice since the 1970s, therefore studies on long-term effects barely exist yet (KIRBY & WATKINS 1998). Recent wood-pastures mainly exist where sites are difficult to access or weak in productivity (RUPP 2013). RUPP names unprofitable low mountain ranges, wetlands, recreation areas in big conurbations and traditional grazing areas as so-called preference areas for today's wood pastures, which have little in common with the historic ones. Hereby especially wetlands are experiencing a paradigm change through this new possibility of maintenance (BUNZEL-DRÜKE et al. 2008).

1.2.4 Browser-Plant Interactions

A combination of herbivores of different species is advisable in order to prevent a one-sided influence on the vegetation (e.g. BUNZEL-DRÜKE et al. 1999, SCHMID 2003). Cattle and horses often appear as preferred livestock classes, especially in wetlands, but sheep and goats are being applied, too. Of all goats kept in Germany, 10% (25.000) are part of ecological farms (RAHMANN 2000). They take up an intermediary position between browsers and grazers (e.g. BUNZEL-DRÜKE et al. 2008). Where available, goats prefer shrubs and bushes to grass, as opposed to sheep, cattle and horses that mainly feed on grass (e.g. RAHMANN 2000). Goats can take up to 60% of their feed requirement from leaves, bark or wooden plant parts (RAHMANN 2000). MÜLLER et al. (2012) observe them spending nearly the same amount of time grazing and browsing. When in a mixed herd with sheep, they were found to feed more on wooden structures than on grass (RAHMANN 2000:204). Therefore, grazing with goats results in more heterogeneous landscape structures. Under a grazing regime in conformity with conservational interests, goats do not achieve a decrease in woody plants. Especially older stands' vitality does not seem to be affected (ZINGG & KULL 2006). Merely stem scratches indicate the attempt to climb up the trees. Goats are the only grazers with facultative bipedality, enabling them to stand on their hind legs in order to reach higher branches. SANON et al. (2007) observe a mean browsing height of 1.65 m, SCHMID (2003) speaks of a maximum height of 1.8 m. Due to their split upper lip, goats are able to browse thorny plants. The impacts of goat browsing on young stands without protective thorns or uncovered main stems are described as devastating (POTT & HÜPPE 1991, RAHMANN 2000). RAHMANN states that too many thorns can still constitute an obstacle. Plants with thorns can therefore present a protective function for young stands and be pioneers of forest regeneration. However, RAHMANN (2000:113) found *Rosa canina* being browsed to death by goats, wherever the main stem was uncovered by side stems or thorns. In his study, it decreased by 43% in growth (RAHMANN 2000:116). He generally observed shoot length growth being significantly decreased by goats (ibid.). The proportion of browsed bark, as opposed to shoots and sprouts, increases with plant height. This type of browsing can be more effective than on leaves or shoot tips, as it has the potential to kill the plant. The goats' destructive behaviour towards seeds, saplings and the herb layer tends to impede rejuvenation (ZINGG & KULL 2006). LISS (1988), on the other hand, holds the view that grazing alone doesn't prevent rejuvenation, and that the presence of game is playing a major role. However, goats are hence useful for pioneer stages of the pasture, when control of bushes and trees is important (SCHMID 2003). Neophytes and reeds can be controlled, too. Over time a typical flora develops, consisting of

annuals, ruderal, toxic and aromatic species, plants with spreading rhizomes or rosettes and plants that are sensitive to mowing (SCHMID 2003). Yet grazing intensities and modalities as well as site conditions determine the look of the landscape (BURRICHTER et al. 1980, POTT & HÜPPE 1991). Goats are not always suitable for permanent grazing, as they don't eat consequently enough. BUNZEL-DRÜKE et al. (2008) describe their feeding behaviour as unpredictable and erratic. It occurs that poisonous plants are tried without noticeable signs of discomfort. For instance, goats feed on honeysuckle and are less sensitive to the toxic ragworts (*Senecio* spec.) than other grazers (BÖRNER et al. 2013, SCHMID 2003). BRUGGISSER (2011) found them to avoid blue flowers, which was shown to be beneficial for threatened species like common centaury (*Centaurium erythraea*). It also grows on the study site (SICKERT 2015). According to BUNZEL-DRÜKE et al. (2008), preferred tree species are *Fraxinus excelsior, Quercus robur* and *Salix alba. Alnus glutinosa, Rosa canina* and *Salix caprea* are being browsed too, covering 5 out of 7 investigated tree species in the present study. Of the remaining two species, *Betula pendula* is barely grazed, and *Acer pseudoplatanus* is not being investigated. According to BEST (n.y.), a gradual release of grazing pressure results in a decrease of oaks (*Quercus robur*), willows (*Salix caprea*) and thorn bushes. POTT and HÜPPE (1991), on the other hand, state that oak trees show low resistance against grazing, especially on sandy soils. Among others (e.g. SCHMID 2003), they name light-loving pioneer species as plants that usually benefit from grazing.

It remains unclear whether and under what conditions sheep can prevent succession and force back trees (BUNZEL-DRÜKE et al. 2008). Sheep are categorised as grazers, even though they do feed up to 50% on wood and leaves (BUNZEL-DRÜKE et al. 2008). In the presence of goats, that percentage shrinks and they focus on grass (ibid.). Therefore, they shall not be further investigated in this study. For detailed information see RAHMANN (1998, 2000), SAMBRAUS (2001), SCHMID (2003) or BUNZEL-DRÜKE et al. (2008).

For the grazers themselves, the stay in the woods or on wood-pasture constitutes a huge benefit for their wellbeing, health and natural immune defence (RUPP 2013:68). The variety of fodder plants provides a large amount of secondary plant substances, which can hinder infections with endoparasites. The trees provide protection from the cold, wetness and heat. They offer a structural and nutritious variety, exemplified by branches and trunks presenting spots for rubbing (SONNENBURG & GERKEN 2004).

Knowledge gaps exist on faunistic behaviour (SCHMID et al. 2001), such as on different animals' reactions under varying habitat conditions. Also interactions between flora and fauna on grazed

sites have barely been looked at. Likewise, interactions between different livestock breeds and species need further investigations.

1.2.5 Significance and Challenges

Wood pastures are multifunctional systems, providing a "broad range of ecosystem services" (BERGMEIER et al. 2010). Simultaneously, their reputation is biased among scientists, farmers and policy-makers. They are not only considered to cause soil impoverishment and nutrient deficiency (ibid.). The danger of overgrazing also poses a constant threat to the ecosystems.

Grazed light forests are described as one of the most species-diverse types of extensively grazed systems in Central Europe (HAUKE & GLASER 2004, BUNZEL-DRÜKE et al. 2008:176, BERGMEIER et al. 2010). Manure and carcasses of the grazers affect nutrient cycles and food chains positively, generating the foundation for microorganisms and beetles (SCHÜLE & SCHUSTER 1997, GLASER & HAUKE 2004). Those for their part form a nutritional basis for various birds and in particular their offspring (KRAWCZYNSKI et al. 2007). In the project area, the red-backed shrike is an example for a species dependent on diverse successional stages (WESENBERG et al. 2012). Animal manure can furthermore buffer soil and water due to its chemical neutrality, and thereby enhance structural diversity (KRAWCZYNSKI et al. 2007). New structures are also created by the grazers: Trackways, grazed lawn, dead wood, wallows and spots for sand baths emerge (BUNZEL-DRÜKE et al. 2008). Species typical for forests' edges and open land occur more often in those landscapes than in enclosed forests (BUTTENSCHON & BUTTENSCHON 2013). Former mining areas offer a diverse topography (e.g. LMBV 2009). Pioneer species inhabit those habitats with ease, and quickly a mosaic-like landscape evolves. Old succession sites attract and accumulate plant species from further distances. From there, marginal and younger sites are more easily inhabited. The plant diversity along with the variety in topographic structures attracts a huge bandwidth of animals, resulting in a potentially very rich environment. Gaps in tree canopy create space for light-loving plants, which are often found to be rare in today's cultural landscapes (KOENIGSLOEW 2013). BERGMEIER et al. (2010) describe a shift in vascular plant species: Those naturally occurring in Southern Europe tend to be present in wood pastures in Central and Northern Europe. The light enables blossoming, which in turn attracts insects to the new habitat (RUPP 2013:68). BUTTENSCHON and BUTTENSCHON (2013) observed increased species diversity in the herb layer in grazed landscapes. Also species composition is being influenced: By disturbing the natural growth pattern of the trees, the grazers create micro habitats for other species like arthropods, gastropods, butterflies or birds (RUPP 2013). Dead

wood emerging through browsing damage provides food and habitat for rare beetles, bats and cave dwellers (RUPP 2013, GEISER 1992). BERGMEIER et al. (2010) detected habitats for rare bird species being created. Structures like hollow branches, rot-holes or water-filled tree holes evolve, providing the basis for bacteria and fungi to start decomposition and close the carbon cycle. Dead wood usually decays more slowly in light forests with less humidity, providing additional diversity for lichens, fungi and mosses (Glaser & Hauke 2004:126). Also species relying on two different habitats benefit, for example birds that nest in trees and feed in the open, or insects that require a nectar source and dead wood at the same time.

On the other hand, wood pastures and especially overgrazing are said to cause damage to vegetation and soil (MAYER et al. 2003). Trampling damage can result in soil degradation, silting, eutrophication and erosion (KOENIGSLOEW 2013). Soil disturbances, on the other hand, can promote the seedlings' ability to sprout. Valuable open soil patches can be created (KRAWCZYNSKI et al. 2007). In combination with an increased light supply in half-open woodlands, a better mineralisation in thick soil layers can take place (MAYER et al. 2003). Browsing damage on trees is often considered negative in scientific research, too (KOENIGSLOEW 2013). It impairs rejuvenation (MAYER et al. 2003) and induces rotting, leading to lower wood and fodder quality, as well as a lower stability of protective stands (SCHMID 2003). Yet, when analysing the actual effects on the trees, is important to distinguish the vision of supporting natural processes from the vision of a perfect commercial forest. Where livestock browses and leaves bite marks, the trees' monetary value decreases. Effects, however, vary depending on tree species. Some will react by pulling back and dying, whilst others will be encouraged to sprout and shoot even more. Abundant trees might be forced back, making space for less competitive species. Effects also depend on available plants and nutrients, landscape structures and animal species. As RUPP (2013:95) points out, plants are usually well adapted to concordant disturbances like grazing, as opposed to discordant disturbances that interrupt life cycles. Modern grazing in forests is classified as an intermediate disturbance regime, resulting in landscapes rich in species but potentially poor in soil nutrients (BERGMEIER et al. 2010:3006, RUPP 2013).

Throughout the history of sending livestock into the woods for feeding purposes, critical voices arose and pointed out the method's drastic impacts on nature (e.g. RUPP 2013, SCHMID et al. 2001, MAYER et al. 2003). According to SCHMID (2003), those effects were mainly a result of overgrazing and additional fertilisation of the soils. Damages can be prevented by reduced animal numbers and adapted pasture management. The voices are still lingering and, together with economic interests, seem to build the basis for a construct of prejudices hard to overcome.

Grazed woodlands are often seen as economically ineffective experiments or as a competition to existing management practises, rather than a supplementary concept (RUPP 2013, BUNZEL-DRÜKE et al. 2008). Acceptance problems can furthermore occur through uncoordinated and competitive goals of hikers, hunters and other land users. A general fear of losing access to the areas may add up to the tension.

1.2.6 Leipzig and Urban Wood Pastures

Since the 90s of the past century, the city of Leipzig is facing population declines and therewith an increase in unused area. This abandoning led to a fall in economic value and aesthetics of many areas. In the course of revitalizing them, the urban planning authority developed the concept of establishing urban forests (Stadt Leipzig 2009). They shall draw a connection between reconstruction and conservation, and serve habitat connection. Especially on the fringe of the city, forests can present a valuable connection between city centre and surroundings (KOWARIK 2005). In urban surroundings, they not only have the potential to connect habitats and therefore actively contribute to species conservation (SCHMID 2003). They themselves provide recreation area, niches for rare plant and animal species to inhabit, and a new approach to combining ecological and economic interests. Largely connected areas that are necessary for grazing moreover pose a contrast to the usual small patch size in urban areas.

The forests for their part are influenced by urban conditions. Leipzig is a large city with an area of 29.700 ha and 570.000 inhabitants (Stadt Leipzig 2016). Its climate, hydrology, soil properties, population dynamics, disturbances, species composition and flows of energy and matter therefore differ massively from the surroundings. Also ecological processes and patterns change under human influence (ALBERTI 2007). The research field of urban ecology is dedicated to those, trying to find ways of combining ecological and human needs in cities (further literature: SUKOPP & WITTIG 1993). As a new understanding of nature in cities, KOWARIK (2005) classifies succession on abandoned areas as “nature of the fourth kind” or a “new wilderness”. It implies evolving ecosystems on heavily altered land and formerly built-up areas (KOWARIK 2011). This approach shall help giving value to nature that is not “original” in the common sense, but still dominated by natural rather than cultural influences and can therefore be particularly valuable.

The soils south of Leipzig are characterised by a wide range of initial substrates, hence the raw soils that resulted from mining have heterogeneous physicochemical characteristics (HAASE et al. 2002). Lignite in soils, where it is left, offers a high binding and buffer capacity. Large-scale

water level dropdowns during mining activity caused huge disturbances of the soil layers. They are building up again slowly, only starting to accumulate nutrients and develop a humus layer. High amounts of sand and gravel retard this process. At present, the soils are low in nutrients and slightly acidic (HAASE et al. 2002). Those oligotrophic conditions, together with low amounts of toxic substances and coarse substrate structure, are favoured by rare plant and animal species, forming the basis for high conservational value. Extensive grazing is likely to support those beneficial characteristics for rare species further whilst at the same time supporting the soils in slowly building up nutrients.

An ecological monitoring on the project site concluded that after 15 years of natural succession, the initial aim of revitalising the landscape has been reached (SICKERT 2014). It was found that open soil patches that used to give room to rare plant and animal species now seem to be decreasing again. Wooden stands have expanded in number as well as height and width. A spread of invasive species (like *Solidago canadensis* and *Fallopia japonica*) as well as native neophytes (like *Calamagrostis epigejos*) has been observed.

Wood pastures in urban surroundings could not be identified as subject to any scientific research so far, putting the present study in an exceptional position. The particular landscape history in this case study adds another dimension. Studies on extensive grazing on former mining areas are rare too, research combining both is a novelty. Research demand is therefore given on both establishing wood pastures in general, and particularly on former mining areas and in urban surroundings.

1.2.7 Legal State

Important determining factors for economic success are sufficient area size, marketing and promotion, operational conditions and subsidy programmes (LUICK 2002). As LUICK observes, a change in marketing strategies and agricultural policies is necessary in order to support and push extensive grazing projects. GEISER stated in 1992:

"Es kann auf keinen Fall hingenommen werden, dass von verschiedener Seite, darunter durchaus auch von öffentlichen und privaten Naturschutzstellen, immer wieder die Forderung nach der Trennung von Wald und Weide erhoben wird."

("Under no circumstances can it be tolerated that, by various quarters including public and private conservation bodies, the separation of forest and pasture is being demanded repeatedly.") WSL 1996:42, own translation

Now, more than 20 years after GEISER voiced his discontentment with the course of the forest legislation, his concerns have shown to come true. Wood pastures are, on a European scale, the habitats most underrepresented in the NATURA 2000 network of natural habitat types (BERGMEIER et al. 2010). Depending on which criteria are met, they could be put in either of the categories protected forest, forest biotope or biotope protection forest (BUNZEL-DRÜKE et al. 2008:171). Subsidies are usually granted for a certain kind of habitat, like forest or meadow. Wood pastures generally don't meet forest habitat definitions as they are man-made. Hence, an undesirable conservation status is pre-determined. Dynamic complex habitats are not determined and therefore often ignored by authorities. The few projects that are supported are usually limited by temporary funding (RUPP 2013). However, areas that are grazed extensively are to receive financial supports, as the European Court of Justice decided in 2010 (DVL 2011). Hence DVL suggests a new definition of eligible permanent pasture, in order to include wood pastures in that subsidy programme.

In Germany, wood pastures are generally forbidden (RUPP 2013). Wherever overgrazing of a legal forest area led to its transformation into agricultural land, the law would be violated. This transformation has to be approved by the upper forestry authorities beforehand. However, legitimate habitat conservation forests allow and even desire grazing for preservation purposes. LUICK and SCHULER (2008), too, stress that usually dogmatic legal regulations are the only barrier for establishing new wood-pastures. Regulations and legal recognition of wood-pastures differ between the federal states, ranking from a general prohibition of wood-grazing to required permissions under private law or from the forest authority. After all, renaturation areas have been acknowledged in terms of their conservational value and set up as an additional land use type. Conservational work can be conducted here beyond agriculture and forestry (LMBV 2009). In Saxony, where the study site is located, wood pasture is an acknowledged side usage as long as it doesn't affect the forest's main functions. It only requires approval of the forest owner (§18 SächsWaldG).

In spite of their well-understood and potentially beneficial grazing behaviour, goats seem to face huge acceptance problems from official quarters. Exemplarily, RAHMANN (2000) describes his own experience with approval procedures for landscape conservation with goats in Central

Germany. Beside area inspections with goat keepers, official and associative representatives, along with clear agreements on the measures to be taken, phytosociological analyses were being made prior to approvals for protected areas. This comparably long procedure could discourage farmers right from the start. A lack of knowledge on animal welfare, performance and behaviour among officials as well as farmers adds up to the confusion.

1.2.8 Management

In the course of establishing successful wood pastures, it gets more important to understand the dynamics behind and the management techniques required. A number of authors have been investigating modern extensive grazing systems in forests based on historical wood pastures (e.g. BURANDT & FELDMANN 1991, CROFTS & JEFFERSON 1994, LÖBF 1994, KLEIN et al. 1997, RIECKEN et al. 1997, RAHMANN 1998, LUICK et al. 1999, BERGMEIER et al. 2010). Information on historical management concepts is an essential foundation for modern approaches in land management (MAERTENS et al. 1990, LUICK 2002, RIECKEN et al. 1997, RAHMANN 1998). Unfortunately, most knowledge on livestock management in light forests started getting lost in the early 19th century (WOLF 2010). What we know today is that the interaction of plants and animals depends on site conditions to a large extent. Determining factors can be weather and seasonal growing conditions, forest type and location, silvicultural measures and spatial dimensions. Accordingly, herd sizes, animal species, grazing duration, frequency, location and seasonal distribution as well as the range of movement need adjusting (STUBER & BÜRGI 2001:492). POTT and HÜPPE (1991) agree that grazing intensities and modalities as well as site conditions are the main determinants of the landscape scenery. KIRBY and WATKINS (1998) point out that often herd sizes are more important than animal species for long-term effects on site. RAHMANN (2000) agrees by stating that generally, the animals' behaviour on the pasture can strongly be influenced by correct management measures, regardless of the species. SCHMID et al. (2001) report that neither grazing type nor species, nor the starting point in grazing time determine the conservation value of the pasture. However, there is still a lot of uncertainty regarding animal choice, grazing regime, animal-plant interactions and long-term effects on vegetation. Many authors realise that no universal recommendations on wood-pastures can be given and management needs to be site-specific, as too many factors vary (e.g. SCHMID et al. 2001, LUICK 2002, ROSENTHAL et al. 2012, RUPP 2013). The number of animals to be kept on a certain area results from the land's productivity, that means from the amount of fodder available. Yet there are some points for orientation: A lower boundary of 0.3 LU/ha (LU – livestock

unit, one dairy cow = 1 LU, one sheep/ goat = 0.1 LU) prevents “alibi grazing” for financial subsidies. Concerning herd sizes, a healthy mediocrity should be aimed for; too little grazing results in natural succession taking over, whereas heavy grazing may make changes to the relative abundance and composition of the vegetation. It can benefit some plants and bring disadvantages to others, though KIRBY and WATKINS (1998) find it generally unlikely that it benefits conservation. However, time of year and grazing duration are crucial for effects on vegetation (DIRKX 1998). Conclusively, a demand for more individual wood studies is seen in order to generalise grazing impacts and give clear management instructions.

SCHLEY and LEYTEM (2004) suggest to aim at the creation of a vegetation mosaic of lawn, patches of high grass and woody plants. General instructions can be taken from Fig. 3. In order to grow and develop single solitary trees, it is necessary to protect them with a natural shrub belt or artificially (POTT & HÜPPE 1991). If trees grow simultaneously and inside shrub groupings, their tops tend to get bitten off whilst their stems are being protected. That leads to side buds and bush-like dense branching. Another means to protect saplings is to plant a few together, so a strong stem develops. It then splits into solitary stems further up, where animals cannot reach any more.

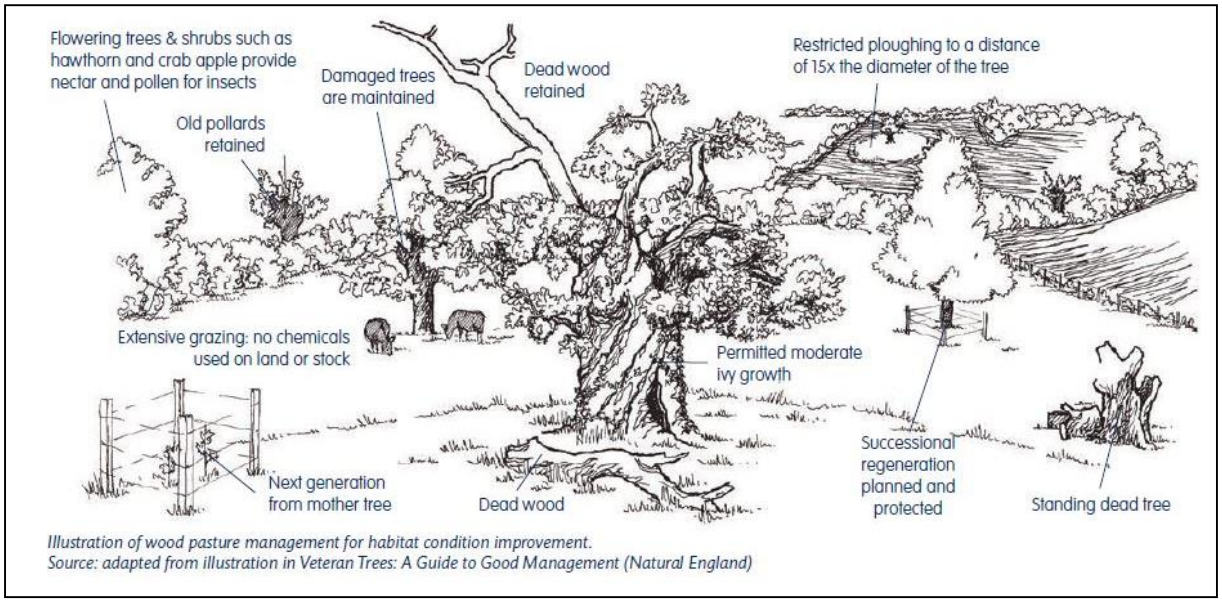

Fig. 3: Wood pasture management for habitat condition improvement. Source: Forestry Commission Scotland 2009

Another aspect to consider is the follow-up treatment of the areas (RUPP 2013). If conservation interests are paramount, as in *Cospuden*, the preservation of natural dynamics and processes in landscapes is to be aimed at (RAHMANN 2000). This usually includes abiotic developments like

floods or fires and vegetation dynamics like succession or mosaic cycles. Management adaptations could involve leaving carrion on the areas, in order to allow for natural decay processes (see Krawczynski et al. 2007). On the study site, a mix of both natural succession and recultivation means took place after mining (SICKERT 2014). In order to prevent rare species from becoming extinct, succession is partly aimed to be stopped now through grazing. Conditions from the mid-90s of the last century shall be re-established, with open areas and light forest.

Agricultural goat farming is still rare in Germany (RAHMANN 2000), and knowledge is just being accumulated. Whereas sheep mainly feed on grass and therefore don't require a diverse environment, goats are more demanding. Structures like hills, sinks, stones and rocks can be useful for satisfying their curiosity. Most goats are being kept for milk, cheese and meat production, demanding high-quality fodder. Workload per meat goat is 15 hours per year, per meat goat with biotope management 6 hours more (RAHMANN 2000:146). RAHMANN states that costs and workload compared to manual site treatment decrease when goats are being kept on-site, and no additional material costs occur. Economic benefits especially arise when hardy grazer breeds are selected. Additional care or fodder is then hardly required, as the animals use resources that are available on-site. They are well adapted to nutrient-poor pastures. Forest management practises can potentially be made redundant, leading to minimised working hours and equipment use (OPPERMANN & LUICK 2002). Compared to continuous grass cutting disposal, the purchase of grazing animals is a cost-efficient one-off investment. Also the usage of fertilisers is economically not recommendable (OPPERMANN & LUICK 2002). From an economic perspective, extensive goat farming can therefore result in a rewarding business.

1.3 Study Aim and Hypotheses

The study's aim is to analyse an exemplary urban grazing project in the city of Leipzig, Germany. It is situated next to *Lake Cospuden*, a flooded former open-cast mine. With the specific site conditions, including mining impacts on the landscape and its urban character, the project is a pioneer that demands for scientific evaluation (SICKERT 2015). Extensive grazing here is aimed to create structures that benefit biodiversity, economy and the city population at the same time. The project started in 2014; first grazing impacts can already be spotted on the vegetation. The aim of the present study is to identify those and consequently evaluate the project advance. By investigating bite marks on the bark, impairments on the trees' vitality can be recognised and predicted. For varying surroundings along the grazed shoreline, factors that influence grazing behaviour shall be determined. Differences between tree species in terms of damage

and vitality shall be revealed to build the foundation for further management advice. The intensity of the current grazing pressure shall be evaluated critically based on the results.

The venture of urban wood-pastures is aimed to be exposed in order to highlight its benefits and challenges, and push towards its recognition as an own research field within the branch of urban ecology.

The following hypotheses shall be analysed:

1. There are significant differences between the tree species in terms of browsing damage and bite depth.
2. Smaller trees are more affected by grazing than taller trees.
3. In light vegetation, damages on the trees are bigger than in areas with dense vegetation.
4. Trees that are located close to the water edge are less strongly affected by grazing. With drinking water available in reach, bites deeply into the juicy cambium of the tree occur less often.

2 Material and Methods

2.1 Study Site

2.1.1 Location

The study site is embedded in *Cospuden Landscape Park*, dominated by a flooded open-cast mine that covers an area of 4.4 km². Coming from Leipzig's city centre, *Lake Cospuden* is the closest one of more than 20 artificially flooded lignite pits in the renaturated landscape called "*Neuseenland*" around Leipzig. Moreover, it is the only lake so far that is connected to the centre through waterways and therefore reachable by boat. With its connectivity and proximity to the city and various touristic attractions like the longest sand beach of Saxony (12 km, EISMANN & RUDOLPH 2006), it intercepts the majority of people coming to the lakes for recreational purposes. It can be assumed that biotic and abiotic factors at the lake are influenced by urban conditions more so than at the other lakes further south (see Fig. 4).

Fig. 4: Position of Lake Cospuden in the region of Leipzig. Source: LMBV 2009

As the landscape park is part of three cities (Leipzig, Markkleeberg and Zwenkau), management responsibilities are shared. The study site on the west shore belongs to the city of Leipzig and falls under the responsibility of the city council (Amt für Stadtgrün und Gewässer, Abteilung Stadtforsten). It covers an area of 7.6 ha (see Fig. 5). Its primary function is habitat connection and biotope protection; recreational usage is of minor importance here (RPV Westsachsen 1998:40). As part of its recultivation, comprehensive soil profiling and planting works were conducted between 1992 and 1995 (Amt für Stadtgrün und Gewässer 2014). Since then, the majority of the areas between the northern dog beach and the bison corral on the south-western end underlie natural succession. This cost-efficient natural development was appreciated by the forest council. Since 1999, the site has been monitored from ecological and landscape-architectural perspectives.

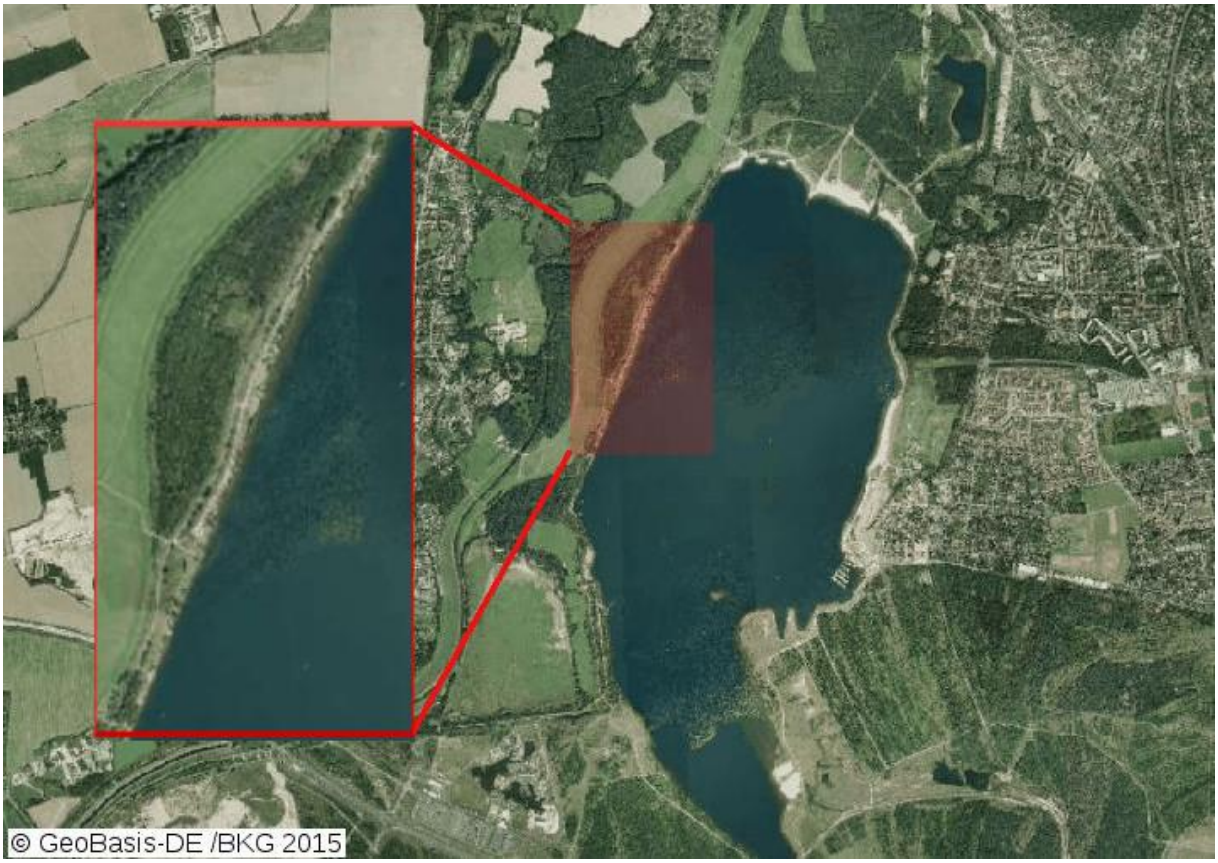

Fig. 5: Location of the study site.

From a landscape architectural view, developments are generally rated positively. However, sight is blocked in some parts through dense vegetation, and visitor streams cannot be guided in an ecologically sensible way anymore. Thorny bushes tend to lead them directly into ecologically valuable reed zones. Therefore, new long-term guidelines and aims have been formulated in 2014 (SICKERT 2014), which shall be summarised in the following chapter.

2.1.2 History

South of Leipzig, open-cast lignite mining has taken place for more than 350 years (HAASE et al. 2002). It shaped the landscape drastically on an area of more than 250 km² (ibid.). Large areas not only lost their original surface appearance, but also their soil and water properties, their land usages as well as their plant and animal communities. The ground moraine, formerly wetlands rich in species and now cut apart, used to be nutrient and matter sinks and a buffer zone for floods and groundwater formation. With the mining taking place, groundwater levels were kept low. According to HAASE et al. (2002), the area almost completely lost those functions. Other landscape characteristics changed under the impact of the mining industry, too. In

the process of terminating all mining activities in the region, landscape functions are shifting again. They partly change back towards a more natural state, mirrored in the lakes and forest land, and partly evolve towards new usages as agricultural land. As LMBV (2009) explain, mining law doesn't implicate an actual restoration of the previous landscapes, but a foundation for present and future generations as well as plant and animal communities. Therefore, recultivation can result in a completely new composition of landscape elements. The challenge remains to recognize long-term sustainable developments on the respective site, and support and promote them. This is an ongoing process, and recultivation aims can shift and change over time.

In Central Germany, about 74% of the former mining areas are being actively recultivated. The rest is being left to natural succession, 40% of which are forest (LMBV 2009). Special "Biotoptypenschlüssel" (habitat order references) underline the uniqueness of those areas.

In *Cospuden*, a mix of both took place (SICKERT 2014). After a citizen initiative brought an end to lignite mining in 1990, recultivation measures took place within the frame of an EXPO project until 1995. Dumped substrates from the other mining areas were used to refill the holes and shape the shore area. The water pumps stopped in 1992, allowing the remaining hole to be filled by groundwater. Together with riverside filtrate from the nearby river *Weiße Elster*, water levels continued to rise. From 1995 on, additional water from the mining site *Profen* was directed into the lake in order to accelerate the flooding. In 2000, the lake reached its final water volume of more than 100 Mio. m³ and level of +110 m (EISMANN & RUDOLPH 2006:10 ff.). Mean depth is 35-45 m (ibid.). Water quality is sufficient for swimming – the mostly neutral groundwater neutralizes acidic dump water coming in from the South. Iron content of 1mg/ l is low. It can be said that the lake is physically, chemically and biologically in a good state. It buffers surrounding groundwater fluctuations and is being buffered itself by surrounding waters.

The shore area was developed into a local recreation area with nature conservation functions. On the southern side of the lake, a water connection to the neighbouring lake *Zwenkau* is under construction, planned to be finished by 2017. The eastern part of the lake is mainly used for recreation (boat rentals, sailing harbour, water sports, golf course, beaches, restaurant, residential area). The northern part was transformed into a landscape park, divided into areas for recreation including sandy beaches, and protected habitats in existing or recultivated parts of Leipzig *Auwald*, one of the biggest remaining riverside forests in Central Europe. The northwest

shore contains mosaics of afforested grasslands, seedings and dry grasslands, bushes, single groups of trees and an afforested deciduous stands. The western shoreline was profiled and planted on until 1995. From then on natural succession took place between the dog beach on the northern coast and the bison enclosure on the southwest end (SICKERT 2014). In 1998/99, a citizen initiative planted a pure common oak stand south of the dog meadow. It borders the study site on its north end.

2.1.3 Project of the Creation of Wood-Pasture like Structures on the Western Shoreline of *Lake Cospuden*

The forestry office aims at combining two seemingly incompatible goals: the creation of open sites as well as forest. At the same time, costs shall be kept neutral and development shall take place in a self-sustaining way, independently of subsidies. Besides, biodiversity is aimed be protected. Those goals shall be reached mainly through extensive grazing.

Since 2014, a herd of sheep and goats is grazing and browsing the area twice a year, before and after swimming season. The whole herd consists of 500-600 female sheep and around 100 goats (SICKERT 2015). A mixed group of 100 animals at a time is being kept for 2 days in one sector. A sector covers about a third of the total area and is fenced off from the surroundings in coppices (see Fig. 6).

Fig. 6: Grazing sheep and goat on the western shoreline of Lake Cospuden. Spring 2016.

Predominant are spontaneous grasslands. Wooded groves of birch, willow, rose, elder, cornel, and others evolved through succession. The birch tree appears as most significant pioneer here (Fig. 7). In spite of its presumed water proximity, water availability is low due to sandy soils. Therefore, conditions are more favourable for young trees like linden, maple, black elder or silver poplar than they are for herbs.

Fig. 7: Birch trees as pioneer species on the study site. October 2015.

The idea is to create a type of forest in between wood-pasture and pasture woodland. The developing sparse forest with relatively low canopy cover (50% on average) shall create room for dry-loving plants and sun-loving visitors. Small-scale patches will be connected to the existing forest stands that present conventional forest according to Saxonian forest law. They will be managed extensively and developed into oak-hornbeam-linden forest. Grazing will continue to take place in those areas, but with less intensity than on the sparse areas. There, dense groups of rose shrubs shall be preserved, as well as insular patches of *Calamagrostis epigejos* and other tall forbs. Also, tree stands that already derived from succession shall persist (Fig. 8). In the long run, they are aimed to make out two thirds of the groves. The other third shall be taken by

oak trees. 70 already existed, about 250 additional oaks have been and are being planted (SICKERT 2015). The forestry office strives for 10 solitary oaks or groups of oaks per hectare (SICKERT 2014). The oak trees can be seen as target species in the project. They are desired to grow into the habitus of tall canopy park trees, creating valuable conditions for forest species. Below and between the trees, grassland and herbs shall be available for grazing sheep and goats. Regrowth of trees that have been cut down shall be prevented by browsing goats. In the long run, a park-like landscape with open as well as dense areas shall be created in an ecologically and aesthetically valuable way. A basic *hudewald* shall be created within the first 5 years with enabled process protection, leaving a margin for unexpected development and flexible reaction.

Fig. 8: Scenery on the study site in autumn 2015

2.2 Study Design

The planned *hudewald* area has been investigated by the city's Urban Greenspace and Water Department in 2014. Single trees and habitat types were recorded, and locations for new plantings planned. The results were visualised on a map (Appendix 1). The grazed area relevant for

this study implies plots 1 to 31. For a representative cross section, 15 transects were spread evenly across the area. They covered the whole west-east width of the study site, went perpendicular to the water edge and were 10 m wide respectively. Later on site, two more transects were added in order to get a more even distribution of tree species. Transects were drawn onto an aerial photograph using a geographic information system (QGIS 2.4.0). On site, they were traced back by using the photographs and a compass measuring the angle from the water edge. Investigated tree species were common oak (*Quercus robur*), common sallow (*Salix caprea*), wild rose (*Rosa* spec.), common birch (*Betula pendula*), sycamore maple (*Acer pseudoplatanus*), common alder (*Alnus glutinosa*) and white willow (*Salix alba*). The species have been defined in agreement with ANDREAS SICKERT (2015), head of Leipzig's Forestry Department, representing those most significant for the project. Within a strip of 5 m each side of the line, trees of the target species that were at least 2 m tall were recorded. Besides tree species, recorded data were water distance, tree height and position, density of the surrounding vegetation and the responding variables of browsing damage, bite depth and tree vitality. For measuring tree heights and transect widths and distance to the water, tape measures and a fold rule were used. Measures were taken with an accuracy of one decimal place. For trees above 3 m, the height was estimated.

Fig. 9: Path dividing the study site into the categories "inland" and "water edge".

A path dividing the study area into two strips along the lakeside defined the trees' position (Fig. 9); trees west of the path were assigned to an inland category, whereas trees between pathway and water belong to the water edge category. The density of the surrounding shrub vegetation was assessed (dense/ light), taking into account the assumed accessibility by goats. Browsing damage was categorised from 0-no damage to 3-heavy damage, similar to GANSKOPP et al. (1997) and RAHMANN (2000:70). Single, isolated bite marks fell into category 1 (light damage, Fig. 10). Extensive damage covering up to 50 percent of the trunk circumference was defined as medium damage (Fig. 10). Was more than half of the trunk circumference affected, the tree was rated as heavily damaged (category 3, Fig. 10). Bite depth was analysed visually; the affected layer could be determined with the help of a pocket knife: green tissue underneath the damaged layers was interpreted as the vital cambium being intact. Where the goats had bitten deeper, solid brown heartwood indicated that the tree's vascular tissue had been disrupted. The original bite depth categories were bark, twigs, bark & twigs, cambium, cambium & twigs, wood. The categories bark and bark & twigs were later, likewise the categories cambium and cambium & twigs. Beside better statistical evaluability, this was done based on RAHMANN'S conclusions, who found that bark browsing impacts trees above 2 m more than leave and shoot browsing (2000:113). Where damage was only done to twigs but not to the main stem or bigger branches and therefore considered unlikely to affect the tree's vitality, it was listed as unaffected. This way, four categories remained: a (not affected), b (bark, bark & twigs), c (cambium, cambium & twigs) and d (wood). Examples of the latter three are shown in Fig. 11. Trees with multiple stems were counted as one tree.

Fig. 10: Light, intermediate and heavy browsing damage on Quercus robur, Alnus glutinosa and Salix caprea (f.l.t.r.)

Fig. 11: Bite depths bark, cambium and wood on Acer pseudoplatanus, Betula pendula and Quercus robur (f.l.t.r.)

2.3 Statistics

In order to reveal dependencies between predictors and response variables, Pearson's chi-square tests for independence were conducted with R 2.13.0. Predictors were tree species, tree height, vegetation density, position (inland/ water edge) and distance to the water edge. Responding variables were browsing damage, bite depth and tree vitality. Each predictor was tested against all of the three response variables. Significant positive or negative correlations indicated the influence of the respective factor on browsing. In order to reveal the dependency of tree vitality on browsing damage and bite depth, chi-square tests were conducted among the three response variables too. Subsequently to those, generalised linear models were generated for an exclusion of intercorrelations between predictors. For optimal presentiveness, browsing damage and bite depth were analysed in 4 as well as 2 categories respectively. With Microsoft Excel 2016, dependencies were visualised.

3 Results

3.1 Distribution of Trees Along the Study Site

In total 477 groves were found, of which 89 were roses and 24 maple, 26 willow, 37 oak, 58 alder, 96 sallow and 147 birch trees (Tab. 1). 317 trees were at least 3 m tall. The majority of the trees (308) were located close to the water edge. A correlation between some species and their position could be detected. Both *Betula pendula* (p-value=9.13e-08) and *Salix caprea* (p-value=2.36e-07) occurred significantly more often close to the water edge. *Salix alba* and *Alnus glutinosa* were only found at the shore side. Of the 37 oak trees found, 11 were below 3 m tall. Most were located inland (30) and in light vegetation (24), where the majority of the total 477 groves were found (261). Of the trees growing in dense vegetation, most were roses (116).

	Density		**Position**		**Height**		
	dense	**light**	**inland**	**water edge**	**≤5 m**	**>5 m**	**Total**
Acer pseudoplatanus	12	12	22	2	19	5	24
Alnus glutinosa	32	26	0	58	10	48	58
Betula pendula	67	80	22	125	34	113	147
Quercus robur	13	24	30	7	26	11	37
Rosa spec.	52	37	80	9	89	0	89
Salix caprea	26	70	15	81	56	40	96
Salix alba	14	12	0	26	3	23	26
Total	**216**	**261**	**169**	**308**	**237**	**240**	**477**

Tab. 1: Investigated trees listed by species and recorded density, position and height.

3.2 Browsing Impacts on Different Tree Species

Between tree species, bite depth, browsing damage as well as tree vitality were found to differ significantly (Fig. 12 & Fig. 13). The species most affected in all three areas was *Salix caprea*. Least affected by browsing was *Betula pendula* (damage and bite depth), only excelled by *Quercus robur* in vitality.

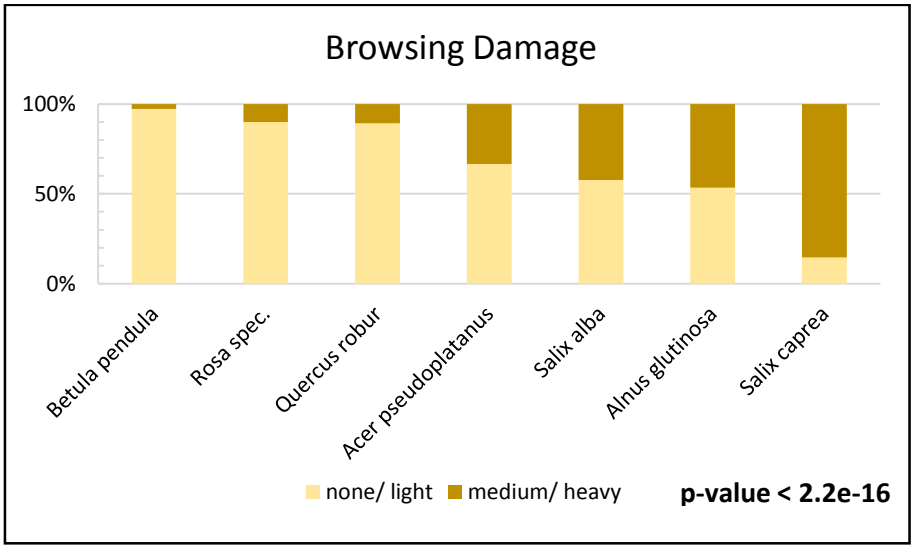

Fig. 12: Browsing damage in two categories in relation to the 7 investigated tree species.

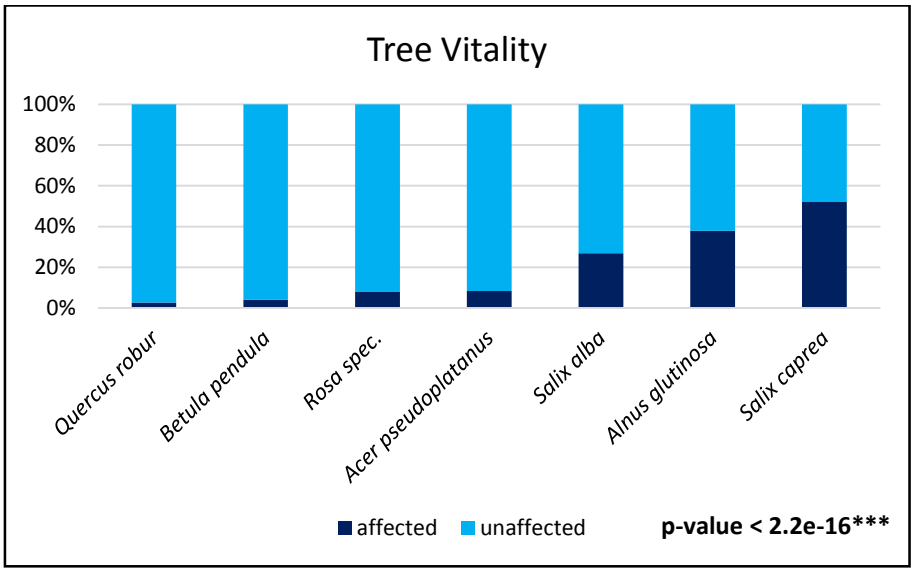

Fig. 13: Vitality (affected, unaffected) of the 7 investigated tree species.

In spite of having found *Salix caprea* most affected, only 12 of the 96 individuals were completely deceased. The sallows' vitality was negatively correlated with browsing damage (p-value = 4.322e-08), but not with bite depth (Fig. 14 & Fig. 15). Even though it was the species most affected in bite depth, biting usually stopped at the cambium layer, distorting the statistics.

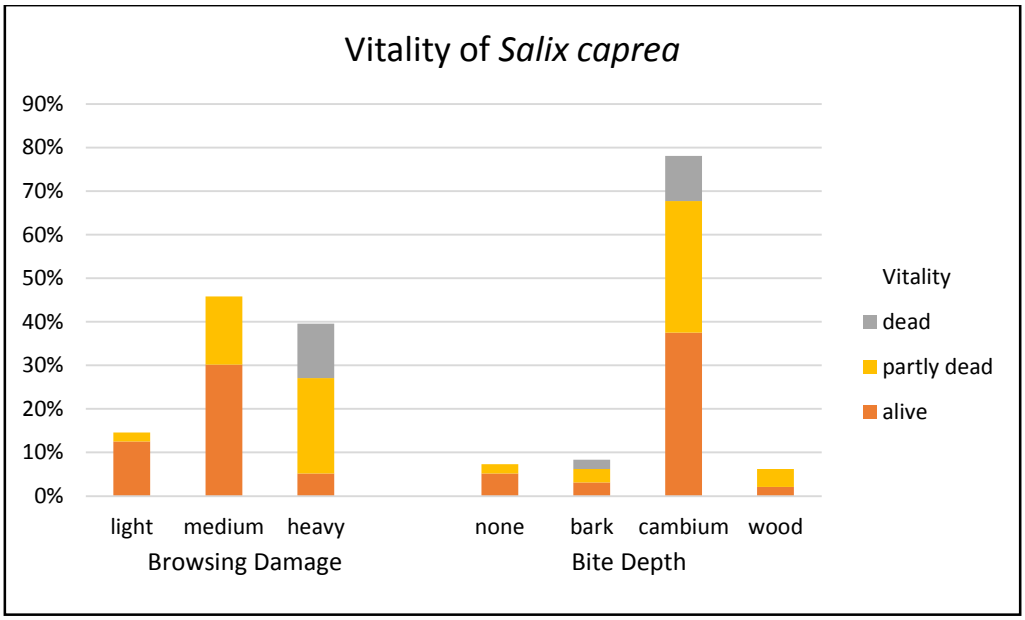

*Fig. 14: Vitality of Salix caprea in relation to browsing damage (p-value = 4.322e-08***) and bite depth (p-value = 0.4918)*

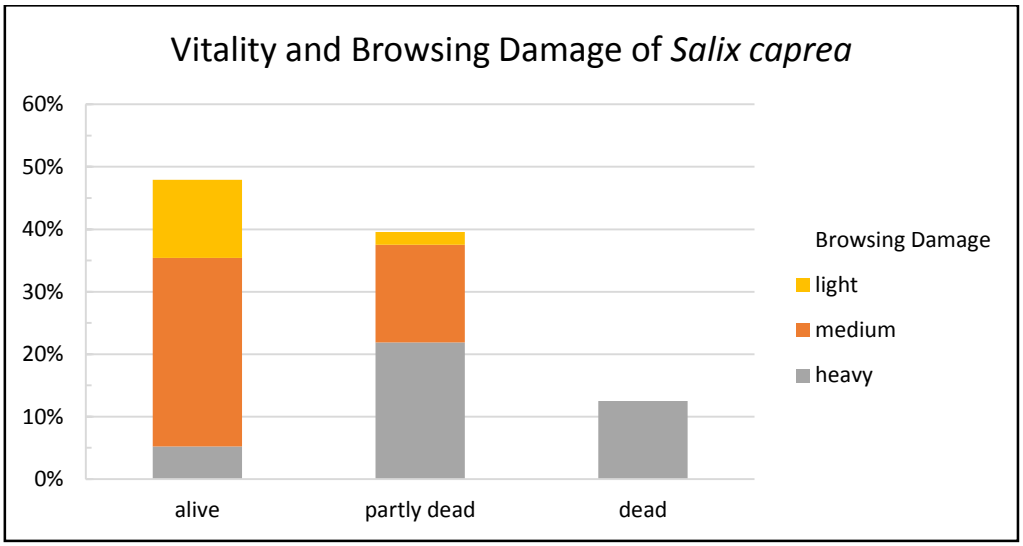

Fig. 15: Vitality and browsing damage of tree species Salix caprea (common sallow).

The target species *Quercus robur* was least affected in vitality. Out of 37 oak trees, one was partly dead. Vitality of the other 36 trees was unaffected (Fig. 16). Most browsing damage rates were low (76%, see Fig. 17). Bite depths were mainly low, too, with 78% of the trees showing small bite marks in the bark and twigs or no damage at all. However, the number of individuals on the study site is still low, as additional oaks have not been planted yet.

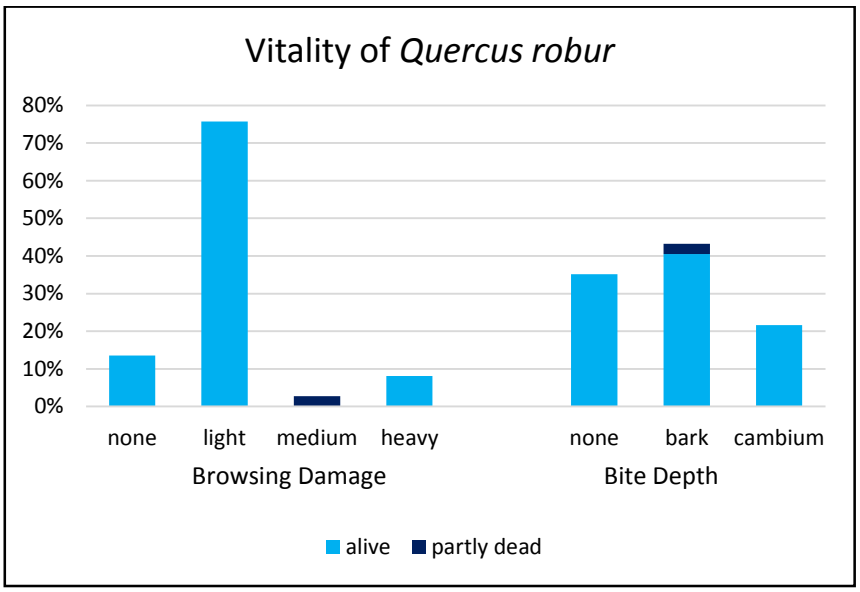

Fig. 16: Vitality of Quercus robur in relation to browsing damage (p-value=4.601e-08) and bite depth (p-value=0.5094)

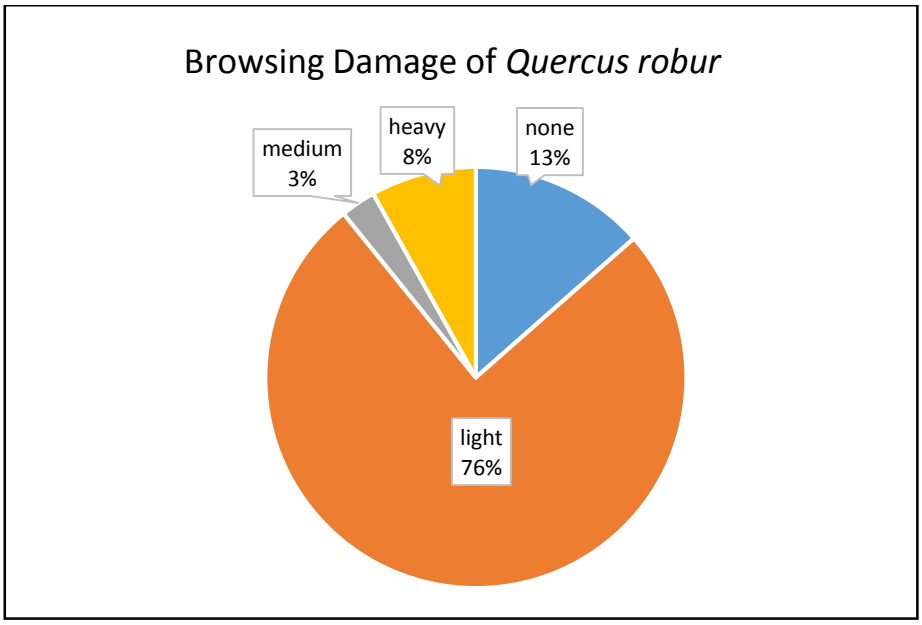

Fig. 17: Browsing damage on the common oak tree (Quercus robur, total tree number: 37)

3.3 Browsing Impacts on Trees of Different Heights

Medium and high browsing damage rates occurred more often in trees below 5 m than in taller groves (55.5%). Trees above that height showed low browsing damage (60% of the trees had no or low damage rates) and better vitality (p-value=0.01). Bite depth decreased significantly with increasing height, too (see Fig. 18).

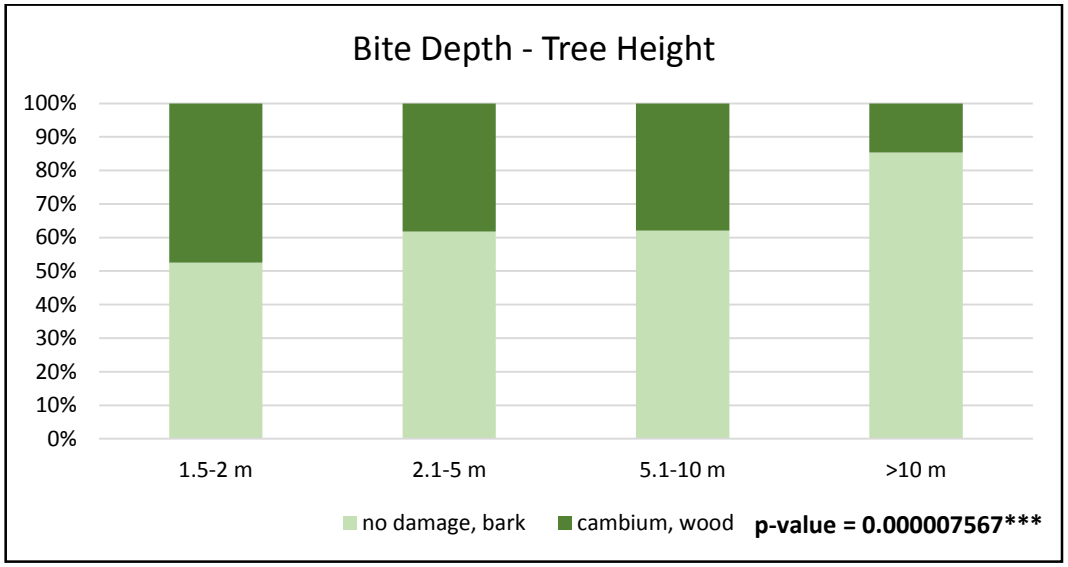

Fig. 18: Bite depth in relation to tree height.

3.4 Browsing Impacts on Trees in Different Vegetation Densities and Positions

All measured site factors – tree height, position, vegetation density, distance to the water edge – correlated more or less strongly with browsing impacts. The only exception was a missing correlation between vegetation density and tree vitality. Density of the surrounding vegetation proved to affect damage rates on the trees (p-value=0.000885, Fig. 19). The higher the damage, the more likely the tree was to grow in light areas.

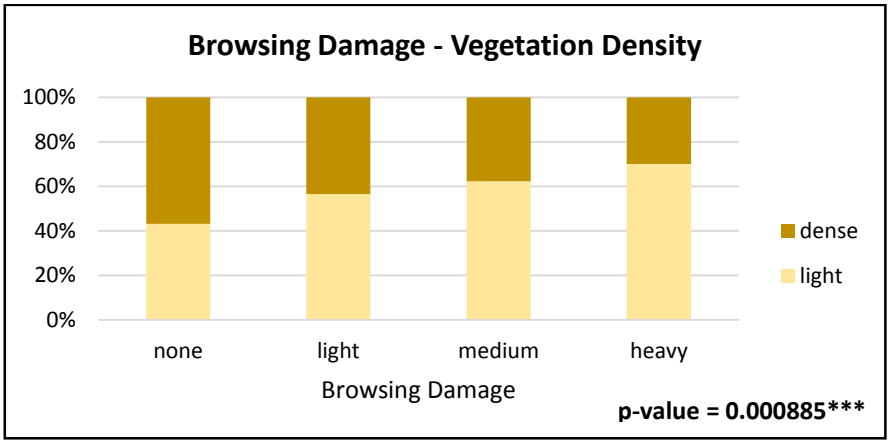

Fig. 19: Browsing damage rates in 4 categories related to vegetation density in the tree's surrounding (light/ dense)

Browsing damage and bite depth both showed to be significantly higher at the water edge (p-values: 1.288e-07, 0.00001096). A correlation between some species and their position could be detected. Both *Betula pendula* and *Salix caprea* showed highly significant dependencies on their position in relation to the water edge (p-values: 9.13e-08, 2.36e-07).

3.5 Summarised Browsing Impacts and Correlations Between Browsing Damage, Bite Depth and Vitality

Tab. 2 shows a summary of the three responding variables browsing damage, bite depth and tree vitality, listed by species.

	Browsing Damage		**Bite Depth**		**Vitality**	
	none-low	**med.-high**	**none/ bark**	**cambium/ wood**	**unaffected**	**affected**
Acer pseudoplatanus	16	8	17	7	22	2
Alnus glutinosa	31	27	31	27	36	22
Betula pendula	143	4	138	9	141	6
Quercus robur	33	4	29	8	36	1
Rosa spec.	80	9	72	17	82	7
Salix caprea	14	82	15	81	46	50
Salix alba	15	11	15	11	19	7
Total	**332**	**145**	**317**	**160**	**382**	**95**

Tab. 2: Tree abundances subdivided by browsing damage, bite depth and vitality in relation to tree species.

The conducted chi-square tests showed that both browsing damage and bite depth not only correlate significantly with tree species, but with all recorded site factors (tree height, density of the surrounding vegetation, position in relation to the water edge). For browsing damage, tree species and position correlated most strongly (p-values: < 2.2e-16, 3.04e-07), for bite depth all correlations were highly significant. The trees' vitality strongly depends on species (< 2.2e-16) and position (6.525e-05). The other correlations, except for density, were significant, too. For an exclusion of intercorrelations between the factors, additional generalised linear models were generated. Browsing damage still proved to correlate with tree species, height, position and density of the surrounding vegetation. Bite depth correlated with species, height and position. Tree vitality correlated with tree species and tree height. When analysing single species, bite depth was detected to be of less relevance for the trees' survival than browsing damage (p-values: 4.15e-05, 1.16e-15, see Fig. 20 & Fig. 21). Yet both showed highly significant positive correlations. The more damaged a tree was, the more likely its vitality was to be impacted negatively. Fig. 22 unites the three responding variables on the seven investigated tree species.

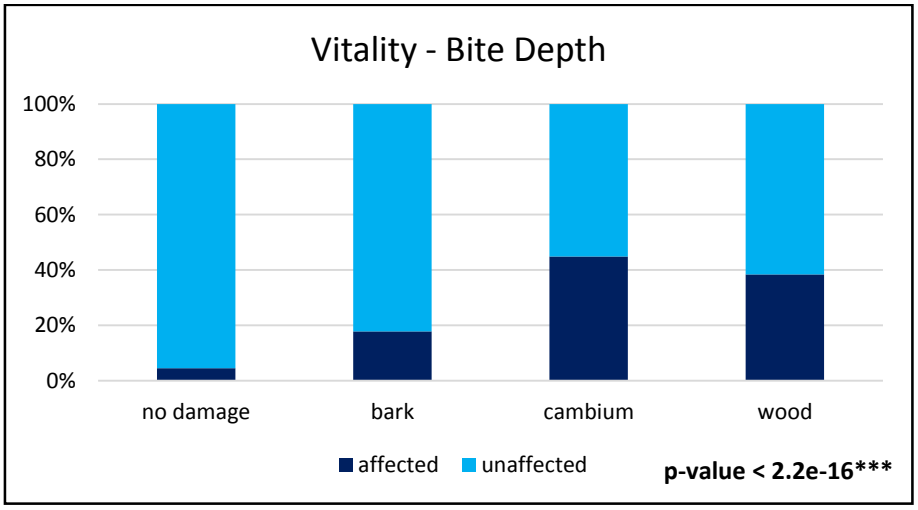

Fig. 20: Bite Depth rates in 4 categories related to the trees' vitality (affected, unaffected)

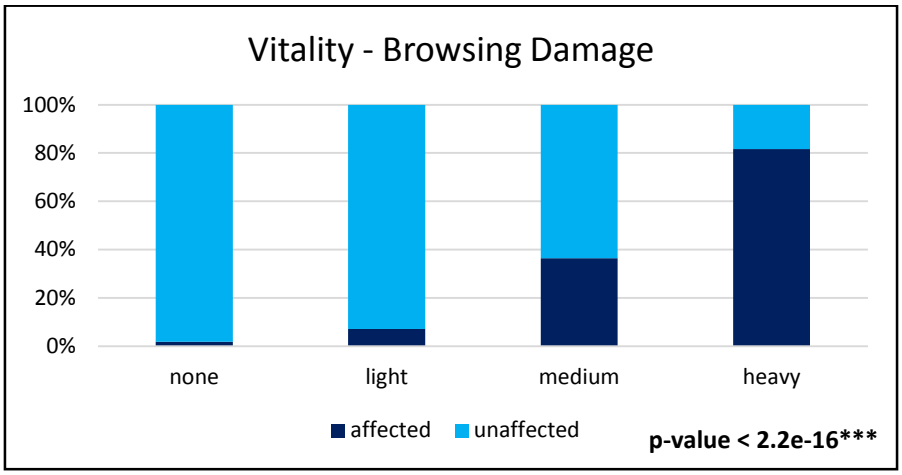

Fig. 21: Browsing Damage in 4 categories related to the trees' vitality (affected, unaffected)

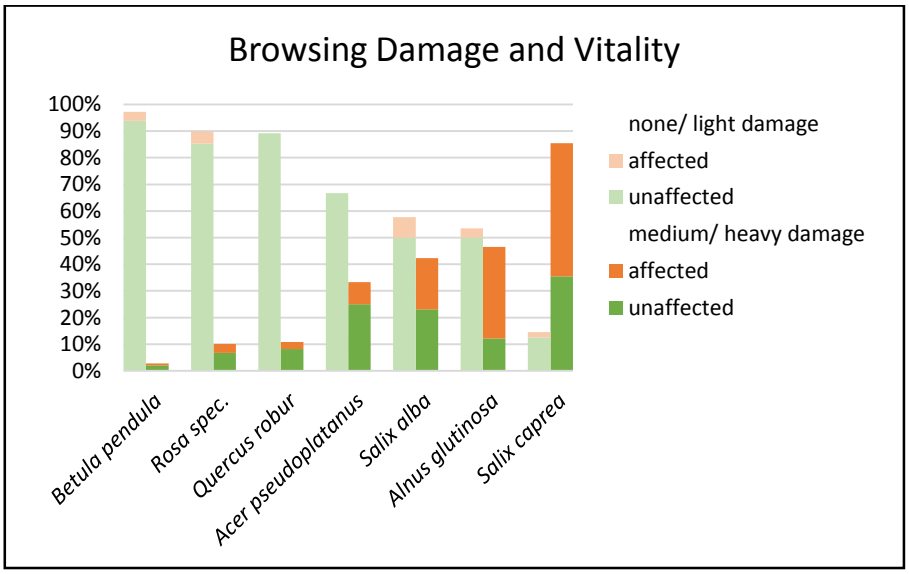

Fig. 22: Browsing damage and tree vitality (unaffected, affected), subdivided by tree species

4 Discussion

4.1 Browsing Impacts on Different Tree Species

The varying priorities of tree species among different browsers is widely known and could be verified in the study at hand (e.g. BUNZEL-DRÜKE et al. 2008). Goats have been found to browse selectively, yet a large bandwidth of plants. Where they had bit deeper, solid brown heartwood indicated that the tree's vascular tissue had been disrupted. When that was the case for the whole circumference, it could be assumed that the tree could no longer be supplied with water and nutrients. SKARPE et al. 2007 found goats to preferably browse common tree species, whereas BARROSO et al. (1995) and PEREVOLOTSKY et al. (1998) figured the opposite – a selective choice of rare species. Both views were partially supported: Birch trees, that were common on the study site, were barely browsed, whereas the likewise common sallow was browsed intensely. The rare alder tree was browsed moderately, the scarcely spread oak trees were barely touched. Oak trees have been proven to be tolerated by goats (present study, RAHMANN 2000), whereas they are poisonous to sheep, horse and cattle. On the study site, no individual of *Quercus robur* was found dead in spite of their young age. This might be due to low grazing pressure resulting from the short grazing periods. It could also present an interim result, with more dramatic impacts on vitality to follow in the coming years. However, this outcome is not expected to occur under the current grazing regime. Older stands of other species have been seen to recover from previous bites (Fig. 23). Stems of *Quercus robur* were mainly lightly affected, leading to the assumption that they are merely browsed randomly and not for their palatability. RAHMANN (2000) rates the species as most nutritional of all deciduous trees for mineral supply of livestock. Concerning potassium and calcium, however, intake rates seem low. Further studies on conversion of nutrients from fodder plants in herbivores need to be conducted in order to clearly assess the influence of nutrient availability in wooden groves on feeding behaviour (ibid.). A future threat for the oak population at *Lake Cospuden* cannot be seen at the present moment. These observations for oak trees are in concordance with previous studies (e.g. BEST n.y.). BÖRNER et al. (2013) analysed planted hedges as fodder source for goats over five days. They found that already on day 2, 25% of young and middle-sized branches on oak groves were browsed. That percentage remained unchanged over the following 3 days. Sallow, on the contrary, started off with 12% on day 2 and then increased up to 41%. Rose bushes were affected in a similar way to sallows. For older branches, percentages were smaller and browsing gaps longer, but trends stayed the same. An assessment on tree vitality is not given, but taking into account the findings

of BEST (n.y.), it can be assumed that oaks, sallows and thorny bushes all benefit from intermediate grazing pressure. Those findings confirm the observations made in *Cospuden* and moreover give inspiration for further management adaptations. The hazel tree, for example, showed high popularity among goats with 100% of the stands being browsed on day 2 in the study of BÖRNER et al. They consider it a palatable species for goats; highest priority amongst them obtained honeysuckle and guelder rose. High grazing pressure could be taken from oak trees by planting those browsing alternatives.

Fig. 23: Healing bite mark on Quercus robur.

The common sallow – *Salix caprea*, which is also known as goat willow, was the tree most affected in the study at hand. Sallows are pioneer trees, known for their ability to quickly regrow and sprout (BÖRNER et al. 2013). They have been proven to be popular among wild browsers like bison, moose, roe and red deer (FALIŃSKI 1998, MYKING et al. 2013). In Białowieża National Park in Poland, *Salix caprea* populations were almost completely forced back through permanent browsing through large herbivores (FALIŃSKI 1998). After 10 years of browsing, half of the trees were dead, and after 19 years up to 99%. However, when browsing pressure then stopped, they regenerated quickly together with other pioneers (*Betula* and *Populus* spec.). FALIŃSKI also describes how growth forms change under browsing pressure. Sallows then tend to grow more into bushes rather than trees, which could be observed in its beginnings on the study site as well. In spite of the high browsing damage rates and deep bite depths, many trees were only partly affected in vitality here. The vast majority was alive. The sallows on the study site are often grown with multiple stems (Fig. 24). Bite marks were usually found on each stem. Thinner side stems seemed to be more likely affected in vitality, yet completely dead multi-stem individuals could not be found. Browsing marks from the previous year could be spotted

(Fig. 24), leading to the assumption that either a general preference for *Salix caprea* exists or, as SKARPE et al. (2007) observed, trees that have been browsed already are preferably browsed again. BÖRNER et al. furthermore attribute a high biomass volume to sallows, hinting to potential economic benefits.

Fig. 24: Browsing marks on Salix caprea from the ongoing (l.) and the previous year (r.) on the study site, October 2015.

Rosa spec. was often peeled where the stem was accessible, which is in accordance with RAHMANN's (2000) observations. Very few of them were affected in vitality. Like GORN (2014) concluded for her study on an abandoned industrial site in Leipzig, rose bushes can be kept unprotected long-term without being significantly harmed by goat browsing. Considering the high amounts of roses at the study side, no impacts on the population are therefore expected in the near future. However, a protective function for enclosed stems of other tree species, as POTT and HÜPPE (1991) suggest, is not predicted for the present shrub density (Fig. 25).

Fig. 25: Food access cooperation between goats and sheep on the study site (April 2016).

4.2 Browsing Impacts on Trees of Different Heights

As opposed to the findings of SKARPE et al. (2007), that trees with a large canopy are preferred by browsers, in the study at hand mainly small and therefore young trees were affected. The second hypothesis can be confirmed. RAHMANN (2000:113), on the other hand, describes an increasing share of browsed bark with increasing tree height compared to leave and shoot browsing. Yet his results are not contradicting, taking into account the better reachability of leaves and shoots on younger trees and the fact that he investigated the share rather than the actual amount of browsed bark. For future studies, however, it could be advisable to measure tree circumference instead of height. Growing pace varies more among tree species than circumference, and diameter growth lasts longer than height increase throughout the lifetime of a tree (BACHMANN 2003). Young trees of one species can therefore be taller than old trees of another species, especially with rose bushes being involved in the study. With bite depth likely depending on resistance and thickness of the bark, results could be more clarifying with circumference data.

4.3 Browsing Impacts on Trees in Different Vegetation Densities and Positions

The third hypothesis, claiming that trees in a light surrounding are being more affected by browsing than those enclosed by dense vegetation, was confirmed too. This effect is likely to result from better accessibility of stems in light vegetation. Yet it can also represent the larger amount of trees and shrubs available for grazing in light vegetation (261 compared to 216 in dense vegetation). This seemingly contradicting fact results firstly from the rose bushes that take up more area per individual than trees. Secondly, in dense areas many tree species that were not part of the seven target species grew.

Taking into account that most of the groves in dense vegetation were roses, density cannot be considered as an independent factor. Visits of the study site during grazing after field research showed that accessibility had been underestimated. The goats were found in previously highly dense rose shrubberies, which now appeared patchy and accessible. Sheep were observed to eat off branches pushed down by goats (Fig. 25), pointing towards another potential study field of interspecific browsing symbioses.

Due to strong intercorrelation between position and measured distance to the water edge, the latter was excluded from further analysis. The fact that both bite depth and browsing damage were higher when trees were closer to the water edge is probably not a cause-effect relationship.

Trees in proximity to the lake shore also tended to grow in lighter vegetation and were therefore much more accessible. This intercorrelation between some tree species and their position demands for more specialised analysis. The fourth hypothesis could therefore not be confirmed. Birch trees, which appeared to be of low popularity among the goats, mainly grew along the shoreline and therefore interfere with position and vegetation density. Thus position might not be an actual determinant for bite depth, browsing damage or vitality. Further research with higher emphasis on single tree species or on sites with more even tree distributions is required in order to clarify interdependencies of environmental factors.

4.4 Correlations Between Browsing Damage, Bite Depth and Vitality

Bite depth was of less relevance to vitality than browsing damage. Yet both indicators of disturbance influenced vitality negatively. For bite depth, the jump between the heaviest two stages made no big difference for vitality. For browsing damage, however, it did make a change: The majority of trees with medium browsing damage were alive, whereas the vast majority with heavy damage were affected in vitality. It appears that single deep bites cause less damage than superficial widespread browsing.

4.5 Project Evaluation

4.5.1 Animal Selection

According to the Federation for Protection of Nature and Environment (BUND 2002), generally suited animal species for extensive grazing are hardy horse or cattle breeds. Comparable projects across Europe often combine both. When sheep and goats are applied, it is usually in combination with larger grazers. Indeed, for the realisation of the investigated project other grazers were under discussion. According to SICKERT (2015), yaks were one of the preferable species during decision-making. However, compared to sheep and goats, they are more demanding in maintenance on site as well as bureaucratically. Besides, due to their weight they could not have been kept on the same dam embankment the present herd is being kept on during summer months. Bisons would have been an adequate alternative for the project, too. Yet they should be kept on permanent coppices. The idea to combine animals with different browsing strategies is suggested by most authors in scientific and non-scientific literature (e.g. SCHMID 2003, BUNZEL-DRÜKE et al. 2008). Together with the availability of the mixed herd of Kerstin Doppelstein, the current grazing regime evolved. It could still be argued (following CORNELIUS & HOFFMANN 1999) that neither sheep nor goats are part of the natural species composition in Saxony, hence a natural state cannot be reached under the current grazing system.

The combination of the sheep herd with goats seems to significantly intensify browsing impact, assuming that most browsing damage on groves is conducted by them. In spite of their small stocking density compared to the sheep on site, and the short stay on the paddocks, noticeable impacts on the vegetation occur. However, single species are not seen in danger under the current grazing regime. As RAHMANN (2000:130) states, goats do not hinder succession with shrubs, but merely decelerate it. Yet for newly planted saplings protection is advisable. Considering the amount of rose bushes on site, goats seem an adequate solution for animal selection. Another benefit can be the grazing on *Solidago canadensis* (Canadian goldenrod, BUNZEL-DRÜKE et al. 2008:67). The common centaury (*Centaurium erythraea*), on the other hand, is not eaten by goats (BRUGGISSER 2011). It is a protected rare plant also represented on the study site.

4.5.2 Grazing Regime

Grazed pastures are multifactorial systems with individual and unpredictable outcomes (SCHMID 2003). Extensive grazing is therefore a very flexible concept for keeping and re-establishing plant diversity in cultural landscapes (ROSENTHAL et al. 2012). Process protection, diversity of habitats and biotope structures increase, whereas size of homogeneous patches decreases under permanent grazing (BUNZEL-DRÜKE et al. 2008). However, extent and duration of those welcoming changes are hardly predictable (ibid.). As SCHMID (2003) states, each animal species, breed and even group behaves differently on-site. Magic formulas for grazing regimes can thus not be given. However, an initial assessment of the current grazing regime shall be attempted.

As scientists on a conference organised by the Environmental Academy of Baden-Wuerttemberg (Umwelt-Akademie Baden-Württemberg 2004) found, stands below 1.20 m can be significantly affected in vitality in intensive coupling. This is within grazing height of both sheep and goats (Sanon et al. 2007). However, it would imply an intensity of 300 animals/ ha in 5 days. With this stocking density, even bushgrass (*Calamagrostis epigeios*) can be controlled (ibid.), which is presenting a potential future threat to the site (Andreas SICKERT 2015). On site, 100 animals graze an area of approximately 2.5 ha at a time, over a period of two days respectively. The proposed livestock density for bushgrass reduction does not seem a realistic alternative with the current herd size, but could be considered at a future point if necessary.

With the paddocks, the animals are kept in rather small areas compared to the typical image of an extensively grazed landscape. ROSENTHAL et al. (2012:195) name the benefits of large-scale grazing: Habitat gradients regarding soil and plants are enhanced, involving acidity, moisture,

nutrient and light availability. Together with multiple-disturbance patterns that likely occur on different scales in large areas, higher beta and gamma diversity can be achieved. This process can be supported by herbivores acting as vectors for diaspore dispersal. Generally, wide habitat borders sustain the animals' wellbeing and their interactions with different site conditions. According to RAHMANN (2000:83), stocking density is less important in paddocks than in herds. The paddocks present a sensible solution in the frame of the *hudewald* project, leaving accessible areas for visitors and given that the animals only spend a short amount of time of year on the site. The rule of thumb mentioned in the beginning of a short grazing and a long resting time (OPPERMANN & LUICK 2002) is met. From a bioethical point of view, the herd is well looked after by the shepherd lady Kerstin Doppelstein. The paddocks are large in size, roughly taking about a quarter of the whole grazing area. The lake borders all paddocks, making both a fourth fence and an additional water source redundant. In the long run, however, the question arises whether more excessive interference will become necessary in order to keep conditions in favour for conservation. Also the aim of pushing back roses for better visitor guidance might require intensified pressure. Light temporary grazing with small herbivores might not represent natural processes and therefore not lead to the desired results (KONOLD 2008). High as well as low grazing pressure over a long period can result in counterproductive outcomes (BUNZEL-DRÜKE et al. 2008). From an economic perspective, higher grazing pressure does not pose a threat. Wood quality is not sufficient for usage as veneer wood, it is merely being used as saw timber and fire wood (SICKERT 2015). Bite marks, as opposed to tree survival, are thus of no importance.

Many authors also hold the view that extensive grazing should be conducted year-round in order to achieve changes in vegetation (e.g. SCHLEY & LEYTEM 2004, BRUGGISSER 2011). SCHLEY and LEYTEM argue with browsing pressure on groves being highest during winter months. An extension of grazing duration on-site is not realistic, given the high frequency of visitors at warm temperatures. As the study site is used as bathing site, conflict potential would be seen here and the current solution seems the most practical. Additional browsing pressure by game might be an undetected significant site factor, considering the findings of LISS (1988) who concluded that game plays a major role in success of preventing rejuvenation. If plant recovery shows to be more efficient than browsing effects, adjustments in browsing intensities might have to be carried out.

A potential benefit of the rose shrubs could be a protective function for enclosed young tree stands. However, under the current grazing regime, roses don't seem to present an efficient

barrier for the goats. If stands are to be protected through roses, grazing pressure has to be lowered or additional rose bushes need to be planted. Alternatively, and as was partly planned, trees can be protected artificially. This approach is recommended; especially as most young trees were not found close to dense rose bushes.

Throughout literature, there is a common accordance that in most cases, grazing acts as a disturbance on the environment (e.g. BERGMEIER et al. 2010, RUPP 2013), even in short intervals (WHITE & JENTSCH 2001:408). On the study site, an immediate disturbance is desired and was visible (Fig. 26).

Fig. 26: Study site before and during grazing (October 2015/ April 2016).

Beside RAHMANN (2000:130), other authors speak of a deceleration rather than a prevention of bush encroachment through grazing too. So does GERING (1994:22), who recommends additional mowing. At the moment, a need for mowing cannot be identified. Also concerning available nutrients, management adaptions do not seem required at present. For soils high in nitrogen, grazing might lead to a lack of phosphorus and thereby facilitate the establishment of competitive grass species (ROSENTHAL et al. 2012:195). This scenario poses no potential threat, with the study site being low in contamination and nutrients. However, the high usage as recreational site could result in an increased nutrient input; especially a high nitrogen deposition (KOWARIK 2005).

A slightly increased grazing pressure could be a considerable approach for the following years, or variations in grazing pressure.

4.5.3 Suitability of the Area

When evaluating the project by the two main vectors of urban dynamics (RAMALHO & HOBBS 2012) – space and time – two questions arise:

Firstly, is the conducted grazing regime recommendable from a temporal perspective?

Secondly, is it recommendable from a spatial perspective?

To answer the first question, past and future site conditions need to be taken into account. As a former mining landscape, it is generally suited for grazing (BUND 2002). Yet it comes along with disturbed water and mass balances resulting from mining (HAASE et al. 2002). Since the beginnings of mining activities, waterways have been cut off and the floodplains of the rivers *Weiße Elster* and *Pleiße* have been largely destroyed (HAASE et al. 2002). Until today, water table dropdowns and annual run-offs are lower than before. The relocation of the floodplains took retention areas and destroyed species-rich habitats. Moreover, their buffer function for floods, groundwater formation and as matter sink got lost, resulting in alterations of mass and water balances in large areas south of Leipzig. However, a potential acidification of soil and water due to mining is unlikely in *Cospuden*, for contaminations are low and buffer capacities of the clayey materials comparably high (HAASE et al. 2002). At the moment, the soils are very heterogeneous, laying the foundation for a diverse vegetation. According to KRAWCZYNSKI et al. (2007), this heterogeneity is a crucial distinguishing feature of former mining areas as compared to other open landscapes. Structurally, the soils here are characterised by sand and gravel, resulting in a high infiltration capacity. A hummus layer has not developed yet, adding up to the general lack in soilmarks (HAASE et al. 2002). Measured pH-values are neutral to slightly acidic (ibid.). On acidic soils, oaks and birch trees find suitable conditions (POTT & HÜPPE 1991). Those trees, in combination with alder, are often found in wet valleys and lowlands close to water. For the target species *Quercus robur*, conditions seem adequate. The former function as huge retention areas cannot be regained. However, the predicted rare plant and animal species establishing on oligotrophic soils are an unusual novelty in landscapes dominated by urban and agricultural influences (HAASE et al. 2002). Oak trees are considered beneficial for plant species richness, especially old and strong ones (SONNENBURG & GERKEN 2004, GLASER & HAUKE 2004). From a conservational point of view, the project aim can thus be evaluated positively from a temporal perspective. The natural productivity on-site is high enough to provide the grazers with food and water at the moment. As the animals only spend a certain time of year on

the project site, structural and nutritional diversity for animal welfare is not considered as essential as it would be for year-round grazing. Future prospects for the area are seen positively too, with ownership as well as project idea and conduction in city hands.

Concerning location, the project is unique in terms of its urbanity. Located at the fringe of the city area, the prospective forest is part of the urban vegetation. This fact makes it stand out from other extensive grazing projects. Along with environmental influences from the city, wellbeing of the city population needs to be taken into account. VERA (2009) explains the phenomenon of shifting baselines, which implies that each generation takes the environmental circumstances it has grown into for granted. It is then difficult to gain the population's support for a new landscape diversity. RUPP (2013) adds that extensively grazed woodlands have gone back in the aspect of European landscapes in the past 180 years. Not only knowledge got lost, but also a broad acceptance of this type of land use. It is therefore a further challenge to promote the benefits of the project on different spatial scales.

4.5.4 Importance of the Project

The project's future impacts on a local, regional and global scale can only be vaguely predicted at the present moment. To assess its long-term developments, patience and further observation are required. Yet it takes on a pioneering role for urban wood pastures and therefore poses a high potential to inspire across borders.

The study site is a transitional landscape in different ways. Firstly, it contains elements of both pasture and woodland (see Appendix 1), supporting the idea of thinking outside the box of "forest" and "grassland".

Secondly, it is in a state between cultural and natural landscape. For a period of more than 350 years, the area has been shaped by mining industry (HAASE et al. 2002). Massive impacts on topography and thereby soil, water, flora and fauna led to a landscape that hardly implies any unspoilt nature. However, large parts are now process protected areas, and succession is being allowed to take over. The term "landscape in between" (GAILING 2008) can be used on both a temporal and a spatial scale here. The temporal perspective refers to the transition from an intensely used mining area in the past to a recreational area of high conservational value at some point in the future. From a spatial perspective, considering its proximity to the city, it can be seen as a cultural landscape in the rural-urban continuum between city and countryside. It therefore presents an innovative approach in urban forest management.

The resulting boundary effects of the landscape can be valued by humans as well as animals (GEISER 1992).

Under the current grazing regime, alpha and beta diversity will likely increase, promoting rare plant species. An aim in the frame of recultivation was to lift the current forest share South of Leipzig of 10% (HAASE et al. 2002). The planned grazing measures help approach this goal further. The setting at the lake secures drinking water supply for the animals, and serves the promotion of plants weak in competition (KRAWCZYNSKI et al. 2007). A structural diversity is being created through grazing and browsing, including raw soil habitats that are essential for epigaic arthropods and xerotherm microclimate (GEISER 1992). Also other animal and plant species might benefit from sheep grazing on the nutrient-poor soils (SCHMID et al. 2001). KRAWCZYNSKI et al. (2007) explain the difficulty in man-made landscapes to obtain mosaic-like landscapes with high structural diversity that is still stable in itself. The continuous opening of soil and thus enabling pioneer species to settle in different spots, whilst in other places pioneers are being forced back by grazers, could be such a dynamic yet stable system. Especially considering the aspect that open soil spots have been observed to decrease within the monitoring programme underlines the importance of grazing practises on the study site. Animal manure can moreover serve as soil and water buffer, as it chemically reacts in a neutral way (KRAWCZYNSKI et al. 2007).

Besides, the socio-geographic importance is not to be underrated. Keeping farm animals in the city area attracts attention and increases the aesthetical value of the landscape (ROSENTHAL et al. 2012:169). By keeping the landscape open rather than building on it, a contribution to functionality of natural landscapes and local habitat connection as an “investment for future” is being made (HAASE et al. 2002).

As SONNENBURG and GERKEN (2004) point out, the project has the potential to act as a role model for other post-mining landscapes. Not only around Leipzig, but also in the eastern part of Saxony large-scale open-cast mining has taken place, and huge areas are now being reshaped. Surface and usage changes are still altering those landscapes. Extensive grazing is already being conducted in some places, but not with sheep and goats. As opposed to large herbivores that would appear alien in the scenery, this approach is an example of modern conservation that allows the population to identify with.

A classification as forest area not only matters on a city scale, but also region- and nationwide. Only one quarter of the federal state of Saxony is covered by forest, 95% being historical old forest stands (Glaser & Hauke 2004:105). Young stands are rare, particularly deciduous trees (0.6%) and mixed stands (1.3%), and especially so in the northwest area of Saxony around Leipzig (Glaser & Hauke 2004:103ff.). Most of Saxony's area is covered by coniferous forest. As a result of the mining activities, deciduous forests widely diminished. Newly established deciduous forests like on *Lake Cospuden* hence constitute an important step on a regional scale towards a greener and more pristine environment.

According to Glaser and Hauke (2004:173), Saxony holds an area of 64 ha of *hudewald* in eight individual stocks. Grazed forests are rare compared to other parts of the country, and according to the authors they have been for a long time. Three of those forests are partly grazed with sheep, the remaining six are not grazed any more. One of the grazed stands contains oak trees, the other two are pine birch alder forests on acidic soils. Against this background, the unique nature of the project as a grazed mixed oak forest shines through.

Compared to a potential sealing of the surface for recreational use, the *hudewald* concept offers an environmentally sound alternative and an important contribution to regional landscape balance (HAASE et al. 2002). It can help re-establish natural buffer functions, especially in terms of water infiltration, habitat connection and, based on that, a diverse flora and fauna. Not only locally, but also on a regional scale dispersal is being enabled, especially between the city of Leipzig and its surroundings. Even concerning existing doubts about re-establishing previous landscape functions (HAASE et al. 2002), the current management appears as a sound compromise on all levels. It can be considered a step forward in the direction of controlled green tourism and sustainable land use management.

On a nation-wide scale, GLASER and HAUKE (2004:179) presume a decline of *hudewald* area, as grazing isn't always a feasible option and abandoned sites often fall victim to succession. Simultaneously, a new approach of developing post-mining landscapes is being made. According to the Federal Agency for Nature Conservation (BfN 2016), the guiding principle in restoring those landscapes has often been to re-establish the old scenery. A strategy shift could support valuable new ecosystems with rare species. The project is a striking example of such process protection and could be a nation-wide inspiration.

The proceedings in *Cospuden Landscape Park* can be seen as a role model in terms of sustainable land-use of unfavourable sites in urban areas. With suburbanisation posing a present trend in industrialised nations, alternative development plans that combine social, ecological and economic benefits are required. Urban wood-pastures could constitute a new approach to counteract the decay and ecological alienation of cities. They can furthermore help to fulfil the goals set by the European Union for protecting and developing biodiversity.

4.6 Conclusions

Varying priorities for different tree species among the goats could be proved. Especially sallows were preferred, oak trees however were barely browsed. Even though this could be owed to the fact that not many oak trees exist yet, a future threat for the population of the target species could not be detected. It is concluded that oaks, sallows and roses benefit from intermediate grazing pressure. Sallows on-site tend to grow into multi-stem trees or bushes, potentially saving them from deceasing. Browsing damage and bite depth decreased with tree height. The goats' feeding behaviour was found to depend on the surrounding vegetation. Vegetation density did affect browsing, however most bushes in dense areas were roses, and most trees in light areas birches, potentially influencing the results. An interdependency of density and distance to the water edge could be identified. For better evaluability, the following points should be given attention to in future studies: Tree vitality could be influenced by other factors than browsing, such as water and nutrient availability, climate and weather. Tree stem circumference could be a factor of importance for the applied study design. The uneven spread of different tree species in different surroundings on the study site led to deviations in tree numbers, which should be adjusted priory. Especially the low oak tree abundance led to reduced statistical verifiability.

Due to the short duration of the project since its launch, long-term impacts cannot be foreseen yet. The current grazing pressure is estimated as sufficient to keep open grassland. It is not considered a threat to any of the tree species at present. Also *Quercus robur*, the target species, seems to flourish adequately. It is recommended to protect newly planted seedlings. If bush-grass and Canadian goldenrod are aimed to be further reduced, more intensified grazing could be applied.

From a temporal perspective, the project poses an interesting approach for restoring the landscape after mining activities. On a spatial scale, acceptance from the city's population might be a major challenge. Yet its value on different spatial scales is significant: Grazing animals enhance attractiveness of the landscape. They support local biodiversity and ecosystem

regeneration, as well as dispersal between habitats. On a bigger scale, the project has the potential to act as a role model for urban land use. It helps revive a historical form of land use under the modern approach of process protection.

Future studies should take into account grazing times and investigate vegetation after winter too, in order to see effects on young trees. Particularly in terms of browsing damage compensation through self-healing, regrowth and vegetative propagation, different tree species should be investigated. The production of substitutive shoots is another interesting aspect mentioned by GORN (2014) that deserves consideration, for it can lead to wrong assumptions of the tree being in a healthy state.

5 Outlook

The ecological unity of forest and game seems logical and is widely confirmed by literature (see for example WSL 1996, LPB 2001). Trying to separate them means creating unnatural circumstances. The idea of herbivores in woodland is therefore generally accepted. At the same time, it is widely assumed that open and half-open landscapes are man-made and therefore, cultural landscapes of today cannot represent species composition of primeval Central Europe. The recognition of the influence of herbivores on landscapes over centuries can be an essential stepping stone in modern land management. Boundaries between conservation principles and uncontrolled ecosystems then become fluid, giving way to a natural, resource-saving and self-regulating system.

Extensive grazing regimes have the potential to pose a major subsequent use for disadvantaged sites in Europe in the future (LUICK 2002). Linking them with half-open forest land implies both ecological and economic benefits, when management is adapted to the site. In order to overcome existing prejudices and re-establish wood-pastures in Central Europe, the basic acceptance of large herbivores needs to shift. Beside grazing management techniques, income opportunities have to be further improved. As DVL (2011) points out, wood-pastures are a societal gain in public goods. Their economic efficiency should not be limited to product value, but extended to societal-monetary values like aesthetics, recreation and tourism (OPPERMANN & LUICK 2002). The animals not only provide a sense of wellbeing, but also a contribution to climate, soil, biodiversity and water protection that should be reimbursed. Long-term financing of the areas needs to be secured, whilst slow progresses and the absence of immediate results should be accepted as inevitable circumstances. For financial security, extensively grazed areas

should be integrated into the first column of the Common Agricultural Policy of the European Union (DVL 2011). From there, they could be evaluated from a conservational point of view. Wood-pastures could then benefit from funding and direct payments. Moreover, landscape elements like single groves should be included in funded areas in order to minimise bureaucratic expenditure. In the frame of the second column, agri-environmental measures for extensive pastures should be co-financed for the federal states. Besides political means, management advise should be available for farmers. As RUPP (2013) points out, usually the broader masses don't have access to new knowledge on topics like this that are kept inaccessible in scientific journals. Animal welfare provisions should be adapted and regulations loosened for hardy breeds (see DVL 2011 for further suggestions).

Future research fields concerning wood pastures could focus on rare and invasive species, dispersal, immigration and extinction, and human demands for recreation. Interactions between animal species and breeds require further attention. Existing studies should be compared in terms of their grazing systems in order to allow for site-specific recommendations. Especially grazing in urban areas requires intensified research.

When inhabitants of highly urbanised areas one day find themselves relaxing among grazing animals, a sense of environmental responsibility and a deeper connection to nature might be regained.

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