Heritage oaks in a changing landscape

– Managing biodiversity in southern Sweden

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Supervisors: Adam Felton
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Swedish University of Agricultural Sciences
Master Thesis no. 197
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Preface

Within the next 60 pages I will address the issue of heritage oaks in a changing landscape, but prior to that I would like to place this study into a context and thank some of the people who have supported me in the realisation of this 30 ECTS point master thesis which marks the end of my two year Erasmus Mundus education, otherwise known as SUFONAMA (Sustainable Forest and Nature Management).

The goal of this project was to address some of the aspects of heritage oaks not often dealt with. The literature review revealed that most things written were either related to oaks (*Quercus robur* and *Quercus petraea*) as a production unit or their role as habitats for associated species. However the management of the adjacent landscape and of individual heritage oaks, to ensure a long-lasting habitat within beneficial surroundings for biodiversity, is rarely the primary focus of the scientific literature.

The large proportion of literature on oak-associated species made me question whether focus on, associated species provides the best chance of protecting heritage oaks in a changing and modern landscape, where they are scattered remnants of a former land-use. If what is on the agenda is basically the protection of heritage oaks as a symbol of the past and the fact that there is a time beyond our own life time then this should also be addressed when planning for protection? However I am a student in forestry so my departure point is not the reasoning behind protection and preservation, it is only a part of the context in which heritage oaks can be seen. I hope that this study can achieve to be a part of the discussion of the future of heritage oaks and the rich flora and fauna associated with them.

Without participation of great people I would never have made it through the materialisation of this master thesis. First I would like to thank my two supervisors Emma Holmström and Adam Felton. They have been a great help to me, and have answered numerous questions of all kind whenever they occurred. Special thanks to Adam for his enthusiastic guidance, his critical question and always welcomed humour. A special thank also to Emma for her knowledge of GIS, her willingness to always answer questions and great input on the operational part of the field component.

I would like to also thank Henrik Tham and Bo Nilsson at Häckeberga estate for their cooperation and guidance during the field inventory. I would like to thank Jörgen Nilsson from the County Administrative Board of Skåne for his help providing legislative material and knowledge.

I would like to thank Marie Fangel Cleemann for reading through this thesis and thanks to Rasmus Vincentz Jensen for making everyday life wonderful and helping me with whatever problems that have appeared.

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Abstract

In Sweden the landscape has been subject to pronounced changes over the past hundred years. In south Sweden, heritage oaks (*Quercus robur* and *Quercus petraea*) of large dimensions are scattered in the landscape as remnants of a former land-use. Heritage oaks constitute important habitats for associated species and are therefore related to Sweden's own and international responsibilities regarding the protection of biodiversity. One conservation strategy is the action plan for protection of trees with high conservation value (THCV). The action plan has resulted in a registration of all heritage trees with a DBH above 80 centimetres. The THCV registration holds measures of spatial distribution and structural features considered relevant to biodiversity. The information on 982 heritage oaks from the THCV register forms the basis for this study. It aims to gain significant insights regarding the current range of threats and the effectiveness of current actions taken to secure the long-term future of heritage oaks and their associated biodiversity in southern Sweden. GIS analysis are assessing the spatial distribution of heritage oaks within nature reserves, 20-meter buffer zones around different land-use categories and those areas subject to commercial timber harvesting. The field component of the study contains a selection of 32 of the largest heritage oaks. During the field work in May 2012 the areas of living and dead crown were measured in order to examine first the influence of the present land-use categories on the area of living crown. Second, the crown areas were compared to the forest density south of the heritage oak, to evaluate competition between the heritage oak and adjacent forest. To compliment these results a visual assessment of aerial photos and orthophotos (georeferenced satellite images) is used to investigate the land-use changes that heritage oaks have experienced over the last 70 years. The assessment revealed that recommendations given in the THCV register for the treatment of 333 heritage oaks planned for within the first 2 years after termination of the inventory have not been fulfilled. The largest oaks are not included in the nature reserves which should provide the optimal protective status. The adjacent landscape appears to be influencing the crown development of the heritage oaks. We find that competition from high and dense vegetation, as found within coniferous forest, is contributing to a decrease in the area of living crown. Regarding associated biodiversity it is found that the density of heritage oaks within Häckeberga nature conservation area is consistent with densities associated with the maintenance of high species richness. Another structural feature associated with biodiversity is the presence of tree hollows and nearly half of the 982 heritage oaks in Häckeberga nature conservation area are known from the THCV register to possess them. We find that one third of those are within the protective category of nature reserves and discuss the implementation of this result. In addition we find that the vegetation adjacent to the heritage oaks has changed during the last 70 years from open land (pastures and fields) to broadleaved-dominated forest, with the amount of oaks growing within pastures and fields having decreased by 40 percent from the 1940s to 2012. We discuss these results in terms of the insights they provide regarding the current range of threats and the effectiveness of current actions taken to secure the long-term future of heritage oaks and their associated biodiversity in southern Sweden.

1 Introduction

1.1 History of land-use

Sweden's forest sector plays a significant role in its national economy compared to other European countries. In 2009 the Swedish forest sector accounted for 10-12 percent of the total employment, and contributed to the economy with three percent of GDP (SFIF 2010). In 2010 the harvested volume was 89.5 million cubic meters (Bäcke, 2011). Despite its relative small size this enables Sweden, to be the second largest exporter of pulp, paper and sawn timber after Canada (SFIF 2010). Since 1910 the harvested volume from forest land has doubled, and modern intensive forestry practice has enabled the volume increment to rise proportionally. Concurrent and relevant changes have also happened in the open-landscape. For example, the share of land allocated to agricultural production has declined by 28 percent, and pastures have been reduced to half a percentage of their former extent (Table 1) (SSNC, 2009). The net effect of these changes is a corresponding increase in the proportion of land cover that Sweden has allocated to forestry by 600-800,000 ha from 1920 to 2005, and a corresponding decrease in agricultural land by 920,000 hectares in the same time period (Statistics Sweden, 2008).

Table 1 The development in land-use and production in Sweden from 1909 until 2009. All numbers are in thousands (SSNC, 2009).

Category	1909	2009	Units	Increase	Decrease	Units	Percent
Field	3691	2661	1000 ha		1030	1000 ha	27.9
Pasture	1307	2 till 7	1000 ha		1305-1300	1000 ha	99.8-99.5
Seed production	2462	5444	1000 ton	2982		1000 ton	54.8
Timber extraction	50000	95500	1000 m^3	45500		1000 m^3	47.6
Increment	60000	110000	1000 m^3	50000		1000 m^3	45.5

Forest land occupies 58 percent of Sweden's total land area but there are regional differences in forest coverage due to geography, climate and land-use. Skåne, the southernmost region of Sweden, has the largest share of arable land, with less than 35 percent of the total area consisting of forest (Statistics Sweden, 2008). In 2010 the forest land of Skåne consists of 38 percent Norway spruce (*Picea abies*), 11 percent Scots pine (*Pinus sylvestris*), 17 percent broadleaves and 17 percent noble broadleaves (Nilsson and Cory, 2011).Noble broadleaves including the species European beech (*Fagus sylvatica*), elm (*Ulmus sp*), oak (*Quercus sp*), Common ash (*Fraxinus excelsior*), Wild cherry (*Prunus Avium*), maple (*Acer sp*) and lime (*Tilia sp*) (Woxbolm 2007). Today's tree species composition is indicative of a shift towards a more coniferous dominated forest landscape (i.e. borealisation) which has taken place during the last 100 years, before that time the forest was more broadleaved dominated (Lindbladh, 1999, Karlsson et al., 1999, Björse and Bradshaw, 1998).

In southern Sweden the status of oak populations are often surveyed, for the benefit of both timber production and biodiversity conservation (Drobyshev et al., 2007, Sonesson, 1999, Lindbladh, 1999, Forbes et al., 2004). These repeated surveys have revealed a long term decline, and a more recent accelerated decline in the oak population (Lindbladh and Foster, 2010). This continuous loss of oaks has different origins depending on the land-use in which it grows. In rural areas it is found to be a consequence of deforestation on agricultural land (Framstad et al., 2000, Höjer and Hultengren, 2004, Lindbladh and Foster, 2010). It is estimated that during the last 25-30 years 15 percent of the heritage oaks have been lost (Forbes et al., 2004), mostly due to this process (Ranius and Jansson, 2000). The decline is rapid with respect to the generation time of oaks, and the result is loss of habitat for associated species (Lindbladh and Foster, 2010), and such declines will continue in the absence of sustainable management (Forbes et al., 2004, Gibbons et al., 2008). In this thesis oaks of large dimensions will be referred to as heritage oaks. We define heritage trees as per Arid (2005) as a conspicuous specimen because of its form, shape and relation to historical and cultural events.

1.2 Oak as habitats

It is estimated that around 60,000 species exist in Sweden. Of these, over 4000 species are on the Swedish red list, and almost 2000 of these are associated with forests (SSIC, 2010, Department of Environment, 2009). Notably, many of these taxa are disproportionally associated with one particular tree species possessing distinct structural characteristics (Sverdrup-Thygeson et al., 2010). Numerous studies have assessed the biodiversity associated with heritage oaks (Skarpaas et al., 2011, Sverdrup-Thygeson et al., 2010, Jansson et al., 2009). The results of the studies are indicative of both the high level of biodiversity associated with oaks and its declining population status. These threatened species mostly consist of saproxylic beetles, lichens and wood decaying fungi (Dahlberg, 2006, Höjer and Hultengren, 2004).

Oak trees can provide such valuable habitat because of their long life cycles, very durable wood (Holten, 1998, Jonsson et al., 2011), and associated potential for varying stages of decay (Nilsson, 2006). Cavity possession and the abundance of mould are important indicators of a wider species richness, and therefore trees with intermediate cavity and dead wood amounts can be used as important indicators of the conservation value of individual trees (Skarpaas et al., 2011). Other features important for biodiversity and oak-associated species are the surroundings in which oaks are situated (Sverdrup-Thygeson et al., 2010, Höjer and Hultengren, 2004, Koch Wiederberg et al., in press). For example it has recently been demonstrated that for some important taxonomic groups (i.e. saproxylic beetles) maximum species richness is achieved when surroundings are relatively open towards the south, which in turns affects the amount of sunlight that reaches the stem (Koch

Wiederberg et al., in press). Such knowledge can be used to explain why species richness for some taxonomic groups is found to be higher on oaks found in open conditions than in secondary woodlands (Paltto et al., 2011).

1.3 Nature conservation in Sweden

Sweden ratified the international Convention on Biological Diversity (CBD) in 1993, and has thereby given consent to safeguard the diversity of life on Earth. Thus Sweden accepted to follow the guiding principles of the convention and to report on the interventions made. The obligations that Sweden has to the CBD are met through 16 environmental quality objectives (Miljömålen) (EPA, 2012) stated by the Swedish parliament, and implemented through action plans framed by governmental agencies, including the Swedish Forest Agency (SFA) (Skogsstyrelsen), the Swedish Environmental Protection Agency (EPA) (Naturvårdsverket) and Swedish Board of Agriculture (SBA) (Jordbruksverket) (EPA 2006, EPA, 2007). Hence relevant sectors are expected to take responsibility for the integration of conservation and the sustainable use of biological diversity in the production of goods (Höjer and Hultengren, 2004, Department of Environment, 2009). To help insure the effective implementation of the environmental quality objectives, Sweden has enacted laws introducing a variety of financial and legislative instruments, mainly aimed at local authorities and the agricultural and forestry sectors (EPA, 2007). One of the conservation strategies specifically targeting the preservation of heritage trees within the cultural landscape is “Action Plan for Trees with High Conservation Values in the Cultural and Urban landscape” (THCV) (Åtgärdsprogram för särskilt skyddsvärda träd i kulturlandskapet). The trees within this action plan are preserved because of the high biodiversity and cultural values associated with these individual trees. The goal for EPA is to recommend specific conservation strategies appropriate in the ecological and cultural context (Höjer and Hultengren, 2004).

1.4 History of oaks and land-use in Skåne

Until 1658 Skåne was a part of Denmark. A law from 1588 declared by Danish king Christian the 4th announcing all oaks to be property of the King, thus including the oaks in Skåne. This declaration was motivated by the navy’s demand for oak timber for ship construction (DN, 2012). Later in 1658, when Skåne came under the Swedish King Gustav Vasa, a similar law had been enforced in Sweden. The subsequent decline of oaks was first a result of the navy’s demand for timber. Later, after the king allowed land owners to use oaks, population reductions were driven by civilians’ deliberately destroying oaks to reduce their interference with agricultural improvement and crop production, thus resulting in a more or less deliberate destruction of oaks. The result has been that most oaks remaining today are growing on land belonging to the crown or on noble land (Eliasson, 2006, Eliasson, 2012, Eliasson and Nilsson, 2002).

In former times both leaves and acorns from oaks were used for animal fodder and sometimes human food, and oaks therefore played a significant role in the basis for living (Rackham, 2006, Bradshaw, 2006, Vera, 2000, Karlsson et al., 1999). Oaks are relative tolerant to fire, and thereby benefitted relative to other species from human activities (Lindbladh and Foster, 2010). Historically there has been a separation in the landscape between inlands (i.e. enclosed meadows closest to the farms) and outlands. The oaks grew within the open landscapes on the inlands. By the beginning of the nineteenth century oaks were seldom found in the outlands as a result of grazing by domesticated animals, and due to human activities like woodcutting, pasturing and pannage (Eliasson and Nilsson, 2002).

Oaks do not regenerate well under a closed canopy of shade tolerant species and they are often browsed by animals. On the grassed fields oaks could establish under thorny shrubs like hawthorn (*Crataegus monogyna*) (Vera, 2000) or under more palatable species like rowan (*Sorbus aucuparia*) and birch (*Betula sp*) (Madsen et al., 2009, Paltto et al., 2011, Bobiec et al., 2011). In recent decades a decline in vitality has been observed in mature oak stands in southern Sweden (Drobyshev et al., 2007, Sonesson, 1999, Sonesson and Drobyshev, 2010). The decline in vitality of oaks can be attributed to several different factors: the bacteria phytophthoras causes a reduction in the fine roots (Jonsson et al., 2005), summer drought (Drobyshev et al., 2007) and unfavourable climate conditions (Sonesson and Drobyshev, 2010). Related to the heritage oaks the damage symptoms seem to increase with increasing age and the oaks exposure to wind (Sonesson, 1999).

1.5 Study aims

The foundation for this study is the data from the THCV register based upon the field inventory made by the County Administrative Board of Skåne terminating in 2008, findings from the study made by Koch Wiederberg et al. (in press) and field work constructed by ourselves in Häceberga nature conservation area. The study is based upon the collective outcome of addressing five distinct but closely related aims.

First we aim to assess the extent to which the recommendations of the THCV register have been carried out. These results will be important for assessing to which degree the THCV action plan (Höjer and Hultengren, 2004) can be relied upon to ensure the long term status of southern Sweden's heritage oaks.

Second, we assess the degree to which current protected area (nature reserve areas) encompasses the heritage oaks possessing the highest amount of indicators of biodiversity value. Such an assessment will indicate whether or not the nature reserve area designation is suitably targeted to preserving heritage oaks possessing the highest biological value (Sverdrup-Thygeson et al., 2010, Jansson et al., 2009, Koch Wiederberg et al., in press).

Third, we assess the relationship between the crown size of heritage oaks, the category of land-use in which the oaks are found and forest density to the south side of the heritage oaks. This assessment will indicate whether some land-use categories are associated with favourable or unfavourable outcomes whit respect to ensuring the long-term retention of biodiversity value for heritage oaks. Likewise, our assessment of the influence of forest density on crown development is an important addition to our understanding of heritage oak development as long-lived habitats. Furthermore, this assessment allows us to consider the likely future of such oaks in different land-use categories in the absence of adequate protective intervention.

Fourth we assess the changes that have happened and are happening in the landscape matrix by three different measures. We analyse the amount of heritage oaks within two different categories of 20-meter buffer zone. One is the buffer zone between open land and forest, and assessing the number/percentage of heritage oaks which are located here enables us to assess their legislative status, as well as edge zone influences on their health and biodiversity indicators. The other buffer zone of interest located between forest land between coniferous forest and broadleaved forest. This assessment is conducted assessed to determine whether proximity to broadleaved forest is sufficient to secure positive biodiversity/health outcomes. If not, then we will need to consider that the impact of coniferous plantations on heritage oaks may extend beyond plantation borders to the possible detriment of heritage oaks in the adjacent matrix. Moreover we will make a GIS based assessment to detect changes in land-use that have happened in the landscape of the heritage oaks during the past 70 year. This is done to determine whether there is a consistent pattern of increasing vegetation density within this heritage oak landscape since the 1940s, thus providing an overall picture of general trends in the matrix vegetation and associated likely impacts on heritage oak health and biodiversity status in this landscape.

Fifth we assess two measures considered positive for biodiversity. We use GIS to the density of heritage oaks within Häckeberga nature conservation area, to see if it is high enough to maintain viable population density of oak dependent species (Ranius et al., 2011). This assessment enables us to infer the realised or potential contribution these oaks could make to sustain populations of dependent taxa. Likewise, an assessment of the number of heritage oaks possessing cavities is conducted to reveal to what extent these important structural features are being provided by the heritage oaks within Häckeberga nature conservation area. This assessment will reveal the extent to which solitary indicators of value can be relied upon as opposed to the need to consider such indicators in relation to their landscape context.

Assessing each of these aims within the Häckeberga nature conservation area will enable us to gain significant insight regarding the current range of threats and the effectiveness of current actions taken to secure the long-term future of heritage oaks and their associated biodiversity in southern Sweden.

2 Background

2.1 The THCV register

The THCV registration is facilitated by the County Administrative Boards, as an outcome of the conservation strategies initiated by the Swedish Environmental Protection Agency. The original purpose of the register is to collect information about heritage trees in Sweden, including data on population size, and protection status, as well as to inform relevant stakeholders of the heritage trees' value and recommend management actions to ensure their long-term preservation (Höjer and Hultengren, 2004). The THCV register includes trees with a diameter at breast height (DBH)[1] above 100 cm or trees older than 140 years with a DBH above 40 cm.

The heritage trees in the THCV register used in the further investigation is from registered in 2008 by the County Administrative Board of Skåne. This registration is equal to the inventory methods used in the other southernmost counties of Sweden. Here trees above 80 centimetres of DBH are measured, and also dead standing and lying trees with a length above two meters are included. The register includes noting the tree species encountered, mapping their spatial distribution using Global Positioning System (GPS), and various measures of structural features considered relevant to biodiversity. These structural features includes such aspects as cavity development, rating of cavity size and location (e.g. cavities are given a rating from 4-7 dependent on size and an "a" if the cavity is on the stem and a "b" if it is by the stem), stage of tree decay, surrounding land-use, the presence and extent of sun exposed wood, morphology of the tree, recommended treatment of vegetation adjacent to the heritage tree, and a timeframe for completion of management recommendations. The recommended treatment consists of clearing and thinning of surrounding vegetation. The THCV registration in Skåne included 9346 heritage trees of different species (Appendix A). Of the 9346 trees assessed in the THCV register 3016 are living and dead heritage oak trees.

2.2 Study object

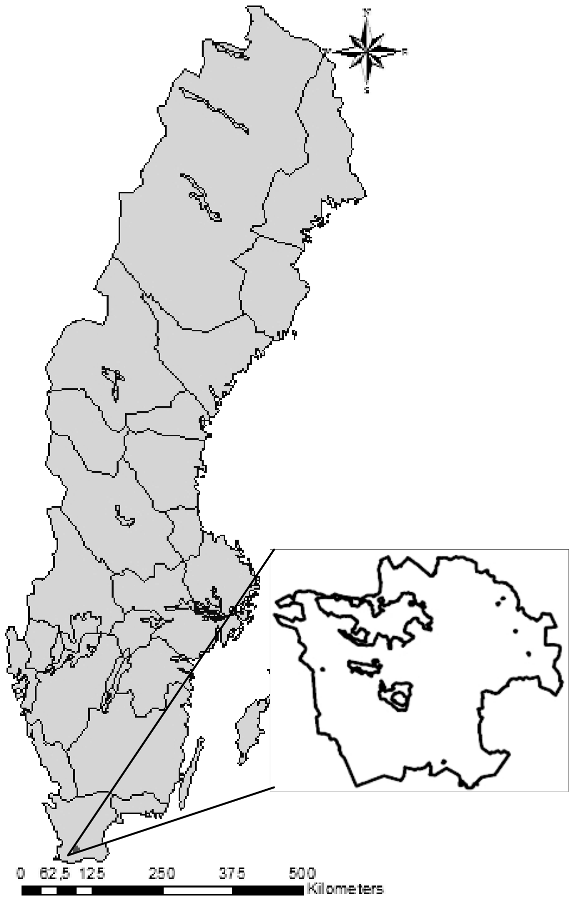
There are two species of oak found in Sweden, the pedunculate oak (*Quercus robur*) and the sessile oak (*Quercus petraea*). They can be found on various soil types, but have the highest growth rates on fertile soils (loams, sandy loams to clay soils). Sessile oak is found on a wider range of sites then pedunculate oak. The two species frequently cross pollinate, and as such they are not distinguishable with respect to the following ecological attributes. Both oak species are intolerant of shade, but when

[1] DBH is measured at 130 cm above ground or at the slimmest point below 130 cm.

exposed to sunlight after release from shading competition they can produce epicormic branches. Both species are found up to 61° N, and to an altitude of 600-700 meters. Frost and a requirement for an average temperature of 10°C in the four month of the growth season (April to September) is the limiting factor of its distribution (CAB International 2010).

2.3 Study area

We conducted our study within the 4450 hectare Häckeberga nature conservation area (naturvårdsområde) (CABS 2012d) located in Skåne southern Sweden (Map 1). Häckeberga is located 30 kilometres east of Malmö (55°N and 13°W) and occurs within the nemoral forest zone. The landscape at Häckeberga estate is hilly with its dominant characteristics defined by the last glacial period which occurred 13,500 years ago (Rapp, 1984). The estate is known for its variety of landscape elements, including agricultural fields with small remnant patches of broadleaved trees, forested areas with both broadleaves and conifers, and Häckeberga lake located in the northern part of the estate (Municipality of Lund, 2012). In terms of biodiversity there is a variety of different species from a diverse range of taxonomic groups in the area including lichens, mosses, mushrooms and insects (Arup et al., 2001, Municipality of Lund, 2012). Of these, 553 species found on the estate are red listed (Höjer and Hultengren, 2004).



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Map 1 The study area in south Sweden indicated by the red square. The cutting shows the area of Häckeberga estate in Skåne where the field inventory is made.

The distribution of land-use on the 4445 hectares within Häckeberga nature conservation area is that the majority of the area (61 percent) is covered by forest, where 36.5 percent is broadleaved forest and 24.6 percent is coniferous forest. Open-land accounts for 36.5 percent of the area, where 24 percent is fields and 12.5 percent is pastures (Figure 1).

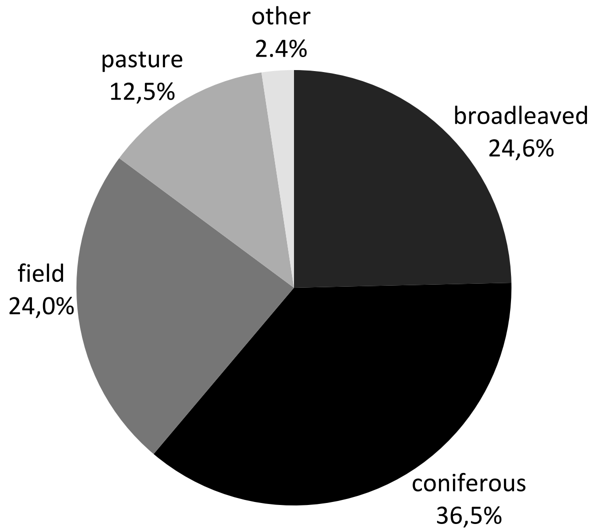


Figure 1 The distribution in percent of the hectares included in the five land-use categories within Häckeberga nature conservation area.

The nature conservation area on Häckeberga was established in 1982 under paragraph 19 in the 1964 nature conservation law (Naturvårdslag §19). This was effective until its repeal in 1999. After this the nature conservation areas of Sweden are administrated under the Swedish Environmental Code (Miljöbalken 1998:808) (Department of Environment, 1998). The Environmental Code maintains the validity of the 1964 law through the enforcement law of the Environmental Code (Lag (1998:811) om införande av miljöbalken). However there are a two other legislative regulations of relevance to biodiversity on Häckeberga. The first is applicable to the three nature reserves (naturreservat) called: Skoggård, Degebergahus and Husarhagen. Through the Swedish Environmental Code (Miljöbalken 1998:808) (chapter 7 §4) the County Administrative Boards can establish nature reserves to insure the protection and management of habitats (Höjer and Hultengren, 2004). These nature reserves were established in 2008 and cover 396.6 hectares or 9 percent of Häckeberga nature conservation area (CABS 2012a). All these areas are also protected under Natura2000 (EEA, 2012b, EEA, 2012c, EEA, 2012a). The management within the nature reserves aims at protecting natural and cultural values characterised by noble broadleaved forest (see chapter 1.1) with varying age-class distribution and with a continuous high amount of dead wood (standing and lying) (CABS 2012a, CABS 2012b, CABS 2012c). Outside the nature reserve areas there is mainly production forest. We use the borders of these distinct conservation legislative areas (nature conservation areas and nature reserves) in GIS for further analysis of the heritage oaks in Häckeberga. All areas investigated within Häckeberga nature conservation area are under the same ownership.

The land-use inside the nature reserves on Häckeberga reflects the overall distribution of land-use in general on Häceberga as see in Figure 2.

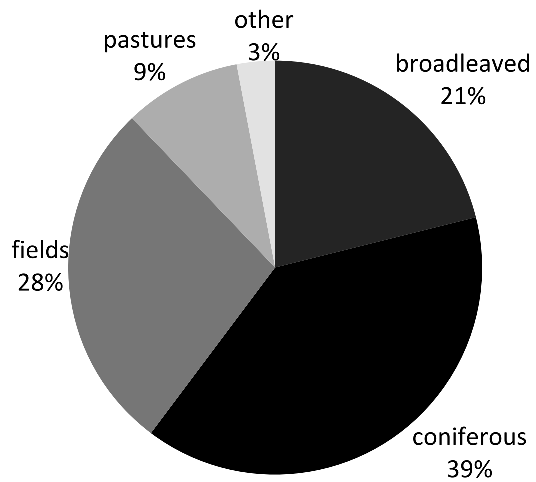


Figure 2 The distribution in percent of the hectares included in the five land-use categories within the three nature reserves.

3 Methodology

The data used for this study consists of two different data sets. One consists of the 982 heritage oaks within the nature conservation area at Häckeberga estate selected from the THCV. The attributes of this census survey can be used to provide an overview of the status on the heritage oaks within Häckeberga estate. The second data set is a sample of 32 of the largest, living heritage oaks within the nature conservation area. These 32 heritage oaks represent a subsample of the 982 heritage oaks. The 32 heritage oaks are selected by their circumference and distribution in land-use categories, thus they are not randomly selected. The oaks with the largest circumference are selected because it is correlated with bark area and the degree of bark granulation, both aspects that are associated with high levels of biodiversity. These 32 heritage oaks are used for the field-based component of this study, to assess current competition between heritage oaks and their surroundings, and to assess the development in their surroundings the last 70 years.

3.1 Assigning attributes to the heritage oaks

All spatial distribution analysis were made using the program ArcGIS for Desktop 10 Education Edition (ArcGIS). GIS is a system for working with and interpreting data which is spatially referenced to the Earth (Hentschlen, 2011). The illustration (Figure 3) shows the different targets to be met, the maps and information used to obtain the desired information, and the relevant commands used in ArcGIS to combine all the relevant information of the targeted oaks in their attribute table.

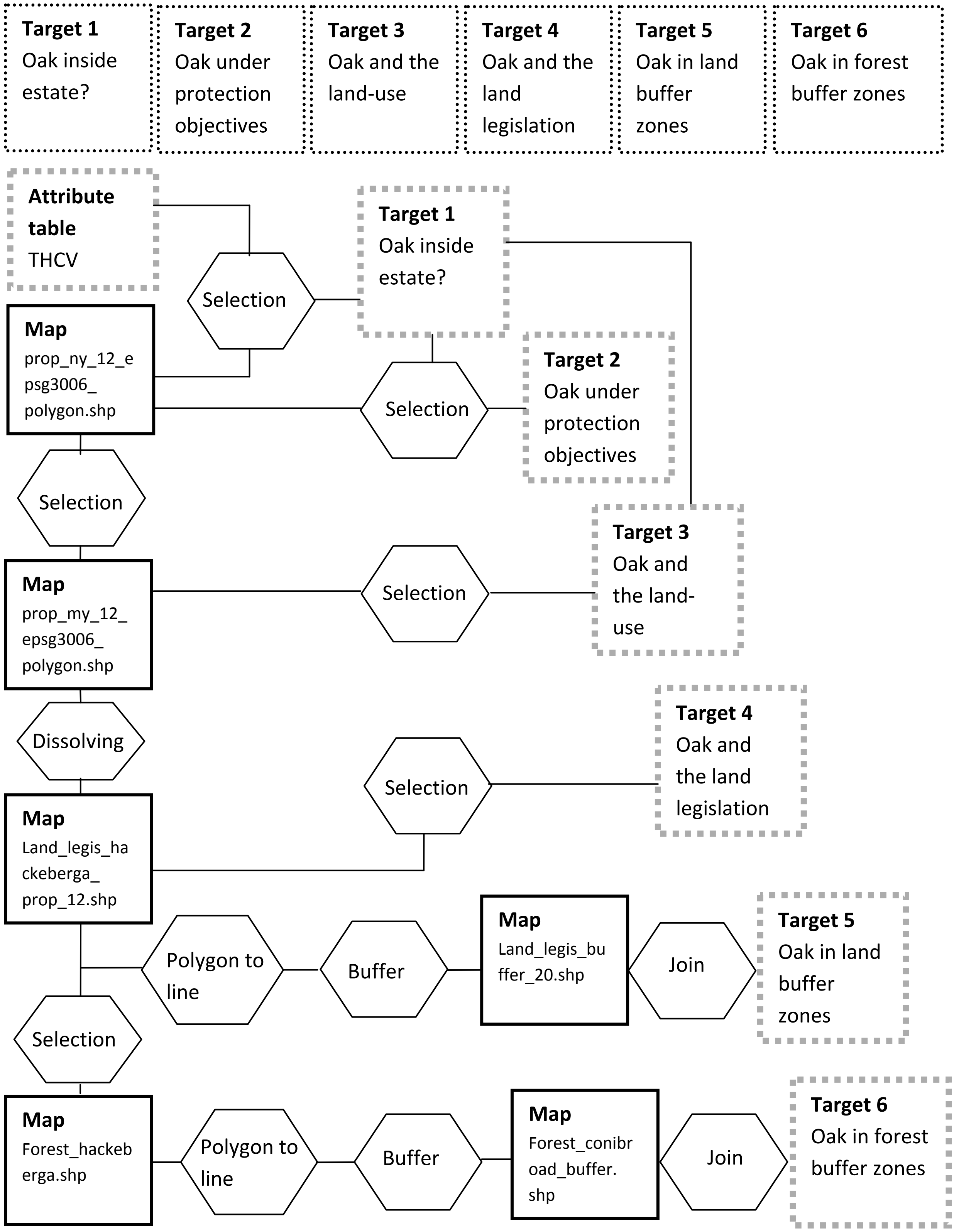


Figure 3 The commands used in ArcGIS to obtain the information used further in this study. The colour-codes: black dashed square = target, gray dashed square = attribute tables or excel files created from the attribute tables, black squares = map, hexagons = commands in ArcGIS10

Inside Häckeberga study area, we selected 982 heritage oaks from the THCV register using a property map containing Häckeberga nature conservation area and a layer-file containing the THCV attributes. A selection was first made in the property map layer by selecting the nature conservation area, and then applying this selection to the THCV register-layer. This selection was exported into a new layer-file containing the heritage oaks (target 1 Figure 3). The selection of the 982 heritage oaks revealed that a majority of 82 percent of the oaks are living in 2008, 3 percent were dying, 15 percent were dead standing or lying or high stumps.

In addition, we were interested in determining the amount of oaks under the objectives of the three nature reserves and whether the oaks located within the reserves had distinct structural characteristics, to see if the nature reserves comprise the largest oaks. The selection was made first by selecting the three nature reserve areas from the property map layer and afterwards adding this selection to the heritage oaks layer. Finally a field in their attribute table called "natur_res" was added, where 0 = outside (no) and 1 = inside (yes) the nature reserve (target 2 Figure 3).

A property map with the land-use categories were cut by using the property map of Häckeberga nature conservation area. This was done in order to assign the adjacent land-use category attributes (fields, coniferous forest, broadleaved forest, water and pasture) to the 982 heritage oaks, thus seeing if there were any differences in the structural characteristic between the heritage oaks within the different land-use categories. In the new land-use layer of Häckeberga the land-use categories were selected one by one, and the selection was applied to the heritage oaks attribute table in a new field called "land_use" and numbered as follows fields = 1, coniferous forest = 2, broadleaved forest = 3, other = 4 and pasture = 5 (target 3 Figure 3). The distribution of the heritage oaks within the five different land-use categories is seen in Figure 4.

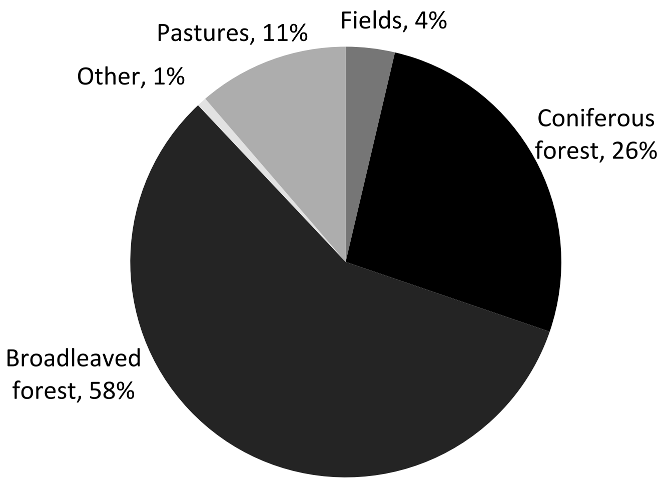


Figure 4 The amount of heritage oaks distributed in the five different land-use categories at Häckeberga nature conservation area.

In addition we were interested in the amount of oaks situated within the border region between the two land-use categories, open land and forest. To reveal whether the oaks located in the border zone have distinct structural characteristics indicating that they have larger dimensions or larger crowns. Firstly we needed to dissolve the five land-use categories from the land-use Häckeberga layer into three new legislative categories (open-land, forest and other). A selection was made in the new legislative layer and this selection was applied to the heritage oak layer in a new field called "land_legis" and the numbers 1 = open land, 2 = forest and 3 = other (target 4 Figure 3). Secondly to ravel if there is an effect on oaks from growing in the edge zone between open land and forest, we constructed a 20-meter buffer zone around the borders between open-areas and forest. The polygons with open-land, forest and other were transformed into lines and all lines between forest and open-land was deleted. A visual assessment was made to avoid false borders where it was the borders of the nature conservation area and not a forest open land border GIS had made into a line-feature. The buffer zone in the forest buffer-layer was selected and the selection was applied to the heritage oaks. A field called "buffer_20" was added in the attribute table of the heritage oaks, where 0 = outside (no) and 1 = inside (yes) the buffer zone (target 5 Figure 3).

To get further information on that possible amount of heritage oaks, which had previously been growing on the stone walls between pastures, we assessed the amount of heritage oaks which were located in the buffer zone between coniferous and broadleaved forest. This was done due to the assumption that the largest transformation in land-use have been from pastures into coniferous plantations (Statistics Sweden, 2008, Lindbladh, 1999). A selection of coniferous- and broadleaved forest was made in land-use layer, and extracted to a separate polygon layer. The two different forest polygons were transformed into lines. Afterwards all lines between forest and open land were deleted, to avoid duplication of selection from the land legislation buffer. The buffer zone in the forest buffer-layer was selected and the selection was applied to the heritage oaks. A field called "buffer_conibroad" was added in the attribute table of the heritage oaks, where 0 = outside (no) and 1 = inside (yes) the buffer zone (target 6 Figure 3).

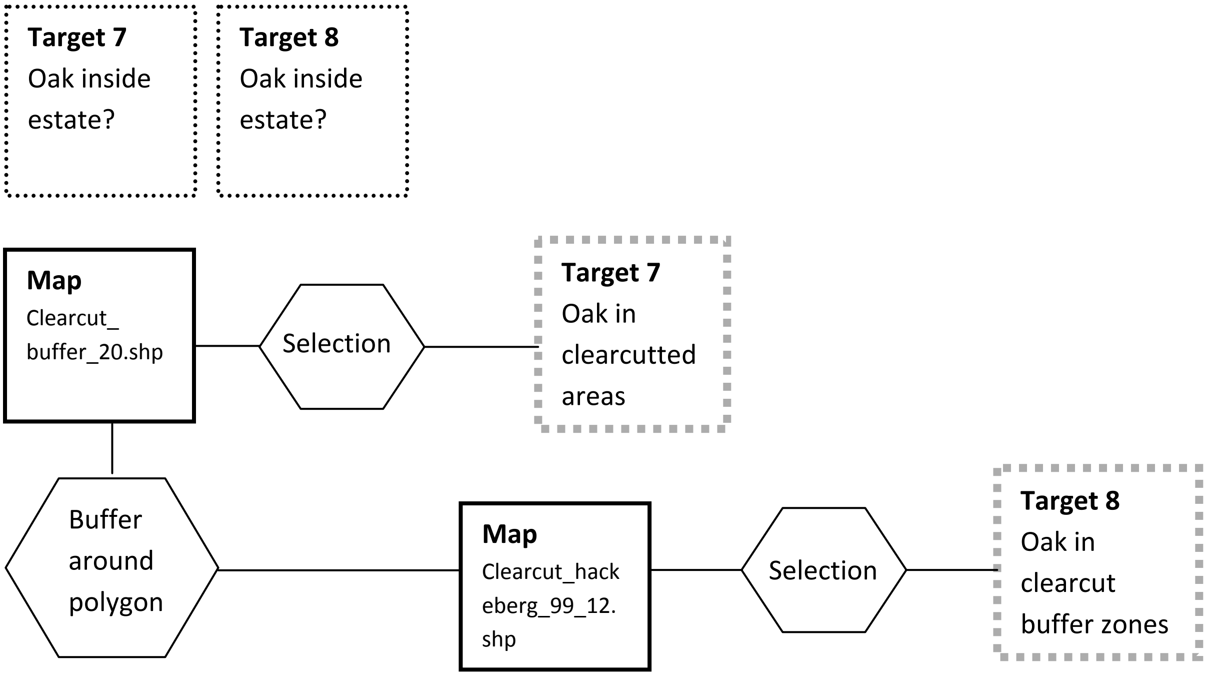


Figure 5 The commands used in ArcGIS to obtain the information's on the heritage oaks in clearcutted areas from 1999 to 2012 or in the adjacent 20-meter buffer zones around the cleracuts. The colour-codes: black dashed square = target, gray dashed square = attribute tables or excel files created from the attribute tables, black squares = map, hexagons = commands in ArcGIS10

Additionally an assessment in GIS was made to reveal how many of the heritage oaks are in an areas which have been subject to commercial tree harvesting during the last 13 years. The period is set to the time period of available data from the Swedish Forest Agency (Swedish Forest Agency, 2012b). To the clearcut data-layer a 20-meter buffer zones around the clearcut polygons were made. A selection was firstly made of all the clearcuts and this selection was applied to the heritage oaks, and a new field was added to their attribute table called "clearcut" (target 7 Figure 5). To reveal the amount of heritage oaks affected by clearcut areas an additionally a selection of all 20-meter buffer zones around the clearcuts was made. The potential for their being affected by the clearcut area is based on the associated changes due to an increase in sun and wind exposure, and a decrease in humidity. The selection was applied to the heritage oaks in a new field called "cc_buffer" (target 8 Figure 5). Where 0 = outside (no) and 1 = inside (yes) the buffer zone the clearcut buffer zones.

The assessments in ArcGIS were made before the selection of the 32 heritage oaks for the field assessment. This means that all the information gathered during the GIS-process is also available for the 32 selected heritage oaks.

3.2 Field assessments

The field inventory had the objective to investigate the relationship between the living crowns and other attributes of a sample of 32 heritage oaks, to reveal if the crown size is influenced by the adjacent land-use categories, the management objectives on the area or by the forest density, measured by the basal area in a half circle south of the 32 investigated oaks. The ratio calculated by the area of living divided by the area of dead crown is used as an indicator for competition between the oak and its adjacent vegetation.

3.2.1 Selection of 32 heritage oaks

From the literature reviewed and the survey made by Koch Wiederberg, Rainus et al (in press) it is clear that there are a variety of different aspects of heritage oaks that can be used as indicators for high biodiversity values. Different attributes of the heritage oaks are assessed in the THCV register, but a relevant indicator for the extent of competition between the heritage oaks and the surrounding vegetation or land-use is not included. The 32 investigated oaks had to meet the criteria of being among the 50 largest living oaks form the THCV register, which concurrently were distributed within the estate equally to the distribution of the 982 oaks (Figure 4). The large oaks were chosen because circumference is correlated with bark area and the degree of bark granulation, both aspects that are associated with high levels of biodiversity. This selection lead to a distribution of heritage oaks according to land-use categories where 53 percent are within broadleaved forest, 28 percent in coniferous forest, 13 percent in fields and 6 percent in pastures.

3.2.2 Crown assessment of 32 heritage oaks

The 32 selected heritage oaks were assessed in a field inventory at Häckeberga nature conservation area in May 2012. The inventory required several aspects to be measured for each heritage oak assessed. The measurements were split up into two parts, one assessing the influence of competition on the oak's crown, and the other assessing the surrounding which were influencing the oaks crown development.

The circumference of the oak tree was the first to be measured. This was measured as close to the instructions from the inventory method from 2007 (CAB, 2007), where the tree was measured at the smallest point below 130 centimetres. From the circumference the DBH was calculated.

For assessing the crown of the oaks the directions south, east, west and north was marked with sticks, as reference point for the measurements. The distances to the living and the dead crown were found by working with a compass in the four directions (south, east, west and north) until the edge of the living or the dead crown. At the border of the living and dead crown in all four directions a stick was placed (Figure 6). The distance from the reference stick by the oak stem to the indicator stick of crown width (living and dead) was measured with a measuring tape. The distance from the reference stick to the actual centre of the oak stem, and thereby the centre of the oak tree, had to be calculated because of the width of the stem. Therefore the angles at the stem were measured from south to east, south to west and east to north (Figure 6), to calculate the distances from the center to the reference points at the stem in all four directions (further calculations see Appendix B). For every oak the height was measured using a Vertex and a photo was taken as documentation and for further assessment.

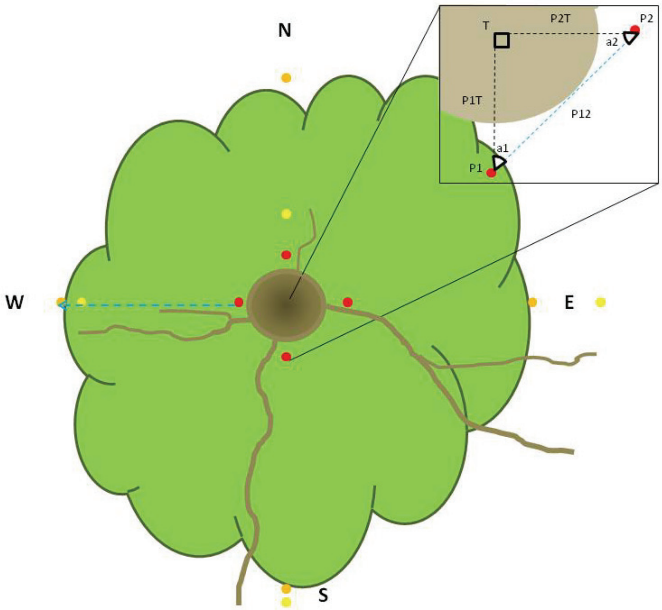


Figure 6 The measurements of the oaks in the field were made in all four compass directions, indicated by the red dots, the sticks were placed as close to the stem as possible. The yellow dots are the indicator of the stick placed at the border of the dead crown. The orange dots are sticks placed at the edge of the living crown. The blue dashed arrowed-line is showing the measurements with measuring tape in one direction (it was repeated in all directions). The cutting shows the measurements of angles at the stem by compass and measuring tape to calculate the distance from the red sticks to the center of the stem.

3.2.3 Measurements of forest density

Related to the findings of the importance of openness towards south for biodiversity by Koch Wiederberg, Rainus et al (in press) we chose to investigate the surroundings of the 32 oaks in a half circle from east to west with a radius of 10 meter from the center of the oak stem. The woody species within the 157 m² half-circle were measured with a calliper if they had a DBH above 5 centimetres, and if they were smaller than 5 centimetres they were counted (Figure 7). This was used for calculating the basal area in the half circle south of the oak, where basal area is an indicator of forest density.

For every oak a short visual assessment of the surroundings was made, including the presence of an understory, an overstory, a public road, a forest road, if the oak is on an open field, if the stem is shaded in the direction south, a subjective visual vitality assessment and a short description. All assessments in the field were handled in an Allegro MX Rugged Handheld.

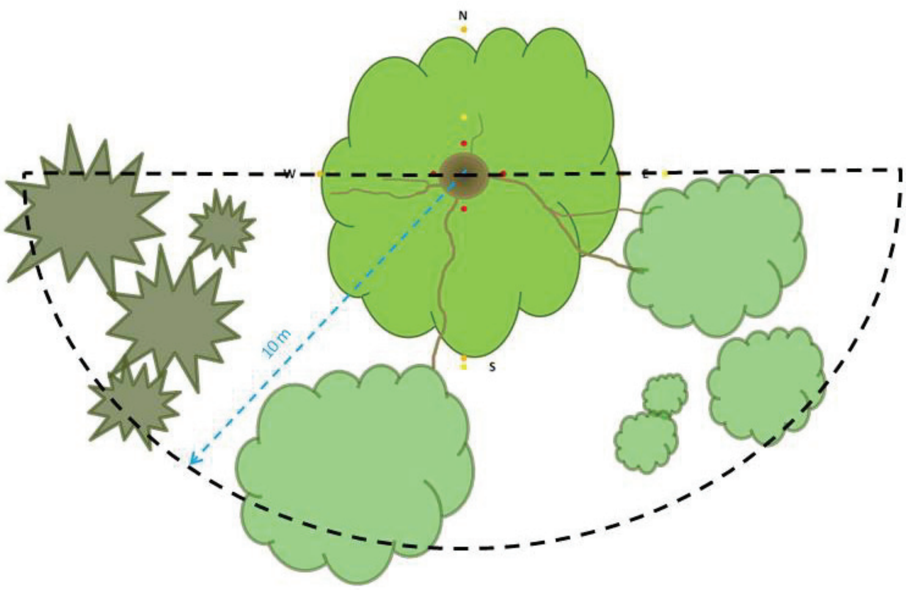


Figure 7 The surroundings of the 32 oaks were assessed, and the basal area of the trees in the 157 m² half circle south of the oaks was calculated (Half circle = 10 meters radius east to west from the center of the oaks trunck).

3.2.4 Photos

The 32 oaks were all photographed from south, or from the direction which gave the best impression of the crown development and the adjacent competing vegetation, all photos can be seen in Appendix C. The photos have been used as documentation of openness and other visual assessment after ended field inventory.

3.2.5 Data assessment

The attributes of the 982 heritage oaks and the applied attributes by the use of GIS were further assessed by using Statistica version 10 and Micro Soft Excel. This also applies for the field assessments of the crown development and competition measurements made on the 32 large heritage oaks.

Statistica version 10 has been used for making graphs and tables in the result chapter, and all histograms and box and whiskers plots are made in Statistica (StatSoft Inc., 2012). The statistical analysis made is One Way Analysis of Variance (ANOVA) tests for significant difference between the means in different groups.

Hypothesis: H_0 $\mu_1 = \mu_2 = ... = \mu_n$ $N(\mu_i,\sigma^2)$ $i = 1,\ldots,n$

$\mu_i = \mu + a_i$ $\sum_{i=1}^{n} ai = 0$

=> H_0 $a_1 = ... = a_n$

This applies to the differences between the mean of the DBH of oaks within the five different land-use categories, the three categories of openness (open, half open and closed) and also the mean area of living crown within the different land-use categories are tested to see if there is a significant difference between the groups. There was found to be a difference and to reveal the difference between means a multiple pair-wise comparison was made by a Turkey-Kramer-test.

Where there are only two groups e.g. within or outside the different buffer zones or within or outside nature reserves the means were tested by t-test.

Hypothesis: H_0 $\mu_1 = \mu_2$

T-test was used because of the small sample size (StatSoft Inc., 2012).

Micro Soft Excel is used when importing the attribute table from ArcGIS10, which are dbf-files, to *Statistica version 10*. It is also used for some of the basic graphs and pie charts in the methodology and result chapter.

As an indicator for competition between the oak and its surroundings the ratio between living and dead crown has been calculated. The calculation of the ratio between dead and living oaks has been made in Excel. Here the area of the living crown is calculated equal to a square by adding the distance west to east and the distance north to south and calculating the area in square meters, equal calculations are made for the area of the dead crown. By dividing the two area we get a ratio where l/d > 1 no decrease and < 1 for a decrease in crown size.

For an overall comparison of the surroundings of the oaks, excel was used to calculate a comparable number for each oak. The calculation were made as follows: first number = an oak in the 20-meter buffer zone between open land and forest given by 1*100, second number = an oak between the two forest types coniferous and broadleaved forest given by 1*10 and third number = the adjacent land-use category 1 till 5 (field =1, coniferous forest =2, broadleaved forest =3, other =4, and pasture =5). As an example an oak within the two buffer zones and in broadleaved forest is identified by a 113. A tree within the open-land and forest buffer and within coniferous forest is identified by a 102, a tree in a pasture is identified by a 5.

3.2.6 Aerial photos and orthophotos

To get a better knowledge of the area during the lifespan of the heritage oaks, there are used two different references for this thesis. One is aerial photos of south Sweden taken from 1939 – 1947. Those are available through services at Lund university (GIS-centrum, 2012). The other is orthophotos from 2012. An orthophoto is a satellite (or space) images of the Earth surface possessing the same accuracy of geographical spacing as maps, so that they are comparable to other data used in GIS. The orthophots of Sweden are a combination of SPOT and Landsat MSS (Lantmäteriet, 2012). The information of the images comes in pixels and the colours are detected in what is called bands. SPOT is multi spectral imagery comes in five bands a red, a blue, a green, a near inferred, a middle inferred band and pan. The pixels are from 10x10 meters in the three first bands, 20x20 in the next and 5x5 meters in the pan (Buschmann, 2011a). Landsat has images from 7 bands a red, a blue, a green, a near inferred and a middle inferred band, a thermal inferred and a lithology. The six of those are in pixels 30x30 meters and thermal is in 60x60 meters (Buschmann, 2010).

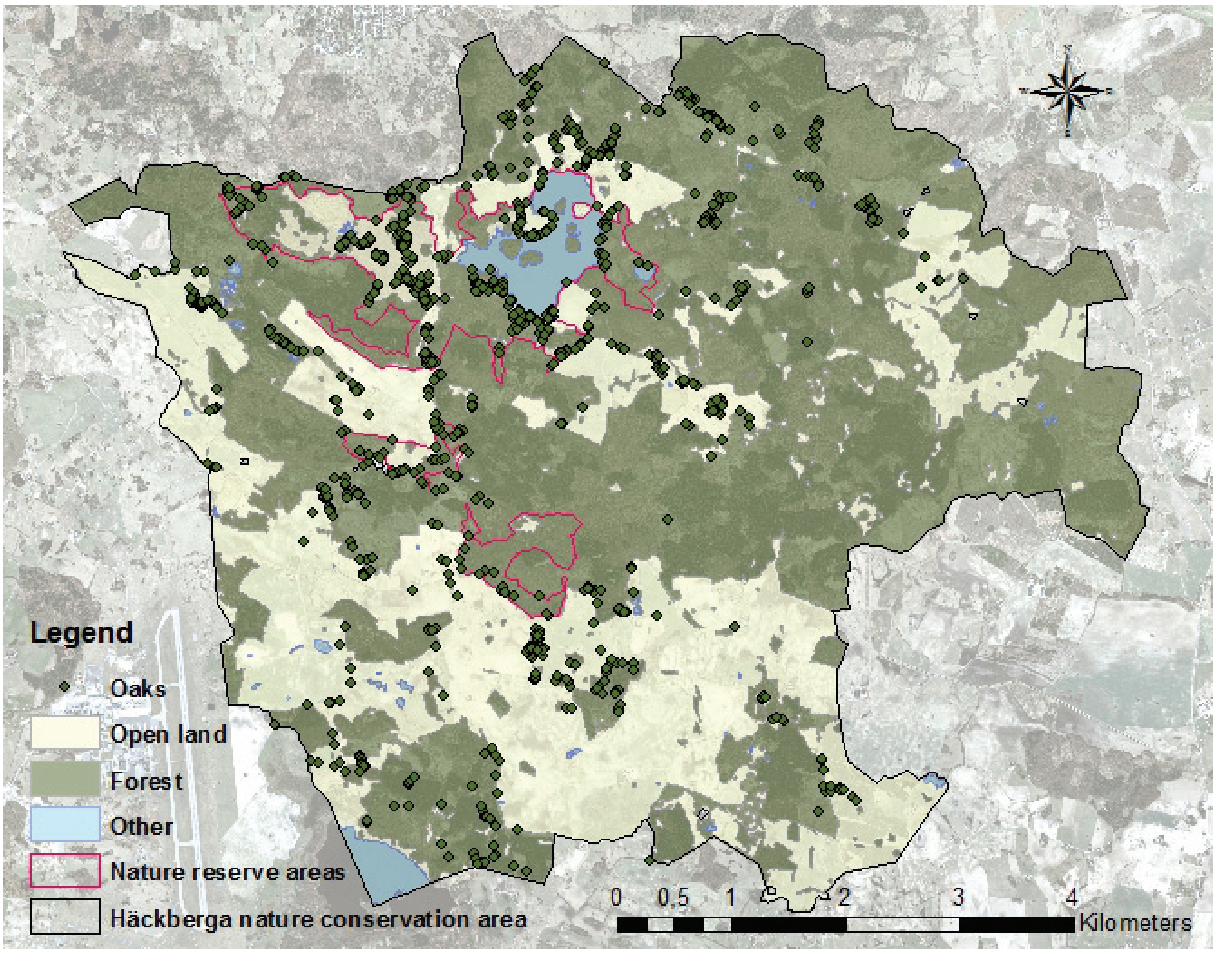
The assessment is made as seen in Figure 8, where every single assessed oak is visual assessed. The oaks is assessed by drawing a line east-west through the center of the oak-crown on the aerial photos from the 1940s and the orthophotos from 2012. Afterwards the land-use category north and south of the line is noted by the numbers 1 to 5 (field =1, coniferous forest =2, broadleaved forest =3, other =4, and pasture =5) and the enclosure is noted (0 = open and 1 = closed canopy)

Figure 8 The uppermost map shows the section of three oaks on a map from the 1940s and the map in the middle shows the same selection on an orthophoto from 2012. The pink circles illustrate three investigated oaks during the field inventory May 2012. The illustration in the bottom shows the visual assessment of the surroundings of the 32 investigated oaks made on both maps from the 1940s and from 2012. The pink circles illustrate the oaks for investigation and the line split it in north and south. This oak will have pasture south and open, and coniferous forest and closed north.

4 Results for the 982 heritage oaks

4.1 Examination of the THCV register

The spatial distribution of the 982 heritage oaks is as shown in Map 2. The map is distinguished according to forest and open land, where 828 of the heritage oaks are situated within forest and 147 on open land, where open land is consisting of either fields or pastures. The density of heritage oaks equals 0.2 per hectare within the Häckeberga conservation area (Table 2).



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Map 2 The spatial distribution of the 982 heritage oaks from the THCV register in Häckeberga nature conservation area of 4445 hectares. The black line encircles the whole study area (Häckeberga nature conservation area) and the pink lines is showing the three nature reserves; Skoggård, Degebergahus and Husarhagen. The map is also showing the three land-use categories: forest (dark green), open land (fields and pastures the sandy colour) and other (water is blue).

The density of the oaks within the different land-use categories differs (Table 2). The highest density of heritage oaks are within broadleaved forest and the lowest density are on fields.

Table 2 The density of heritage oaks within Häckeberga conservation area differs between the five land-use categories.

Land-use category	ha	Oaks	Density
Field	1066.27	36	0.03
Coniferous forest	1623.70	261	0.16
Broadleaved forest	1095.26	567	0.52
Other	106.23	7	0.06
Pasture	554.06	111	0.20
Total	4445.52	982	0.20

The heritage oaks found in the Häckeberga conservation area have a mean diameter of 96.6 centimetres, with the largest individuals exceeding 2 meters in diameter (Figure 9). Of all oaks found in the estate, 795 individuals have diameters above 80 centimetres, and are therefore accounted for by the THCV register. The remaining 187 oaks have other characteristics, which include them in the THCV register (see background chapter 2.1).

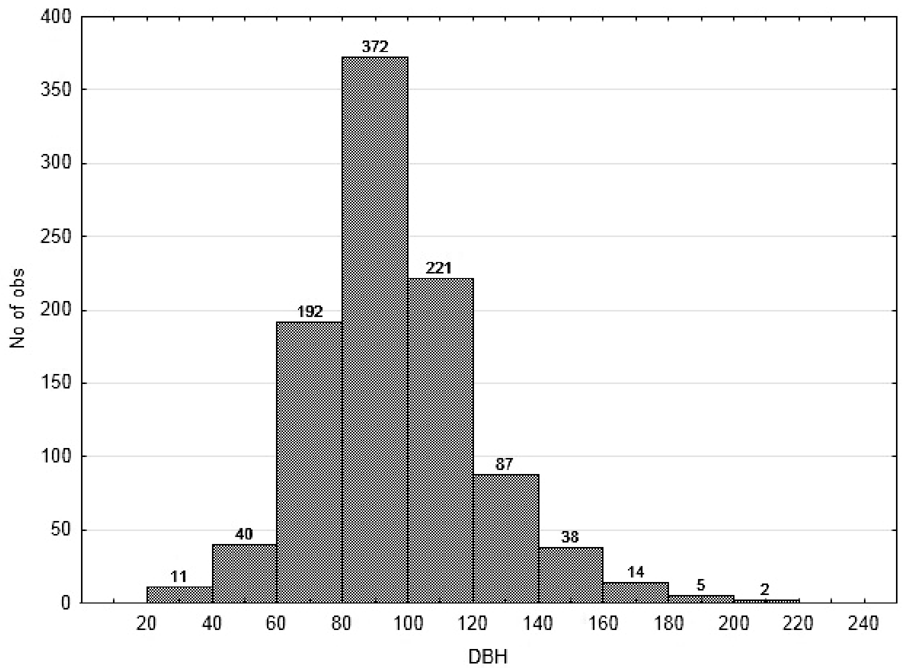


Figure 9 The histogram of the distribution of the DBH of the 982 heritage oaks within Häckeberga nature conservation area. Where number of observations are on the y-axis and DBH is on the x-axis

When assessed according to the land-uses within which the 982 heritage oaks are distributed, 57.7 percent are found within broadleaved forest, 26.6 percent within coniferous forest, and 11.3 percent in pastures. The remaining five percent of heritage oaks are distributed among fields and “other” (Table 3).

4.1.1 Management recommendations

A recommendation of treatment of vegetation adjacent to the heritage oaks has been assigned during the inventory in 2008. The treatment recommendations in 2 or 10 years apply mainly to heritage oaks in forest, with 93 percent of the prescribed treatments within this category (Table 3). The treatment in 2 years is assigned to 210 heritage oaks within broadleaved forest. This is 63 percent of the assigned treatments, but only 37 percent of heritage oaks within broadleaved forest. The 104 oaks assigned for treatments within coniferous forest constitute 31 percent of the total amount of heritage oaks assigned for treatment. However it is 40 percent of the heritage oaks within coniferous forest. Hence, after the first ten years the treatment should be applied to 69 percent of the heritage oaks growing within coniferous forest and 56 percent of the heritage oaks growing within broadleaved forest.

Table 3 The treatment recommendations registered during the inventory with termination in 2008.

	Land-use category					
Treatment	Field	Coniferous forest	Broadleaved forest	Other	Pasture	Total
In 2 years	3	104	210		16	333
In 10 years	3	75	108	1	15	202
No need	30	79	241	6	79	435
Free development			2			2
Not assessed		3	6		1	10
Total	36	261	567	7	111	982

4.1.2 Cavity

The majority of the 982 oaks do not possess a trunk cavity (54 percent), whereas a substantial number equals 46 percent have stem hollows according to the THCV registration. Of the oaks with hollows the largest group (22 percent) possess small cavities on the stem. 193 heritage oaks are found to have medium cavity (category 5 and 6) and only few of the heritages oaks have hollows of any size at the base of their trunk. Of the 451 heritage oaks possessing hollows within Häckeberga nature conservation area, 35 percent are found on the 9 percent of land designated as nature reserves.

The distribution of the hollow heritage oaks within the five different land-use categories reveals that 57 percent of the hollow oaks are in broadleaved forest, which amounts to 45.7 percent of all oaks in broadleaved forest having some cavity. The second largest share is found in coniferous forest, which amounts to 47 percent of the total number of oaks within coniferous forest containing cavity. The third largest share of hollow oaks is on pastures, and this amount to 42 percent of all oaks on pastures having some cavity. Only 4 percent of the hollow oaks are found within fields, however these hollow oaks amounts to 50 percent of all oaks found within fields.

4.1.3 Openness around the heritage oaks

The oaks within Häckeberga nature conservation area was also assigned into three groups "closed", "half open" and "open", assessing the characteristics of the openness surrounding the heritage oaks. The mean DBH of the group "closed" is 93.6 centimetres, the mean DBH of the group "half-open" is 95.0 and of the group "open" it is 104.3 (Figure 10).

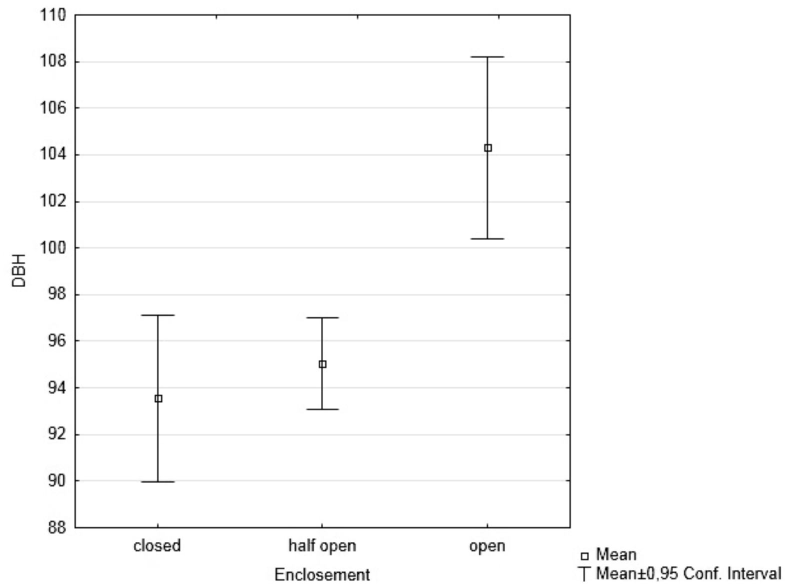


Figure 10 The box-plot is showing DBH on the y-axis distributed within the three different categories of enclosement on the x-axis. The square in the middle indicates the mean of the sample, the bars equals the 95% confidence interval (CI).

There is a significant difference between the mean DBH of the three different groups (F-value 12.08, df =2 and p = 0.0001). The differences are also significant when the group means are tested individually against each other, "closed" versus "open" p = 0.0001 and "open" versus "half open" p = 0.0007. However there is no significant difference between "closed" and "half open".

4.2 The adjacent landscape

4.2.1 Management objectives (Nature reserve)

The heritage oaks outside the nature reserves have a mean diameter of 99.5 centimetres, whereas the oaks inside the nature reserves have a mean diameter of 91.3 centimetres (Figure 11). There is a significant difference between the mean DBH of the oaks within and outside of the nature reserves (t-value = 4.82, df = 980 and p = 0.002)

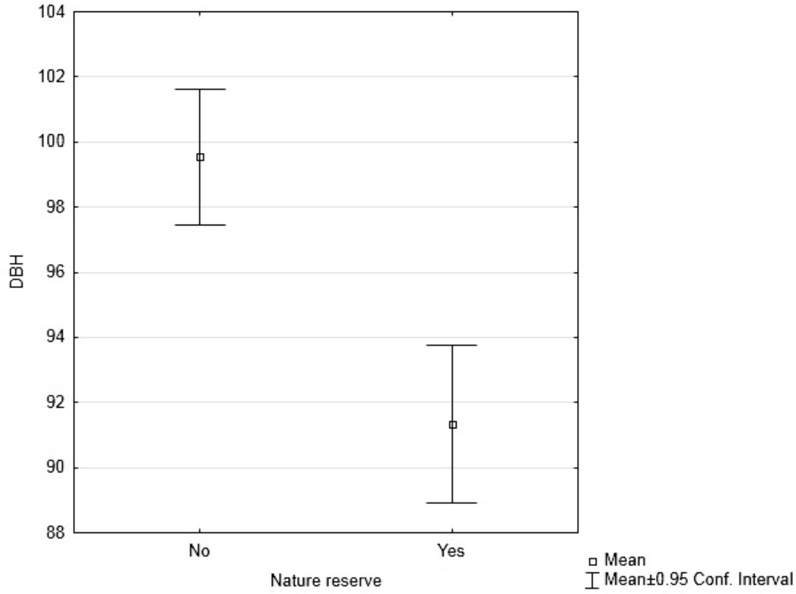


Figure 11 The distribution of the DBH (y-axis) of the oaks outside (no) as an oppose to inside (yes) the nature reserves (x-axis). The square in the middle indicates the mean of the sample, the bars equals the 95% confidence interval (CI).

We found that 35 percent of the heritage oaks occur within the three nature reserves. Thus, 9 percent of the Häckeberga conservation area contains 35 percent of the heritage oaks. Inside the nature reserves 98 percent of the heritage oaks are contained in the three main land-uses broadleaved forest, coniferous forest and pastures, with broadleaved forest supporting 68.3 percent of the heritage oaks.

Table 4 The amount of the 982 heritage oaks outside (no) and inside (yes) the nature reserves and under the five different land-use categories.

	Land-use					
Nature reserve	Fields	Coniferous forest	Broadleaved forest	Other	Pastures	Total
No	36	207	330	1	61	635
Yes		54	237	6	50	347
Total	36	261	567	7	111	982

4.2.2 Land-use

The mean DBH of the heritage oaks in the five different land-use categories spans from an average of 102.6 centimetres in fields over 97centimetres in the broadleaved forest, 96 centimetres in the coniferous forest to mean DBH of 95 centimetres in pastures (Figure 12).

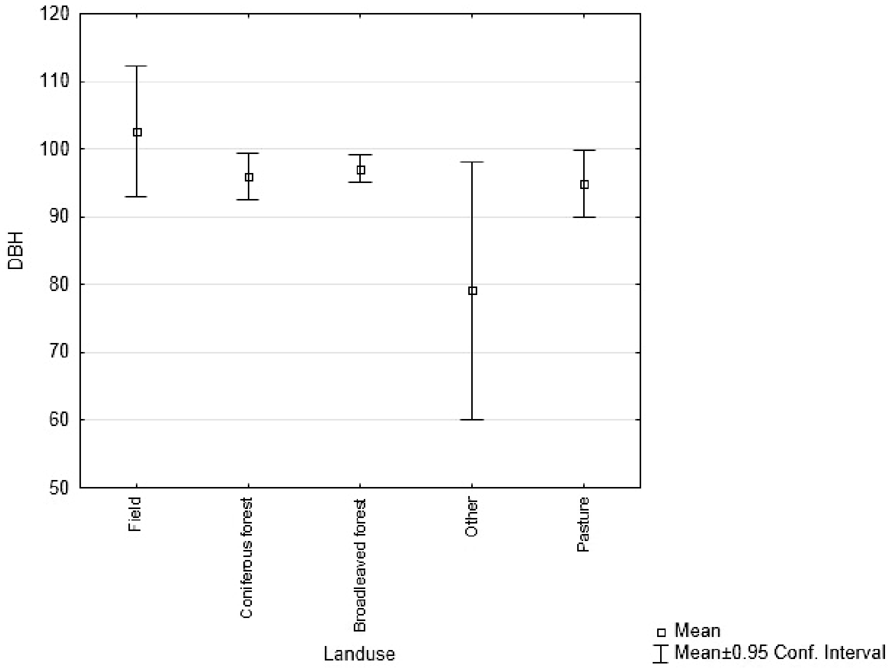


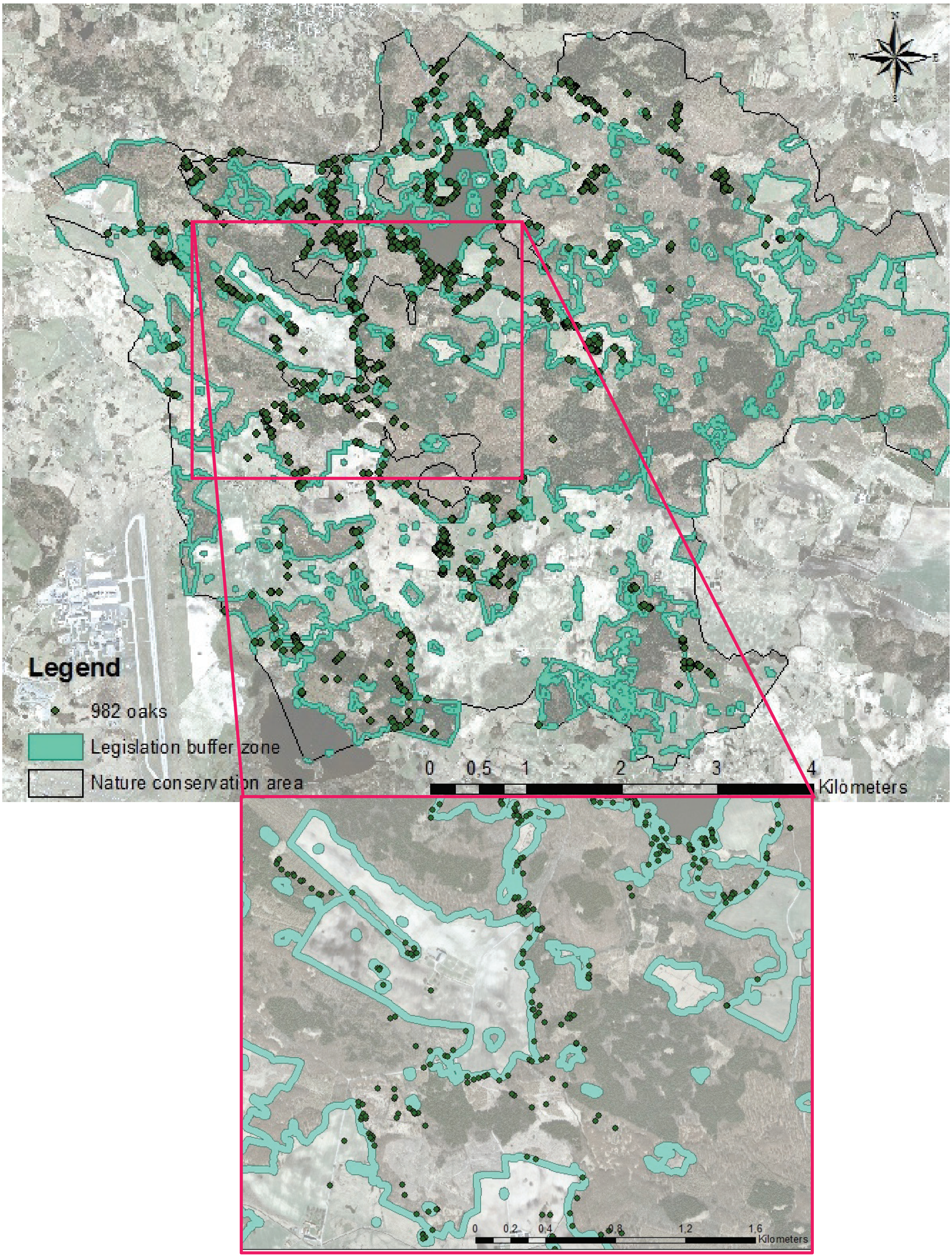
Figure 12 The distribution of DBH on the y-axis within the five different land-use categories on the x-axis. The square in the middle indicates the mean of the sample, the bars equals the 95% confidence interval (CI).

There are no significant difference between the mean DBH within the five different land-use categories (F-value = 1.51, df = 4 and p = 0.197, Figure 12).

4.2.3 The buffer zones

Buffer open land forest

The oaks within the 20-meter buffer zones between open land and forest have a spatial distribution as seen in Map 3. There are 536 heritage oaks are located within the 20-meter buffer zones between open land and forest within Häckeberga nature conservation area. This amounts to 55 percent of all heritage oaks found within the estate.



Map 3 The 20-meter buffer zones (ice-blue) between open land and forest made in GIS is seen in this map. The cutting is made to give a better impression of the interaction between the 20-meter buffer zone and the heritage oaks.

Buffer within forest

The 20-meter buffer zone between coniferous forest and broadleaved forest affects 11 percent of heritage oaks situated within forest, 12 percent of the oaks within broadleaved forest and 9 percent of oaks within coniferous forest (Table 5).

Table 5 The amount of heritage oaks outside (no) and inside (yes) the 20-meter buffer zone on the borders between coniferous forest and broadleaved forest.

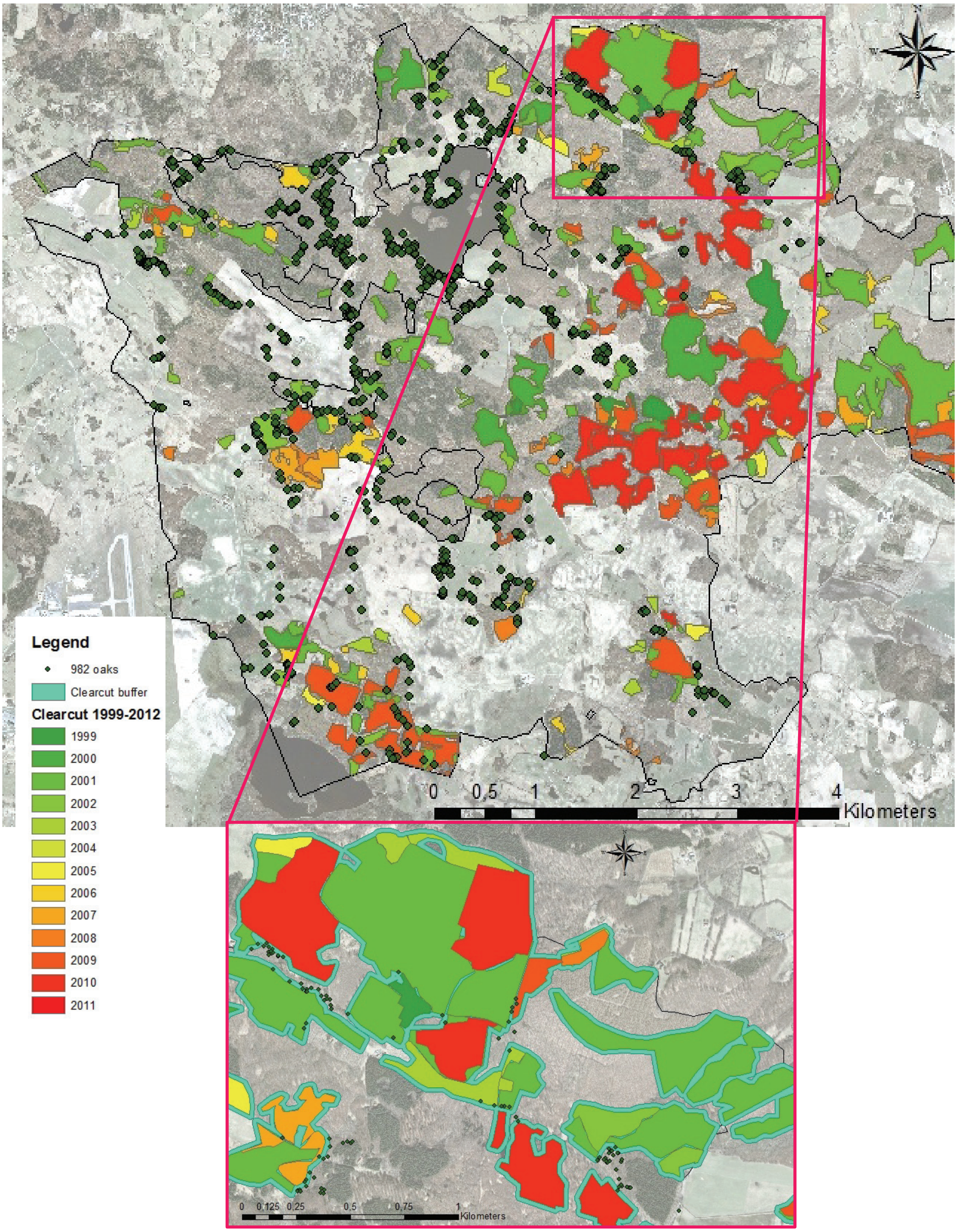
Forest buffer zone	Coniferous forest	Broadleaved forest	Total
No	237	498	735
Yes	24	69	93
Total	261	567	828

Buffer around areas subject to commercial harvest

There are 88 heritage oaks growing within the Häckeberga conservation area that were located within areas subject to commercial tree harvest from 1999 to 2012 (Map 4). 10.6 percent of these were located within areas designated as forest-land. In the 20-meter buffer zone outside the clearcuts there are an additional 88 heritage oaks. In total, this result in 18 percent of the heritage oaks either located within clearcut forest, or located proximate to clearcut forest over a period of 13 years.

Table 6 The proportion of heritage oaks outside (no) and inside (yes) of clearcut areas in the period 1999 to 2012 and the proportion of oaks outside (no) and inside (yes) the 20-meter buffer zone constructed outside the clearcut areas.

Nature reserve	Sum of oaks within clearcuts	Sum of oaks within 20-meter buffer zone of clearcuts
No	78	80
Yes	10	8
Total	88	88



Map 4 The clearcut areas from 1999 to 2012 are shown in this map. The colours indicates the timescale, where the red end of the colour scheme indicates the most recent harvested areas, whereas increasing time since harvest is indicated by the green. In the section we indicate the buffer zones of 20-meters around the clearcuts in ice-blue.

Summation of oaks within buffer zones

To summarise the attributes assigned by the assessment in GIS to the 982 heritage oaks and their surroundings an aggregation of the oaks surrounding attributes is made, hence the oaks are distributed in the 14 categories as seen Figure 13. These attributes include whether the heritage oak occurs within the 20-meter buffer zone between open land and forest, the 20-meter buffer zone between coniferous and broadleaved stands inside the forest, and the land-use categories. The analysis of the buffer zones reveals that one-third (327) of the heritage oaks are located in the 20-meter buffer zone between forest and open land within broadleaved forest. The second and third most common categories are heritage oaks located within broadleaved forest (not in buffer zone) (171) and coniferous forest (not in buffer zones) (156). 603 heritage oaks are within some kind of buffer, either between open land and forest or within forest land.

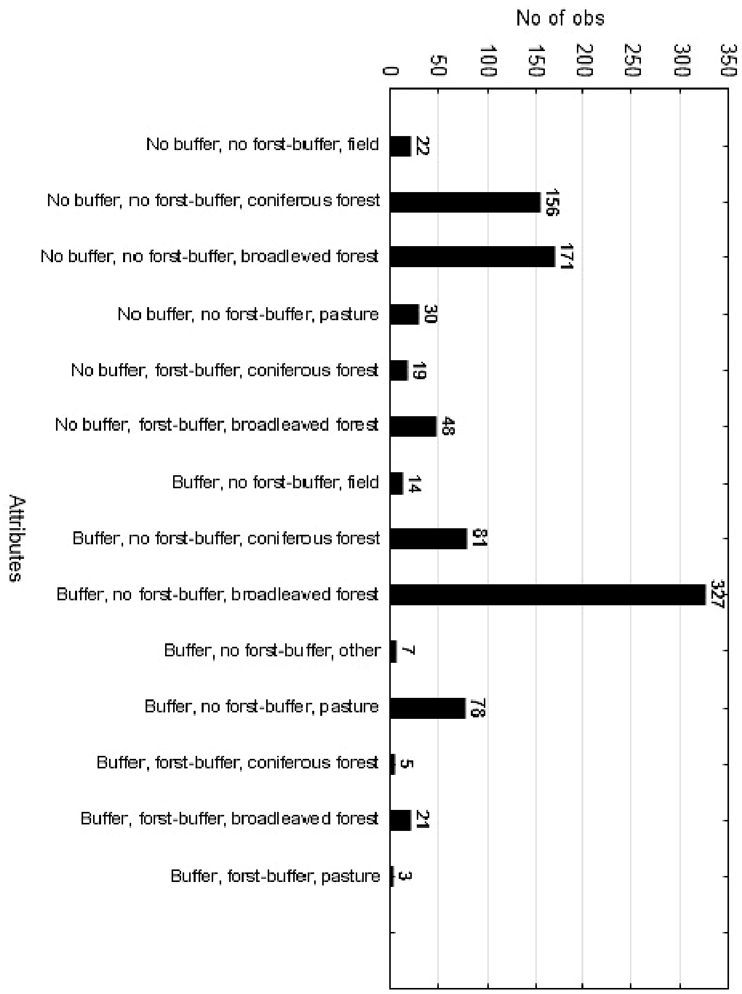
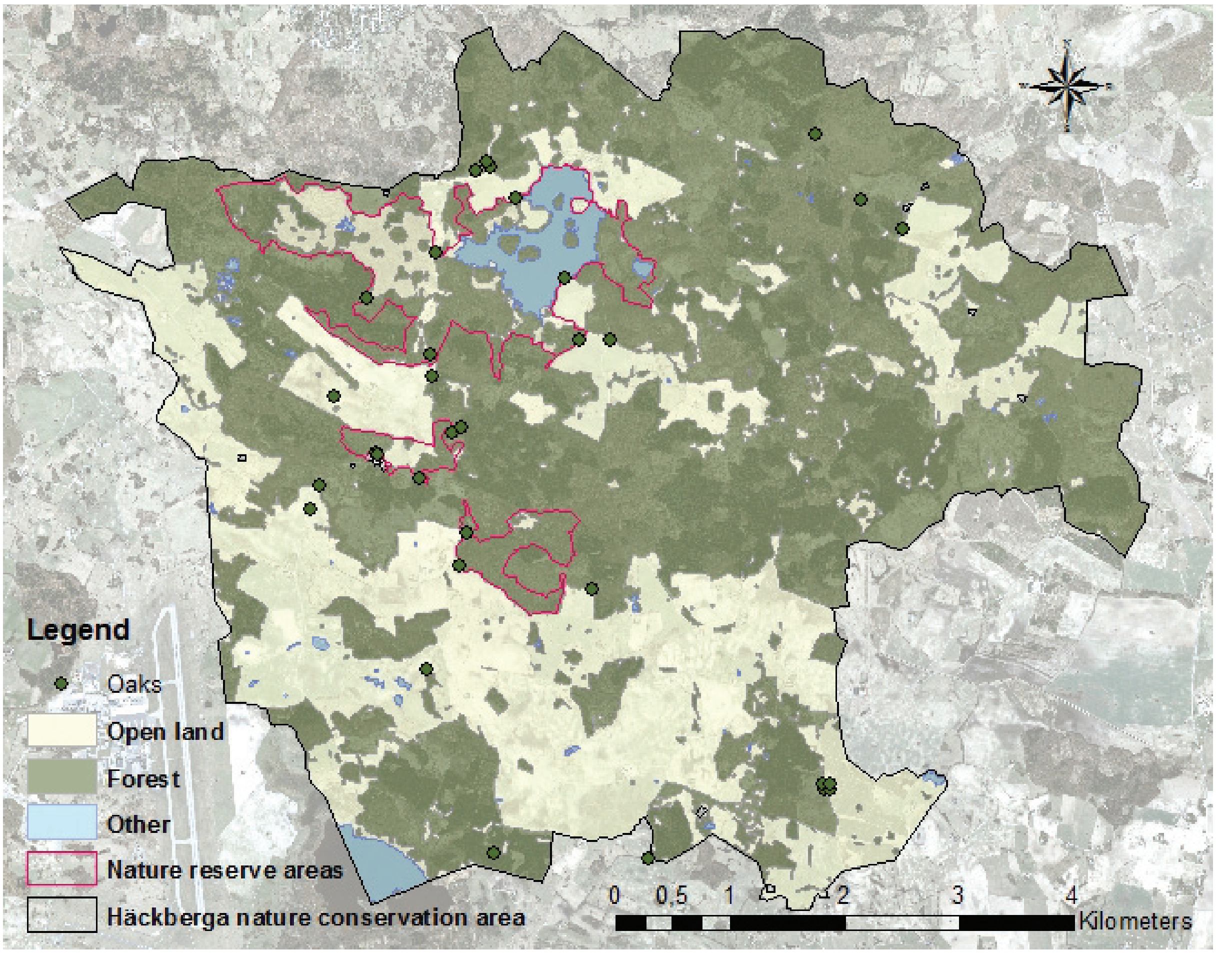


Figure 13 The 14 different categories made to accumulate the information obtained by the heritage oaks' surroundings. The y-axis is the number of observations and the x-axis shows the accumulated attributes: 1st the 20-meter buffer between open land and forest, 2nd the 20-meter buffer zone between coniferous and broadleaved forest, and 3rd the land-use category.

5 Results for the 32 heritage oaks

5.1 The 32 assessed oaks

The spatial distribution of the 32 investigated oaks is as seen in Map 5. When sorted in the two broad categories of forest versus open land, 26 of the heritage oaks grow within forest and 6 on fields and pastures.



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Map 5 The spatial distribution of the 32 investigated oaks in Häckeberga nature conservation area of 4445 hectares. The black line is the whole study area (Häckeberga nature conservation area) and the pink lines shows the three nature reserves; Skoggård, Degebergahus and Husarhagen. The map is also showing the three land-use categories: forest (dark green), open land (fields and pastures the sandy colour) and other (water is blue).

When sorted by land-use, the 32 assessed oaks are distributed as 53 percent within broadleaved forest, 28 percent within coniferous forest, 12.5 percent in fields and 6.5 percent in pastures. If totals are combined, broadleaved forest, coniferous forest and fields, contained 93.5 percent of the assessed oaks.

5.1.1 Management recommendations

A timeframe for completion of management recommendations was prescribed by the inventory staff in the inventory from 2008 (CAB, 2007). The evaluation of the 32 assessed heritage oaks in 2012 showed that only one of the 32 oaks was treated within the timeframe recommended. This oak was among the 17 oaks that should have received treated within two years after the completion of the inventory. This means that 5 percent of the oaks that should have been treated after the 2^{nd} years were treated by 2012, four years after termination of the inventory.

5.1.3 Enclosement

The examination of enclosure after the field inventory in 2012 reveals that 14 of the oaks are standing under half open conditions, 6 under closed conditions and 12 in open conditions. There is no significant difference between the mean area of living crown in the three groups (F-value = 1.19, df = 2 and p = 0.32), contradicting the mean DBH within the same enclosement groups seen in Figure 10. The mean are of living crown within the three different groups are 423 m² under open conditions, 312 m² under half open conditions and 409 m² under closed conditions.

5.1.4 Management objectives (Nature reserve)

31 percent of the investigated oaks are within nature reserves. The oaks inside the nature reserves have a mean diameter of 156.6 centimetres whereas the oaks outside nature reserves have a mean diameter of 164 centimetres, there is no significant difference between the two means (t-value = 1.17, df = 30 and p = 0.41) as seen in Figure 11.

5.1.5 Accuracy of land-use

A comparison between the land-use categories assigned to the 32 assessed oaks by GIS in 2012 and the assessment from the field inventory in May 2012 shows an overall accuracy of 69 percent with respect to the land-use within which they are found. The heritage oaks correctly included in the land-use categories by GIS, is most accurate for coniferous forest with 100 percent, then broadleaved forest with 79 percent, largest differences are found among fields where only 43 percent match and pastures with no matches (Table 7). Because of differences between the land-use categories assigned by GIS and the assigned land-use categories after the field inventory, the assigned land-use categories from the field inventory are used from here onwards.

Table 7 The correlation between the land-use categories assigned to the 32 assessed oaks by GIS is seen in the horizontal rows and the land-use assigned after the field inventory are the numbers in the vertical columns. The green numbers are the correctly assigned heritage oaks by GIS within the four land-use categories.

	Land-use assessed				
Land-use GIS	Field	Coniferous forest	Broadleaved forest	Pasture	Total
Field	**3**			1	4
Coniferous forest	1	**4**	3	1	9
Broadleaved forest	2		**15**		17
Pasture	1		1		2
Total	7	4	19	2	32

5.2 The structural characteristics of the 32 oaks

5.2.1 Crown assessments

The assessment of living crown (m²) as a function of DBH shows no tendency of a correlation between the two (Figure 14).

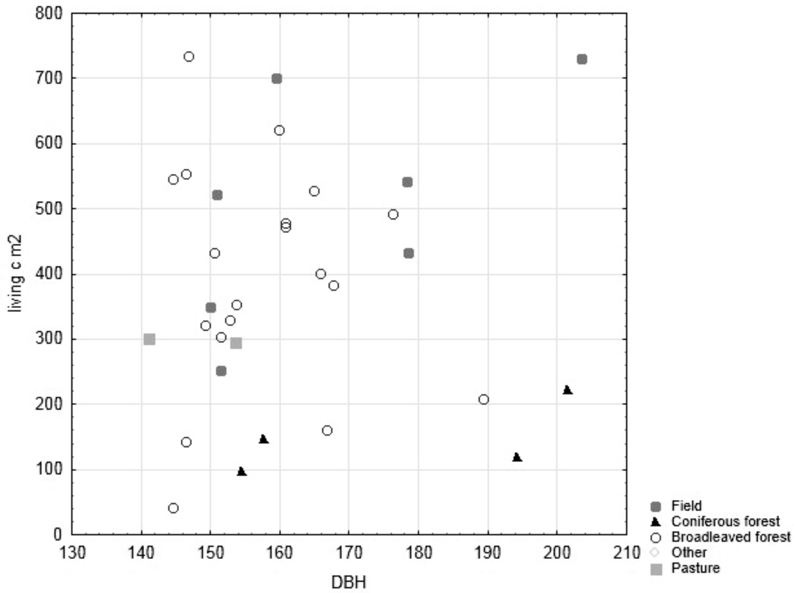

Figure 14 The scatterplot is showing the relationship between the living crown (m²) on the y-axis and DBH on the x-axis. The points has a symbols related to the adjacent land-use category of the oaks.

5.2.2 Living versus dead crown

The mean area of living crown is larger than the mean area of dead crown within three of the four different land-use categories (Figure 15). There is a significant difference between the mean area of living and dead crown within fields (t-value = 3,52, df = 12 and p=0.004), broadleaved forest (t-value

= 3.90, df 36 = 18 and p=0.0004) and there are no significant different between the mean area of living and dead crown in coniferous forest (t-value = 2.01 , df = 6 and p=0.091).

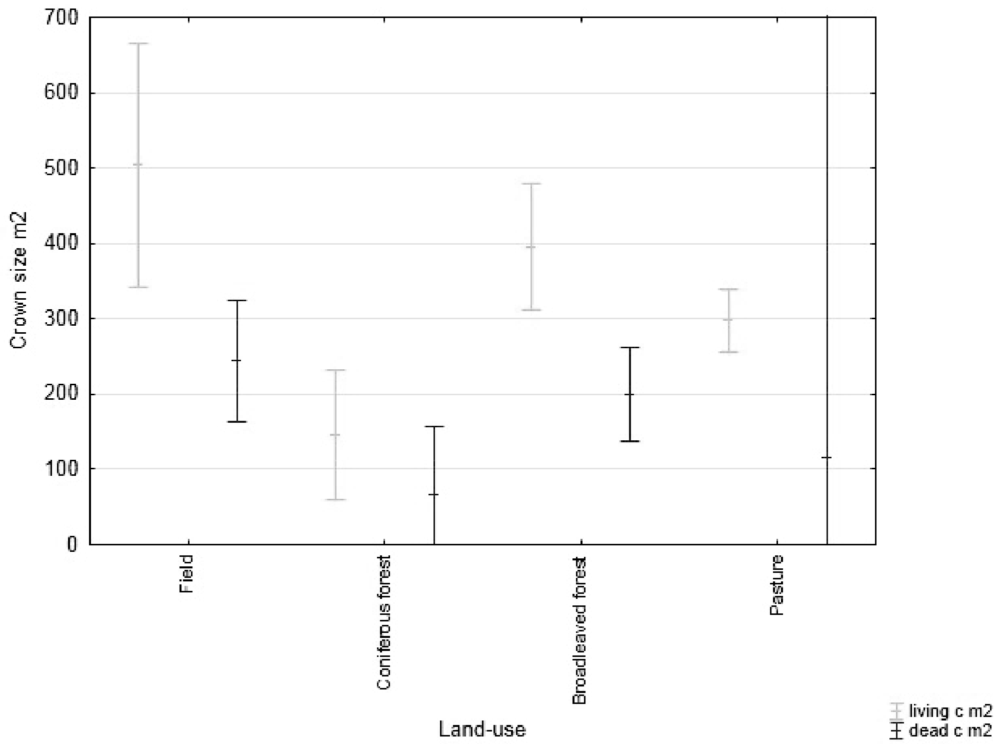

Figure 15 The distribution of area of crown (m²) on the y-axis under the four different land-use categories on the x-axis. Information related to the living crown is green and to the dead crown is brown. The line in the middle shows the mean of the sample, the bars show the 95% confidence interval (CI).

The ratio between living and dead crown (l/d) has been calculated to give an indication of competition between the heritage oaks and their surroundings. Where the ratio l/d > 1 there is assumed no competition with adjacent vegetation and when the ratio l/d < 1 there is a decrease in crown size or a possible increase in competition with the surrounding vegetation.

The ratio between area of living and dead crown has no clear correlation with the ratio between living and dead crown height (Figure 16)

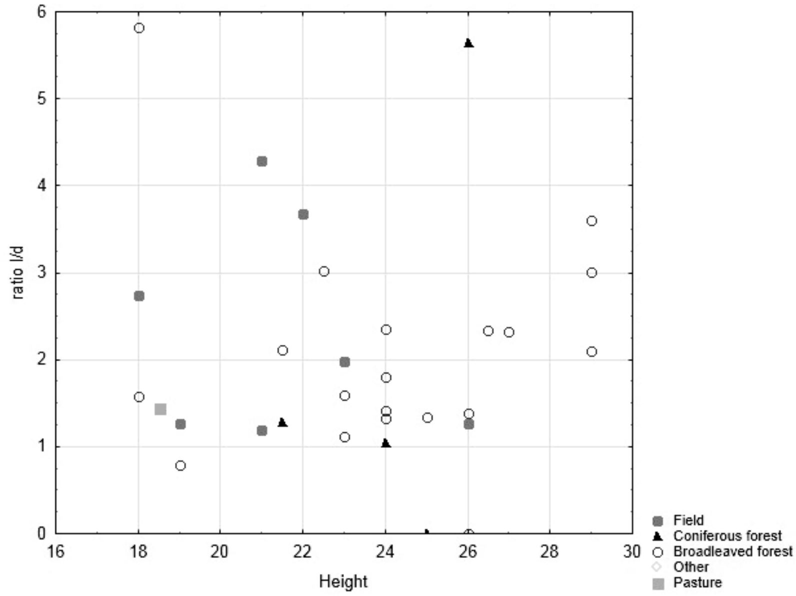

Figure 16 The relation between the ratio living and dead crown on the y-axis and the heights of the heritage oaks on the x-axis. The points has a symbols related to the adjacent land-use category of the oaks. An outlier (coordinates 6158636;1352271) is not included as its extreme ratio between living and dead crown of 14.13 disturbed the general picture.

There seems to be a coherence between the ratio of living and dead crown as a function of basal area (m^2/ha) (Figure 17). Here basal area represents the forest density in the half circle south of the investigated oaks.

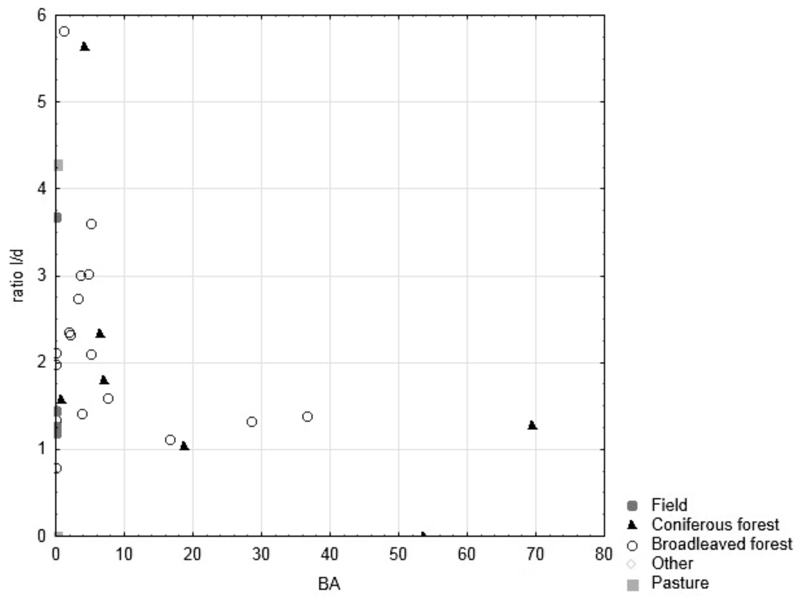

Figure 17 The relation between the ratio living and dead crown on the y-axis compared with the basal area (x-axis) in the half circle south of the 32 heritage oaks points has a symbols related to the adjacent land-use category of the oaks. An outlier (coordinates 6158636;1352271) is not included as its extreme ratio between living and dead crown of 14.13 disturbed the general picture.

5.2.3 Land-use

The mean diameter of the 32 assessed oaks is 161.6 centimetres. Within the four different land-use categories the DBH spans from 176 centimetres in coniferous forest over 167 centimetres on fields to 158 centimetres in the broadleaved forest. There are only two observations for oaks within pastures and they are not included in the following assessment (Figure 18). There is no significant difference between the mean DBH within the four different land-use groups (F-value = 2.51, df = 3 and p= 0.079).

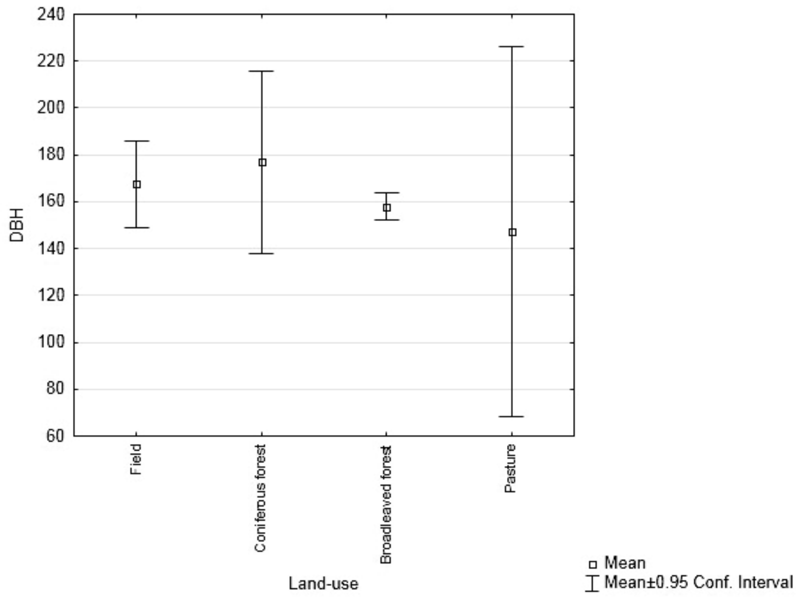

Figure 18 The distribution of DBH on the y-axis under the four different land-use categories on the x-axis. The square in the middle indicates the mean of the sample, the bars equals the 95% confidence interval (CI).

Contradicting to DBH the examination of area of living crown (m²) reveals large differences within the four different land-use categories. The overall mean of area of living crown is 382 m². The largest crowns are found among oaks on field with mean crown area above 500 m². The intermediate crowns are found in broadleaved forest with means around 400 m². The lowest mean area of living crown (below 150 m²) is found among oaks growing within coniferous forest (Figure 19). There is a significant difference between the groups when tested by ANOVA (F-value = 4.29, df = 3 and p = 0.013). When the mean between the groups are tested individually the Tukey-test reveals that the difference is between oaks within fields and those within coniferous forest (p = 0.02).

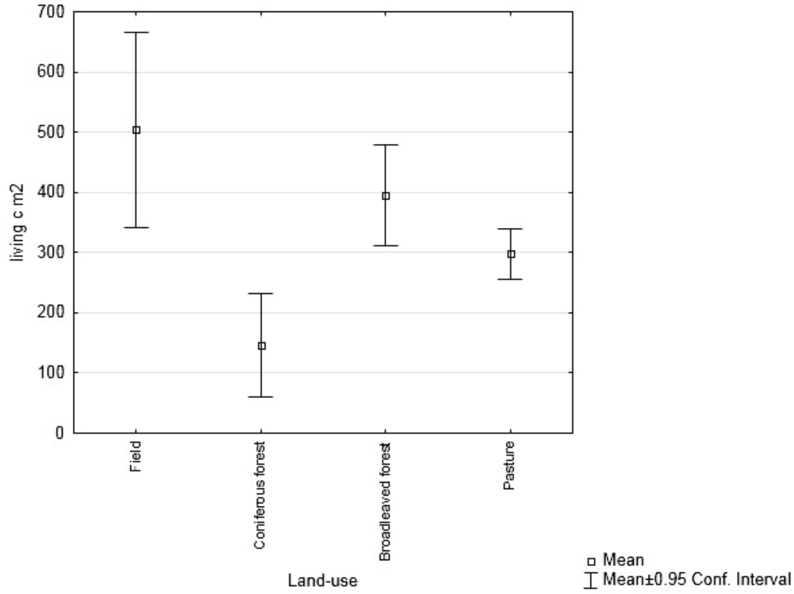

Figure 19 The distribution of living crown (m²) on the y-axis under four different land-use categories on the x-axis. The square in the middle indicates the mean of the sample, the bars equals the 95% confidence interval (CI).

5.2.4 Buffer zones

The oaks within the 20-meter buffer zone between open land and forest reveals no significant different in mean area of living crown compared to the oaks outside the buffer zone (t-value = -0.08, df = 30 and p= 0.89). The mean area of living crown is 378 m² for oaks not within the 20-meter buffer zone and 384 m² for heritage oaks within the 20-meter buffer zone.

A calculation of the mean area of living crown (m²) of the 32 assessed oaks inside and outside the 20-meter buffer zone assigned to the legislative borders between open land and forest divided into the four land-use categories reveals that the area of living crown (m²) is larger for oaks which are not in the edge zone (Table 8). Though it is not applicable for oaks inside coniferous forest, where the mean area of living crown is equally proportioned whether in a buffer zone or not.

Table 8 A comparison of mean area of living crown (m²) outside (no) and inside (yes) the 20-meter buffer zone between open land and forest related to the four different land-use categories.

	Land-use category				
Buffer zone	Field	Coniferous forest	Broadleaved forest	Pasture	Mean
No	533.57	146.35	429.49	301.59	352.75
Yes	481.82	146.37	379.26	294.97	325.61
Mean	507.70	146.36	404.37	298.28	339.18

5.2.5 The last 70 years

A comparison of the land-use adjacent to the 32 assessed oaks in the 1940s and in 2012 by visual assessment was made using aerial photos and orthophotos. The result reveals that 22 of the oaks in the 1940s were under completely open conditions both towards south and north. Eight oaks were under half open conditions and only one oak was completely within closed conditions (Table 9).

Table 9 The different heritage oaks and their adjacent land-use category. The table shows the results of the visual assessment of the 32 and their adjacent landscape in the 1940s and 2012.

	South				North				Chan-ges south
Oak no.	1940		2012		1940		2012		
718	Pasture	*Open*	Field	*Open*	Field	*Open*	Broadleaves	*Open*	yes
9	Pasture	*Open*	Conifers	*Open*	Pasture	*Open*	Conifers	*Closed*	yes
10	Pasture	*Open*	Conifers	*Closed*	Pasture	*Open*	Conifers	*Closed*	yes
277	Pasture	*Open*	Broadleaves	*Closed*	Field	*Open*	Broadleaves	*Closed*	yes
932	Pasture	*Open*	Broadleaves	*Closed*	Field	*Open*	Broadleaves	*Closed*	yes
840	Pasture	*Open*	Broadleaves	*Open*	Pasture	*Open*	Broadleaves	*Closed*	yes
182	Pasture	*Open*	Broadleaves	*Closed*	Broadleaves	*Closed*	Broadleaves	*Closed*	yes
88	Field	*Open*	Pasture	*Open*	Broadleaves	*Closed*	Conifers	*Closed*	yes
775	Field	*Open*	Pasture	*Open*	Field	*Open*	Pasture	*Open*	yes
167	Field	*Open*	Conifers	*Open*	Broadleaves	*Closed*	Broadleaves	*Closed*	yes
554	Field	*Open*	Broadleaves	*Open*	Field	*Open*	Pasture	*Open*	yes
553	Field	*Open*	Broadleaves	*Open*	Field	*Open*	Pasture	*Open*	yes
898	Field	*Open*	Broadleaves	*Open*	Field	*Open*	Broadleaves	*Closed*	yes
62	Field	*Open*	Broadleaves	*Closed*	Field	*Open*	Pasture	*Open*	yes
721	Field	*Open*	Broadleaves	*Closed*	Field	*Open*	Pasture	*Open*	yes
115	Pasture	*Open*	Pasture	*Open*	Other	*Open*	Broadleaves	*Closed*	no
206	Pasture	*Open*	Pasture	*Open*	Broadleaves	*Closed*	Broadleaves	*Closed*	no
328	Pasture	*Open*	Pasture	*Open*	Pasture	*Open*	Field	*Open*	no
576	Pasture	*Open*	Pasture	*Open*	Pasture	*Open*	Field	*Open*	no
107	Other	*Open*	Other	*Open*	Pasture	*Open*	Broadleaves	*Closed*	no
961	Other	*Open*	Other	*Open*	Pasture	*Open*	Broadleaves	*Closed*	no
728	Field	*Open*	Field	*Open*	Field	*Open*	Field	*Open*	no
768	Field	*Open*	Field	*Open*	Field	*Open*	Field	*Open*	no
766	Field	*Open*	Field	*Open*	Field	*Open*	Field	*Open*	no
288	Field	*Open*	Field	*Open*	Other	*Open*	Other	*Open*	no
755	Field	*Open*	Field	*Open*	Field	*Open*	Field	*Open*	no
79	Field	*Open*	Field	*Open*	Broadleaves	*Closed*	Broadleaves	*Closed*	no
756	Field	*Open*	Field	*Open*	Field	*Open*	Field	*Open*	no
310	Conifers	*Closed*	Conifers	*Closed*	Broadleaves	*Closed*	Broadleaves	*Closed*	no
260	Broadleaves	*Closed*	Broadleaves	*Closed*	Pasture	*Open*	Broadleaves	*Closed*	no
259	Broadleaves	*Closed*	Broadleaves	*Closed*	Pasture	*Open*	Broadleaves	*Closed*	no
119	Broadleaves	*Closed*	Broadleaves	*Closed*	Pasture	*Open*	Broadleaves	*Open*	no

In 2012, 12 of the oaks are still under completely open conditions. 13 oaks were under half open conditions and the amount of oaks completely enclosed amounts to seven. 12 oaks have remained under open conditions during the 70-year period.

The closed canopy adjacent to the assessed oaks in the two directions south and north have increased from four enclosed oaks in the 1940s to 10 in 2012, and towards north it has increased from six in the 1940s to 17 in 2012.

South of the oaks 11 areas with were pastures have decreased to four, and the remaining have respectively changed to two coniferous forest, four broadleaved forest and one has changed into a field. Within fields seven out of 15 fields have remained fields from the 1940s to 2012. The rest have respectively changed to five broadleaved forest, two have changed into pastures and one has changed into coniferous forest. On the north-facing side the land-use has also changed within pastures, where the ten oaks on pastures in the 1940s have changed completely into 6 in broadleaved forest, and two in both coniferous forest and on fields. Likewise to the south the changes within fields, where the 14 oaks on fields have decreased to five and the rest are now respectively five in pastures and four within broadleaved forest (Table 9).

6 Discussion

The aim of this study was to use Häckeberga nature conservation area to assess how short- to long-term changes in land-use and conservation status have affected health and biodiversity indices for heritage oaks. Our results indicate that the largest oaks within Häckeberga nature conservation area are not currently receiving adequate management interventions to ensure their future health and their important role as habitats for associated species. This view is based on five important findings. First, government recommended actions to ensure the long-term health and continued role of heritage oaks as vital habitats for biodiversity are not taking place. Second, the largest heritage oaks are not found within land-uses providing the optimal protective status. Third we found that the area of living crown is closely related to the adjacent land-use category, and the density of forest south of the heritage oaks. The land-use category capturing the heritage oaks with the smallest area of living crown is coniferous forest. Fourth we found that the adjacent landscape of the heritage oaks has changed the past 70 years, and that the heritage oaks of 2012 are more enclosed in other vegetation then they were during the 1940s. Fifth, with respect to biodiversity indicators, increased forest cover surrounding the heritage oaks means a lower insolation on the coarse bark and a higher competition for light for the shade-intolerant oaks. The overall density of heritage oaks within Häckeberga nature conservation area can support high species richness. Cavity as another measure of importance for biodiversity is possessed by nearly half of the heritage oaks. We discuss each of these contributing factors in turn.

6.1 Assessment of the THCV implementation

The treatment and protection of the heritage oaks hold a share in fulfilling the 16 environmental quality objectives of Sweden. The heritage oaks within Häckeberga conservation area have been recommended for treatment of adjacent vegetation by the County Administrative Board of Skåne. The treatment recommendations for the heritage oaks were prescribed during a field inventory between 2005 and 2008. The first treatments should have been carried out within the first two years following the inventory completion. In 2012, four years after termination of the THCV registration, only 5 percent of the 32 heritage oaks investigated by ourselves, and designated as requiring treatment, had received treatment. We emphasize that our assessment involved the largest heritage oaks in the study area, and thus represents those heritage oaks which could conceivably be the starting place for any restorative actions. As such our results may in fact give an inflated picture of actions taken. Nevertheless, assuming that the largest heritage oaks status is indicative of the total, this indicates that for all of the Häckeberga nature conservation area only 17 heritage oaks may have received treatment relative to the 333 heritage oaks for which treatment have been recommended (Table 3). The findings are in contrast with the THCV action plan for which 60 percent of the heritage trees should have benefited from protection status by 2008, with this result improving to 80 percent by 2014 (Höjer and Hultengren, 2004). The action plan from the Swedish Environmental Protection Agency applies to Sweden in general, but within our area of concern the action plan does not seem to be sufficiently implemented, and it is clear that the recommendations have not been followed.

6.2 The adjacent landscape

6.2.1 Analysis of the THCV register

Our analysis of the THCV register revealed that the DBH of the heritage oaks within protected areas (nature reserves) have a significantly lower DBH then the oaks which are outside of the nature reserves (Figure 11). This means that the current approach of reserve selection is not targeted to protect the oaks within Häckeberga nature conservation area of the greatest heritage value. One explanation of the low mean DBH inside nature reserves could be that the areas designated for protection status are concentrated on protecting forested areas. For example, 60 percent of the protected area in Hackeberga consists of forest (Figure 2). This apparent preference for the protection of forested areas may select for the inclusion of oaks less likely to achieve their full growth potential due to competition for resources with the surrounding vegetation. The management plans hosted by the County Administrative Board of Skåne expands the area of beech on behalf of the areas with oak, even though there is put emphasis on protection of biodiversity, and beetles related to oaks are found in all the reserve areas (Tham et al., 2008a, Tham et al., 2008c, Tham et al., 2008b). The future sustainable protection of the associated species is dependent on the maintenance of suitable habitats (heritage oaks and their surroundings), hence the responsible authorities are aware of the existents of species associated with heritage oaks, whereby the protection of heritage oaks within the reserves should be insured by the objectives of the nature reserves.

6.2.2 Crown assessments

The DBH is only one metric for assessing the health and potential biodiversity value of a heritage oak. The crown area, and associated area of living crown, is an important additional measure that complements the use of DBH. For example, a study by Skarpaas, et al. (2011) assessing models for the capacity of different indices to predict habitat quality, concludes that an important factor for species richness within heritage oaks in forests is the vitality and area of the crown. As such, one aim of the field component of our study was designed to use the crown area, and the calculated ratio between the area of living crown divided by area of dead crown, to be used as an indicator of competition between the heritage oaks and the adjacent vegetation. The intention was that such metrics would be indicative of differences in level of competition for the oak with the surrounding vegetation. We found that the largest mean crown areas are found on oaks within fields, and the smallest area of living crown, is found among heritage oaks growing in coniferous forest (Figure 14). Furthermore, the mean area of living crown was significantly larger than the area of dead crown, except for those oaks growing within coniferous forest (Figure 15). The results from this study were not entirely consistent, however there seems to be a decreasing ratio between area of living and dead crown with increasing forest density south of the heritage oaks (Figure 17). Our results may indicate that the heritage oaks within coniferous forest have a restricted area of living crown due to both their possession of a small crown and a higher percentage of dead tissue (Figure 15, but note the sample size). Other factors than crown competition not included in this assessment could however reduce the area of living crown. This could be the results of soil compression from heavy machinery in fields within stands, or the operations resulting in cutting off fine-roots.

6.2.3 Openness around the heritage oaks

An assessment of the mean DBH of heritage oaks within open, half open and closed conditions was made and it revealed that there was a significant difference between the DBH of the oaks standing under open conditions compared to the two other categories (Figure 10). However an assessment of the area of living crown within the three categories "open", "half open" and "closed" showed no significant difference between the mean area of living crown in the three categories. Our expectation was that because of oaks being a shade intolerant species (CAB International 2010) there would have been a significant difference between the mean area of living crown in the three categories. Our expectations were that the oaks under open conditions would have the largest area of living crown followed by the two other groups. Regarding the last two groups there is a tendency as seen in Table 8 that the heritage oaks under the land-use categories field and broadleaved forest have smaller areas of living crown when growing in the edge zone (half open) than within a stand (closed) or on an open field (open). A combination of our findings may indicate that the competition within the edge zone is so high that it is not beneficial to rely only on the edge zone as future habitats for heritage oaks. Our results also indicate that there is a need for further research within this field.

6.2.4 The heritage oaks within clearcut areas

Some oaks are located within regions where abrupt disturbances in surrounding land-use appear because they are area subject to commercial harvesting for timber. The last 13 years 88 oaks are within these areas, representing 10.6 percent of the oaks within forest land. However, by analysis in GIS, where a 20-meter buffer zone was applied outside all clearcut areas, it is found that additionally 88 heritage oaks are likely affected by clearcuts due to their close proximity (Table 6). The potential affected by growing within or near clearcut area is based on the associated changes due to an increase in sun and wind exposure, and a decrease in humidity. Also the working procedures within these areas can affect the oaks because of soil compression of heavy machinery, and the effect that soil preparation can have on the fine-roots of the remaining trees. This reveals that within 13 years, the timeframe of available data of clearcut areas (Swedish Forest Agency, 2012b), 18 percent of the heritage oaks located on forest land are likely affected by commercial harvesting for timber. Hence twice the amount of heritage oaks is revealed by GIS analysis, than by only matching the data from the Swedish Environmental Protection Agency with the data on clearcut areas from the Swedish Forest Agency (2012b), as impacted by commercial harvesting in adjacent areas. However to fully understand the impact of commercial timber harvest on the heritage oaks further studies are required.

6.3 Changes in the adjacent landscape

6.3.1 Openness the past 70 years

The changes in the land-use categories adjacent to the 32 assessed oaks were detected by visual assessment of aerial photos and orthophotos (a satellite (or space) image of the Earth surface geographically referenced so that it possesses the same accuracy of spacing as a map). The assessment revealed an increas from 3 to 18 percent in heritage oaks growing within closed forest from the 1940s to 2012 (Table 9). The amount of heritage oaks growing under completely open conditions has decreased from 72 percent in the 1940s to 38 percent in 2012. The changes have caused more than half of the heritage oaks to growing on land consisting of secondary forest. In the future, assuming the current trajectory persists, the proportion of enclosed oaks will increase within Häckeberga nature conservation area (own observations). Furthermore, 43 percent of the heritage oaks have experienced a change in land-use immediately south of their stem during the past 70 years. More than half of the heritage oaks have a changed land-use category towards north. The combination of the findings of the changes during the past 70 years, and the assessment of the half circle south of the 32 assessed oaks, revealed that an increasing forest density south of the heritage oaks will likely result in a decreasing area of the oaks' living crown and a decreasing ratio between area of living and dead crown (Figure 16) in the future. Nevertheless further studies are required to fully understand the impact that changes in land-use the past 70 years have on biodiversity and the crown development of the heritage oaks.

6.3.2 Oaks within buffer zones

Within Häckeberga nature conservation area 61 percent of all heritage oaks are within one of the two buffer zone categories (between open land and forest or between coniferous- and broadleaved forest)(Figure 13). This result may be indicative of these heritage oaks formerly being located between previous land-use categories, like fields and pastures. If so, then this would also indicate the large proportion of the heritage oaks which were formerly situated under conditions favourable to free development. The assessment of the oaks within the 20-meter forest buffer zone between coniferous- and broadleaved forest reveals that most of the oaks located within forest are found to be situated completely within the stand and not in the forest buffer zone (Table 5). The amount of oaks within both of the two buffer zones can be influenced by a shortcoming of the assessments in GIS. When there is coniferous- or broadleaved forest on both sides of a former edge, this will not be detected as an edge by the GIS analysis of land-use maps (Figure 20). The oaks will not be detected in the buffer zone analysis from 2012, because the forest edges have changed (see ice-blue circles Figure 20) compared to the map from 2009 where the oaks were edge trees. Hence these heritage oaks are not accounted in the buffer zones by the analysis we have made in GIS. Whereby the amount of heritage oaks which were formerly between fields and pastures could be higher than the number we have received by our analysis.

The findings by Björsen and Bradshaw (1998), that a large proportion of heritage oaks are today within land transformed from pastures to coniferous plantations, is not supported neither in the analysis of buffer zones nor by the visual assessment of the changes in land-use categories. An explanation for the low amount of heritage oaks within coniferous forest can be a result of the study area being in south Sweden where broadleaved forest is more common (see introduction chapter 1.1 History of land-use). The assessment of the changes the past 70 years (Table 9) reveals that 13 percent of the areas have changed into coniferous forest whereas 44 percent have changed into broadleaved forest. On the other hand an interpretation of the relatively high density of heritage oaks (Table 2) with large DBH within coniferous forest (Figure 12) could be an indication of the expansion of coniferous plantations on former pastures. This compared to the findings of the relatively small area of living crow on heritage oaks within coniferous forest (Figure 14 and Figure 19) adds to the attention that should be made to the treatment recommendations prescribed in the THCV register.

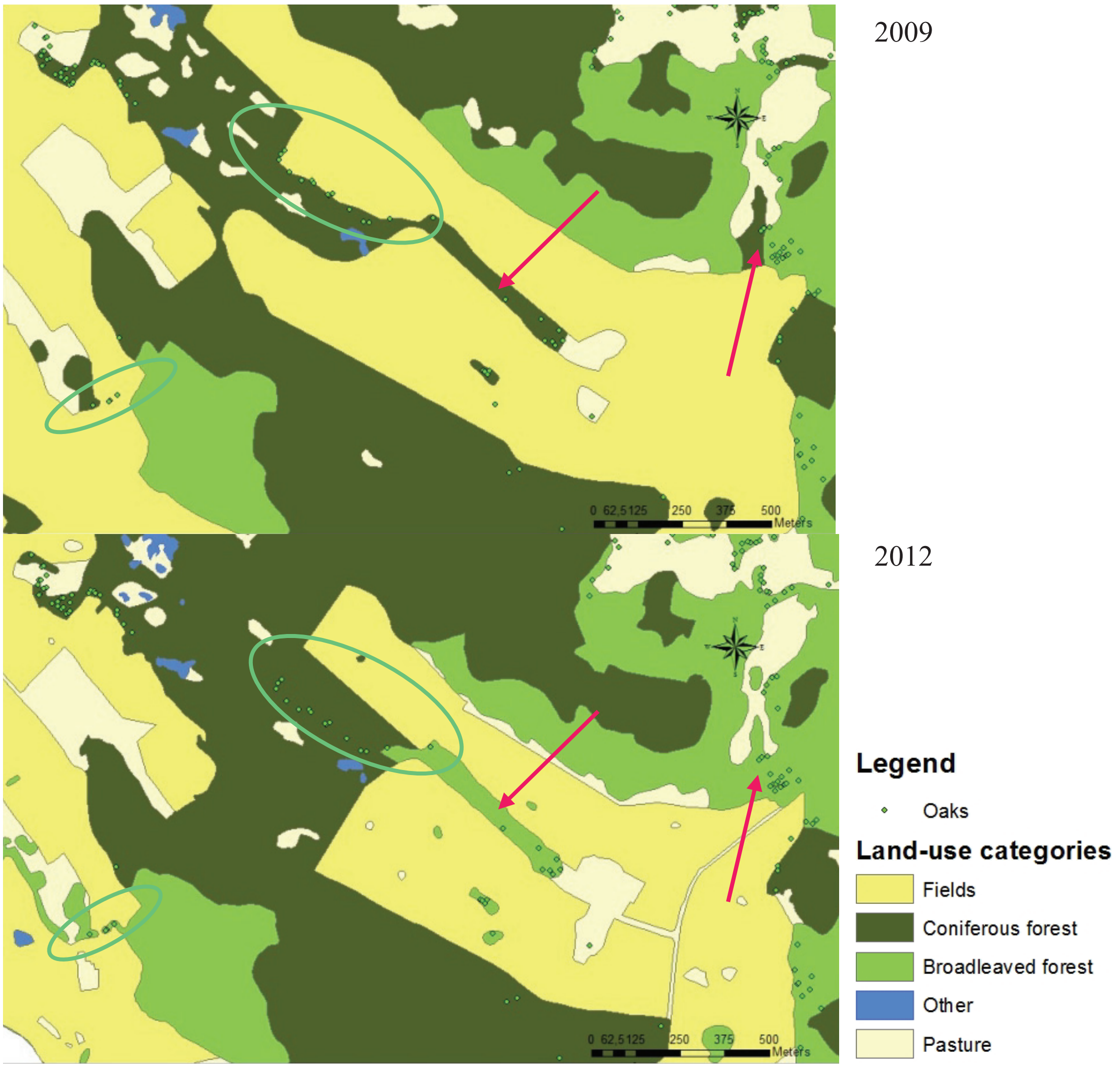

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Figure 20 The figure provides evidence of the oaks which are not included by the analysis in GIS. The top land-use maps are the one from 2009 and in the bottom one is from 2012. This reveals one of the areas where GIS has a drawback in our analysis. The ice-blue circles is indicating where there is new edge zones, and the pink arrows is indicating some of the places with changed land-use categosies.

The examination of the land-use adjacent to the heritage oaks indicates that the whole landscape matrix has been subject to large changes in a short time (seen in the life-span of the oaks). The finding that there is no significant difference between the mean diameters within the five different land-use categories (Figure 12) is possibly indicative of this more homogeneous open landscape matrix surrounding the heritage oaks in the past.

6.4 Biodiversity

6.4.1 Density and cavity of heritage oaks

The occurrence of possible habitats within a landscape is important for the dispersal of different species, whereby it is also important that the density of heritage oaks is high enough for the requirement of associated species (Ranius et al., 2011). At a landscape scale the overall density of oaks within Häckeberga conservation area is 0.2 oaks ha^{-1} (Table 2) which is above the density ensuring species richness investigated by Bergman et al. (2012). Notably, the density varies across areas with different land-use categories. The highest density of oaks is found within broadleaved forest with 0.5 oaks ha^{-1} (Table 2) and the lowest density is found within fields (0.03 oaks ha^{-1}).

The oaks within field encompass most of the features regarded as positive for biodiversity (Koch Wiederberg et al., in press, Bergman et al., 2012). The oaks within the field matrix have the largest mean DBH (102.6 cm, Figure 12) and the open conditions secure a high level of bark insolation. Half of the oaks growing on fields possess some kind of cavity, and these heritage oaks should be important habitats for their associated biodiversity. One limiting factor for the importance of heritage oaks within the field matrix may be their isolation. The results by both Ranius et al. (2011) and Bergman et al. (2012) indicate that their spatial distribution and distance to other oaks may reduce the number of species capable of dispersing to them.

Density provides an index of the capacity of a population of oaks to support biodiversity possessing varying degrees of dispersal capacity (Ranius et al., 2011). Likewise, at the level of the individual oak, certain keystone structures provide an indication as to the value that each tree has for biodiversity. In the THCV register one biodiversity measure of note are the presence and attributes of cavities. Cavities are used as indicators of the heritage oaks' value in terms of being a habitat for red-listed and other species. A little less than half (46 percent) of the heritage oaks within Häckeberga nature conservation area possess hollows, categorized by different stages of decay. Research made by Sverdrup-Thygson, et al. (2010) and by Skarpaas, et al. (2011) indicate that the oaks with medium cavities are the ones capturing the highest richness of associated species. This means that within Häckeberga nature conservation area 20 percent of all oaks possess the cavity most important for biodiversity. The future of important habitats related to hollow heritage oaks could be secured because of the largest share of oaks possessing hollows are the once possessing small cavities, hence there is future candidates for long-lasting habitats possessing medium sized hollows.

6.5 Conservation strategies and management plans

The management plans for the nature reserves within Häckeberga nature conservation area are hosted by the County Administrative Board of Skåne. The aims of the management plans are to retain broadleaved forest and maintain habitats for a broad range of species, done by protecting natural and cultural values characterised by noble broadleaved forest with varying age-class distribution and with a continuous high amount of dead wood (standing and lying) (Tham et al., 2008a, 2008c, 2008b). There seems to be a contradiction within the management aims between trying to optimise the estate's capacity to support forest-associated biodiversity and their current promotion of beech forest as opposed to oak forest, which is the broadleaved forest type promoted within the largest share of the nature reserve areas. This contradiction occurs because of the close relationship between oaks and high associated levels of biodiversity. It could be argued that to ensure the long-term capacity of this estate to support high levels of biodiversity requires that the wooden meadows and pastures beneficial for the oaks within Häckeberga nature conservation area are maintained or re-established, because of their higher associated levels of species richness (Jonsson et al., 2011).

The aim for Sweden under CBD was to cease biodiversity loss by 2010. However, the vast majority of the actions taken have not required monitoring and follow-up (EPA, 2007) and the result by the fourth report on biodiversity by the Swedish Department of Environment (2009) is that the goals could not be met within the timeframe allocated. The THCV action plan appears consistent with this approach. Within Sweden the policy of letting the individual economic sectors assume responsibility for the impact of their activities on environment and nature conservation (EPA, 2007) has among other things resulted in voluntary set-aside-areas which has increased the area of protected forest (Department of Environment, 2009). However, as the investigation of the 32 heritage oaks indicates, there remains a great deal to be done to ensure the long-term sustainable use of the ecosystems and the resources they provide. The findings by the Swedish Environmental Protection Agency (2007) in the third report on biodiversity is that the incentives to preserve nature offered to private businesses and individual users are too weak to have their intended effect. In the fourth report, one explanation for failure as stated by the Swedish Department of Environment (2009) is the reduction in incentives for preservation, and further that this is however only an obstacle because people are lacking to comprehend the importance of biodiversity. An example of an economical incentive is given for restoring former hayfields with scattered heritage trees. Here the compensation is given per hectare for removing competing vegetation (Swedish Forest Agency, 2012a). The incentives referred to before regard private owners, nevertheless within the nature reserves, which are made to secure protection and preservation of habitats (Höjer and Hultengren, 2004), the treatment recommendations have not been followed within the area we have investigated. These factors may contribute to the low number of heritage oaks treated within the timeframe of the treatment recommendations within Häckeberga conservation area. Nevertheless, the low rate of conduction of the treatment recommendations, at least within Häckeberga nature conservation area, can result in a loss of habitats and species richness (Jonsson et al., 2011).

6.6 Limitations with the method

6.6.1 Sample size

The sample of 32 oaks is not a large sample, and this has mainly caused limitations regarding drawing any strong conclusions for oaks within pastures. Limitations occurred in our ability to draw firm conclusions occurred with respect to effects on crown sizes in 20-meter buffer zone between open land and forest (Table 8), and with respect to assessing the area of living and dead crown and increasing forest density south of the heritage oaks (Figure 17). Ideally, in addition to the 32 largest oaks, we would have measured additional oaks to ensure that the major land-use categories each contained a minimum number of measured individuals.

6.6.2 Crown measurements

The sizes of the area of both living and dead crown are calculated as (length N+ length S) * (length E+ length W) as seen in Figure 21 (additionally Figure 6). By this calculation the heritage oaks get the maximum area of crown compared to other possible calculation methods and the areas may seem relatively large compared to the results of other methodologies (Figure 14). However as all areas are multiplied by the same factor this does not make an impact when relative comparisons are made.

The crown measurements were also used to calculate the ratio between area of living crown divided by area of dead crown. This was thought to be a method for identifying competition between the heritage oak and its adjacent vegetation. However, what we found was that the ration l/d was often not below one, which was our indicator of competition, but nevertheless the ratio l/d seems to be decreasing with increasing forest density south of the heritage oaks. So the crown measurements did not fulfil our expectations, also because of the findings that the living crown was significantly larger than the dead crown within all other croups then coniferous forest (Figure 15). This implies that there are room for further refinement if this measure should be applied in other studies.

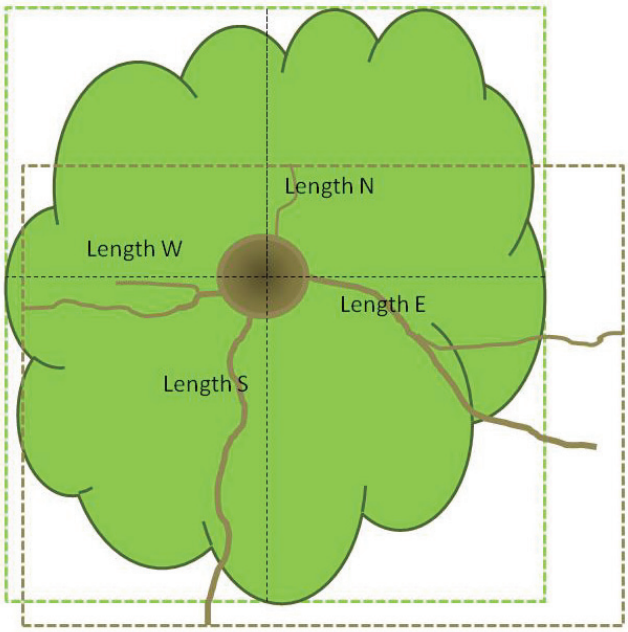


Figure 21 The measurements made in the field inventory of the lengths has been calculation to find the crown area. Bothe for area of living crown (green) and area of dead crown (brown) applies the calculation (length N + length S) * (length W + length E) = crown area.

6.6.3 Accuracy of land-use categories

The accuracy assessment of the oaks within different land-use categories, assigned by GIS and assessed during the field inventory in May 2012 had an overall accuracy of 69 percent Table 7. Normally a good accuracy within one category should be around 85 percent (Buschmann, 2011b). The best assessed land-use category was coniferous forest (100 percent) and the worst was fields (43 percent) and pasture (0 percent). The assessment of accuracy of the assigned land-use category by GIS gives an indication of how sure we can be of the categorisation by GIS. It also reveals that the hardest land-use categories to assign for the maps used in GIS are the more open areas. The fact that more than 60 percent of the oaks are within the 20-meter buffer zone between open land and forest, means that a small deviation in the maps from the actual land-use has an impact on the accuracy.

6.6.4 Forest density measurements

In the measurement of forest density we calculated the basal area from the 157 m^2 half circle south of the heritage oaks. One of the calculations has given a basal area of 70 m^3/ha which is much more than the expected 30-35 m^2/ha for these soil types. The measurements are only made in a small area and if the density in this area is high then the calculated density of a hectare would also be high. Nevertheless a high basal area is indicative of high forest density.

6.6.5 Study area

The study site was chosen because of its high density of old oaks (Table 2 and Map 2), which is often the case on old estates (Eliasson and Nilsson, 2002). This estate in particular was chosen due to the fact that the data for Häckeberga nature conservation area was available from SLU (Swedish University of Agricultural Sciences), and all the attributes used in GIS were formatted. However the high density of heritage oaks is not representative for the rest of Skåne, where the overall density is lower. Also because Häckeberga is in the southern most part of Sweden there can be regional differences, limiting some of our findings to only apply to the southern part of Sweden. In general the data on biodiversity measures available through the THCV register was limited. There were different measures like vitality, woodpeckers, and associated species, however the registration was not consistent. To relate the THCV registration to our findings, it would have been beneficial to have more structural characteristics available in the THCV register for a more detailed investigation of the 982 heritage oaks. The assessment of the 32 heritage oaks was a way of increasing the knowledge on the structural characteristics lacking in the THCV register, however a larger sample would have increased the accuracy of the statistical assessment.

7 Conclusion and recommendations

Our conclusion is that the recommendations for treatment of 333 heritage oaks planned within the first 2 years after the termination of the inventory has not been fulfilled. Moreover the current approach of reserve selection is not targeted to protect the oaks within Häckeberga nature conservation area of the greatest heritage value. The effects of this, together with major changes in the adjacent landscape of the heritage oaks, have resulted in our drawing of the following conclusions.

The adjacent landscape of the heritage oaks appears to be influencing the crown development of the oaks. Open conditions results in increasing crown expansion, whereas competition from high and dense vegetation, especially found within coniferous forest, decreases the area of living crown. There is room for further refinement of our assessment with respect to measures of competition. However the ratio between area of living crown and area of dead crown clearly decreased with an increasingly dense surrounding forest. GIS analyses are a strong tool for the assessing different attributes related to the heritage oaks spatial distribution. In the assessment of heritage oaks affected by areas subject to commercial tree harvesting a comparison of the data from Swedish Environmental Protection Agency with the data on clearcuts from the Swedish Forest Agency only the heritage oaks within clearcut areas are included. However, by including buffer zones around clearcut areas in the GIS analysis, twice the amount of heritage oaks affected by areas subject to commercial tree harvesting are revealed.

With respect to long-term observable trends, the degree of openness around heritage oaks has decreased during the last 70 years by over 30 percent. The vegetation has changed from open land (pastures and fields) to broadleaved-dominated forest south and north of the heritage oaks. The changes have been more pronounced towards north. The decrease of oaks in pastures and fields amounts to 40 percent from the 1940s to 2012.

Regarding associated biodiversity it was found that the density of heritage oaks within Häckeberga nature conservation area is consistent with densities associated with the maintenance of high species richness. However there are large differences in density within the matrix and other measures have to be considered in the management for protection and preservation of sustainable habitats within Häckeberga nature conservation area. Another structural feature associated with biodiversity is the presence of tree hollows, and nearly half of the 982 heritage oaks in Häckeberga nature conservation area are known to possess them (THCV). We found that one third of those are within the protective category of nature reserves. Therefore long-lived oak habitats within those nature reserve areas should be recognised and enhanced. Nevertheless, there seems to be a contradiction between the aims of the current protection and management strategies within those areas, which is not beneficial for the accomplishment of the treatment recommendations.

8 Future perspectives

The goal of this project was to address some of the aspects of heritage oaks not often dealt with. We evaluated measures of structural characteristics for heritage oaks to reveal the influence that the management of the adjacent landscape and of individual heritage oaks have on the objective to ensure long-lasting habitat within beneficial surroundings for biodiversity.

The methods used gave varying results. The GIS component of the study revealed useful information on attributes associated with the oaks spatial distribution. The only drawback of the analysis is the accuracy of the data provided, which showed to be relatively low. The attributes applied by GIS and combined with the information available from then THCV register revealed some interesting correlations between structural characteristics and the heritage oaks spatial distribution. Those comparisons are fairly easy to do, and they can be applied to large areas and large datasets. The field component of this study applied some extra structural characteristics to the heritage oaks. Those characteristics could be indicative of the heritage oaks crown development and thereby an indicator of health and competition with adjacent vegetation. We would have liked the measure for competition to be unambiguous, however this will take further refinement, and would preferably need a comparison with the competition for light within the crown to clarify how this measure is more sufficiently assessed and used. The crown assessments took a fair time to do, however, the information that it is providing is important when the focus is heritage oaks. The crown assessments could be applied to a sample, but it is not efficient to apply this on a whole estate.

By the applied measures and the focus on oaks in this thesis the aim was to contribute to the discussion of the future of heritage oaks and the rich flora and fauna associated with them. The loss of biodiversity is one aspect in the management of heritage oaks in a cultural landscape, but to ensure a sustainable future, economical and recreational aspects also have to be considered. Before an evaluation, as the word implies, of the future management of heritage oaks, it could be beneficial to look at the costs and benefits of all of the three aspects biodiversity, economy and recreation. One future study could investigate the effect of different treatments of the adjacent landscape, with respect to their gains and losses in respectively economy, ecology and recreation, e.g. based on the findings by Koch Wiederberg et al.(in press). A value on all of those different aspects of a sustainable management could maybe contribute to a more differentiated discussion about the future of heritage trees in a cultural landscape. As such, all aspects should be considered in the management planning for protection of landscape elements such as heritage trees, and the interests of nature and recreation should be prioritised and have a value comparable to the incentives to exploit natural resources (Framke, 1989).

9 Bibliography

AIRD, P. L. 2005. Heritage, natural heritage, cultural heritage and heritage tree defined. . *Forestry Chronicle,* 81**,** 1.

ARUP, U., HANSON, S.-Å. & HUGGERT, L. 2001. Rödlistade arter i sydskånska trädsmiljöer. En översiktlig inventering av lavar, mossor, svampar och insekter i 20 områden. *In:* BLOMBERG, P. (ed.). Malmö: Naturskyddsföreningen i Skåne.

BERGMAN, K. O., JANSSON, N., CLAESSON, K., PALMER, M. W. & MILBERG, P. 2012. How much and at what scale? Multiscale analyses as decision support for conservation of saproxylic oak beetles. *Forest Ecology and Management,* 265**,** 133-141.

BJÖRSE, G. & BRADSHAW, R. 1998. 2000 years of forest dynamics in southern Sweden: suggestions for forest management. *Forest Ecology and Management,* 104**,** 15-26.

BOBIEC, A., KUIJPER, D. P. J., NIKLASSON, M., ROMANKIEWICZ, A. & SOLECKA, K. 2011. Oak (Quercus robur L.) regeneration in early successional woodlands grazed by wild ungulates in the absence of livestock. *Forest Ecology and Management,* 262**,** 780-790.

BRADSHAW, R. Year. The history of oak in the Scandinavian landscape since the last ice age. *In:* ENGVALL, M., ed. The Oak - History, Ecology, Management and Planning, 9-11 May 2006 Linköping, Sweden. Naturvårdsverket, 10-12.

BUSCHMANN, A. 2010.12.06 2010. *RE: Steps in remotes sensing application/projects.*

BUSCHMANN, A. 2011.04.12 2011a. *RE: Digital image prosessing workflow - SPOT images.*

BUSCHMANN, A. 2011.04.26 2011b. *RE: Steps in remote sensing application/projects - Accuracy assessment.*

BÄCKE, J. 2011. Skogsstatistisk arsbok - Skog och Skogsmark. *In:* LOMA, J.-O. (ed.). Jönköping: Swedish Forest Agency.

CAB, C. A. B., LÄNSSTYRELSEN; 2007. Skyddsvärda träd i Skånes kulturlandskap, Inventerigs Metodik 2007. *In:* COUNTY ADMINISTRATIVE BOARD, L. S. (ed.). Malmö: County Administrative Board.

CAB INTERNATIONAL 2010. Acacia auriculiformis. 2012 ed.: CAB international.

CABS , T. C. A. B. O. S. 2012a. *Häckeberga - Degebergahus* [Online]. Malmö: The County Administrative Board of Skåne. Available: http://www.lansstyrelsen.se/skane/Sv/djur-och-natur/skyddad-natur/naturreservat/lund/hackeberga-Degebergahus/Pages/_index.aspx [Accessed 2012.06.22 2012].

CABS , T. C. A. B. O. S. 2012b. *Häckeberga - Husarahagen* [Online]. Malmö: The County Administrative Board of Skåne. Available: http://www.lansstyrelsen.se/skane/Sv/djur-och-natur/skyddad-natur/naturreservat/lund/hackeberga-Husarahagen/Pages/_index.aspx [Accessed 2012.06.22 2012].

CABS , T. C. A. B. O. S. 2012c. *Häckeberga - Skoggård* [Online]. Malmö: The County Administrative Board of Skåne. Available: http://www.lansstyrelsen.se/skane/Sv/djur-och-natur/skyddad-natur/naturreservat/lund/hackeberga-Skoggard/Pages/_index.aspx [Accessed 2012.06.22 2012].

CABS , T. C. A. B. O. S. 2012d. *Häckeberga naturvårdsområde* [Online]. Malmö: The County Administrative Board of Skåne. Available: http://www.lansstyrelsen.se/skane/Sv/djur-och-natur/skyddad-natur/naturreservat/lund/hackeberga-naturvardsomrade/Pages/_index.aspx [Accessed 2012.06.22 2012].

DAHLBERG, A. Year. The fauna and flora on oaks - how important are the Swedish oak habitats in a European perspective? *In:* ENGVALL, M., ed. Tha Oak - Habitat, Ecology, Management and Planning, 9-11 may 2006 Linköping, Sweden. Naturvårdsverket, 18-19.

DEPARTMENT OF ENVIRONMENT, M. 1998. Miljöbalken (1998:808). *In:* MILJÖDEPARTEMENTET (ed.) *SFS 1998:808.* Rigeringskansliets rättsdatabaser: Rigeringskansliets.

DEPARTMENT OF ENVIRONMENT, M. 2009. The fourth national report to the Convention on Biological Diversity. *In:* MILJÖDEPARTEMENTET (ed.). Rigeringskansliets rättsdatabaser.

DN, D. N. 2012. *Fredskov* [Online]. Copenhagen: Danmarks Naturfredningsforening. Available: http://www.dn.dk/Default.aspx?ID=6514 [Accessed 0702 2012].

DROBYSHEV, I., LINDERSON, H. & SONESSON, K. 2007. Temporal mortality pattern of pedunculate oaks in southern Sweden. *Dendrochronologia,* 24**,** 97-108.

EEA, T. E. E. A. 2012a. *Häckeberga - Degebergahus* [Online]. Copebhagen: EEA, The European Environmental Agency;. Available: http://eunis.eea.europa.eu/sites/SE0430154 [Accessed 08.13 2012].

EEA, T. E. E. A. 2012b. *Häckeberga - Husarhagen* [Online]. Copebhagen: EEA, The European Environmental Agency;. Available: http://eunis.eea.europa.eu/sites/SE0430155 [Accessed 08.13 2012].

EEA, T. E. E. A. 2012c. *Häckeberga - Skoggård* [Online]. Copebhagen: EEA, The European Environmental Agency;. Available: http://eunis.eea.europa.eu/sites/SE0430153 [Accessed 08.13 2012].

ELIASSON, P. Year. The political history of the oaks in Sweden from the 16th to the 20th century. *In:* ENGVALL, M., ed. The Oak - History, Ecology, Management and Planning, 9-11 May 2006 Linköping, Sweden. Naturvårdsverket, 12-14.

ELIASSON, P. 2012. *The swedish oak during the 18th and 19th centuries - aspects of quantities, qualities and biodiversity* [Online]. Malmö: Nordic Forest History Network. Available: http://www.skogshistoria.nu/network/members/eliasson_per.html [Accessed 2012-06-04 2012].

ELIASSON, P. & NILSSON, S. G. 2002. "You should hate young oaks and young noblemen". The environmental history of oaks in eighteenth- and nineteenth- century Sweden. *Environmental History,* 7**,** 659-677.

EPA , S. E. P. A. 2006. ACTION PLAN ON BIOLOGICAL DIVERSITY. *In:* TERSTAD, J. (ed.). Stockholm.

EPA, S. E. P. A. 2007. Sweden and the Convention on Biological Diversity Summary of Sweden's third National Report to the Secretariat of the Convention on Biological diversity. Stockholm, Sweden.

EPA, S. E. P. A. 2012. *Sveriges miljömål* [Online]. Stockholm: Naturvårdsverket. Available: http://www.miljomal.nu/Miljomalen/ [Accessed].

FORBES, V., FAY, L., LINDHOLM, M. & ROSE, B. 2004. Hördalen Veteran Oak Survey & Arboricultural Management Plan. Halmstad: Country Administrative Board Halland (Länstyrelsen).

FRAMKE, W. 1989. LANDSKABSOPFATTELSE, LANDSKABSPRÆFERENCER OG LANDSKABSEPLANLÆGNING I DANMARK. *In:* BEK, L. (ed.) *Natur opfattelse og landskabsæstetik.* 1 ed. Århus: Aarhus universitetsforlag.

FRAMSTAD, E., ROMSTAD, E., SVENDSRUD, A. & SOLBERG, B. 2000. Biologisk mangfold i skogen i de nordiske lande. *In:* MINISTERRÅD, N. (ed.). Copenhagen: Nordisk Ministerråd.

GIBBONS, P., LINDENMAYER, D. B., FISCHER, J., MANNING, A. D., WEINBERG, A., SEDDON, J., RYAN, P. & BARRETT, G. 2008. The Future of Scattered Trees in Agricultural Landscapes. *Conservation Biology,* 22**,** 1309-1319.

GIS-CENTRUM. 2012. *Skåne från luften kring andra världskriget - flygbilder på Internet* [Online]. Lund: University of Lund. Available: http://hilma.keg.lu.se/Website/flygbilder/viewer.htm [Accessed 06.20 2012].

HENTSCHLEN, S. 10th June 2011 2011. *RE: GIS-basic keynotes*

HOLTEN, N. E. 1998. Kæmpeege i Danmark En beskrivelse af de 30 tykkeste træer. *Dansk Dendrokronologisk Årsskkrift,* 16**,** 25-111.

HÖJER, O. & HULTENGREN, S. 2004. Åtgärdsprogram för särskilt skyddsvärda träd i kulturlandskapet. Stockholm: Naturvårdsverket.

JANSSON, N., BERGMAN, K. O., JONSELL, M. & MILBERG, P. 2009. An indicator system for identification of sites of high conservation value for saproxylic oak (Quercus spp.) beetles in southern Sweden. *Journal of Insect Conservation,* 13**,** 399-412.

JONSSON, M. T., THOR, G. & JOHANSSON, P. 2011. Environmental and historical effects on lichen diversity in managed and unmanaged wooded meadows. *Applied Vegetation Science,* 14**,** 120-131.

JONSSON, U., JUNG, T., SONESSON, K. & ROSENGREN, U. 2005. Relationships between health of Quercus robur, occurrence of Phytophthora species and site conditions in southern Sweden. *Plant Pathology,* 54**,** 502-511.

KARLSSON, M., LINDÉN, M., BJÖRSE, G., ELMBERG, J., LINDBLADH, M. & VOLLBRECHT, T. (eds.) 1999. *Fortida skogar och framtida skogsbruk i södra Sverige,* Alnarp: SLU Alnarp.

KOCH WIEDERBERG, M., RANIUS, T., DROBYSHEV, I., NILSSON, U. & LINDBLADH, M. in press. Increased openness around retained oaks increases species richness of saproxylic beetles. Alnarp: Swedish University of Agricultural Sciences.

LANTMÄTERIET. 2012. *Saccess - What does the different data sets contain* [Online]. Lantmäteriet. Available: http://www.lantmateriet.se/templates/LMV_Page.aspx?id=14344&lang=EN [Accessed 2012.08.12].

LINDBLADH, M. 1999. The influence of former land-use on vegetation and biodiversity in the boreo-nemoral zone of Sweden. *Ecography,* 22**,** 485-498.

LINDBLADH, M. & FOSTER, D. R. 2010. Dynamics of long-lived foundation species: the history of Quercus in southern Scandinavia. *Journal of Ecology,* 98**,** 1330-1345.

MADSEN, P., MADSEN, T. L., OLESEN, C. R. & BUTTENSCHØN, R. M. 2009. Skovforyngelse under højt vildttryk. *Kanstrup, N. Asferg, T. Flinterup, M.Thorsen, B.J.Jensen, T.S Vildt & Landskab. Resultater af 6 års integreret forskning i Danmark 2003-2008.,* 1**,** 110.

MUNICIPALITY OF LUND 2012. Grönstruktur- och Naturvårdsprogram. *In:* STADSBYGGNADSKONTORET (ed.). Lund: Stadsbyggnadskontoret.

NILSSON, P. & CORY, N. 2011. Skogsdata 2011 - Aktuella uppgifter om de svenska skogarna från Riksskogstaxeringen. *In:* FRANSSON, J. (ed.) *Skogsdata 2011.* Umeå: SLU, Institution för skoglig resurshushålling.

NILSSON, S. G. Year. Changes in the biodiversity of oak habitats in Sweden through the last centuries. *In:* Tha Oak - History, Ecology, Management and Planning, 9-11 May 2006 Linköping, Sweden. Naturvårdsverket, 16-18.

PALTTO, H., NORDBERG, A., NORDEN, B. & SNALL, T. 2011. Development of Secondary Woodland in Oak Wood Pastures Reduces the Richness of Rare Epiphytic Lichens. *Plos One,* 6.

RACKHAM, O. Year. European oaks: cultural history and ecology. *In:* INGVALL, M., ed. The Oak - History, Ecology, Management and Planning, 9-11 May 2006 Linköping. Naturvårdsverket, 6 -7.

RANIUS, T. & JANSSON, N. 2000. The influence of forest regrowth, original canopy cover and tree size on saproxylic beetles associated with old oaks. *Biological Conservation,* 95**,** 85-94.

RANIUS, T., JOHANSSON, V. & FAHRIG, L. 2011. Predicting spatial occurrence of beetles and pseudoscorpions in hollow oaks in southeastern Sweden. *Biodiversity and Conservation,* 20**,** 2027-2040.

RAPP, A. 1984. Nivation Hollows and Glacial Cirques in Söderåsen, Scania, South Sweden. *Geografiska Annaler. Series A, Physical Geography,* 66**,** 11-28.

SFIF , T. S. F. I. F. 2010. The Swedish Forest Industries Federation – Facts and figures 2009. 1 ed.: The Swedish Forest Industries Federation.

SKARPAAS, O., DISERUD, O. H., SVERDRUP-THYGESON, A. & ODEGAARD, F. 2011. Predicting hotspots for red-listed species: multivariate regression models for oak-associated beetles. *Insect Conservation and Diversity,* 4**,** 53-59.

SONESSON, K. 1999. Oak decline in southern Sweden. *Scandinavian Journal of Forest Research,* 14**,** 368 - 375.

SONESSON, K. & DROBYSHEV, I. 2010. Recent advaces in oak decline in southern Sweden. *Ecological Bulletins,* 53**,** 197 - 207.

SSIC, S. S. I. C., ARTDATABANKEN, ;. 2010. *Sök rödlistade arter i Sverige 2010* [Online]. ArtDatabanken, Artfakta. Available: http://www.artfakta.se/GetSpecies.aspx?SearchType=Advanced [Accessed 0702 2012].

SSNC, S. S. F. N. C., NATURSKYDDSFÖRENINGEN; 2009. SSNC, Naturskyddsföreningen 100år. Stockholm.

STATISTICS SWEDEN 2008. Landuse in Sweden. *In:* ERIKSON, M. (ed.) Fifth ed. Stockholm: Statistics Sweden, Regions and Environment Department.

STATSOFT INC. 2012. *StatSoft Electronic Statistic Textbook* [Online]. Tulsa: StatSoft, Inc. Available: http://www.statsoft.com/textbook/statistics-glossary/s/button/s/#Skewness [Accessed].

SVERDRUP-THYGESON, A., SKARPAAS, O. & ODEGAARD, F. 2010. Hollow oaks and beetle conservation: the significance of the surroundings. *Biodiversity and Conservation,* 19**,** 837-852.

SWEDISH FOREST AGENCY. 2012a. *Arealstöd* [Online]. Jönköping: Swedish Forest Agency. Available: http://www.skogsstyrelsen.se/sv/Aga-och-bruka/Skogsbruk/Stod-och-bidrag/Bevara-skogens-mangfald/Arealstod/ [Accessed 08.23 2012].

SWEDISH FOREST AGENCY. 2012b. *Skogs Källa* [Online]. Jönköping: Swedish Forest Agency. Available: http://www.skogsstyrelsen.se/Aga-och-bruka/Skogsbruk/Karttjanster/Skogens-Kalla/ [Accessed 05.15 2012].

THAM, H., KNUTSSON, L., PERSSON, C., RUNGE, J. & MALMQVIST, A. 2008a. Skötselplan för naturreservatet Häckeberga - Degebergahus. Malmö: The County Administrative Board Skåne (Länstyrelsen). .

THAM, H., KNUTSSON, L., PERSSON, C., RUNGE, J. & MALMQVIST, A. 2008b. Skötselplan för naturreservatet Häckeberga - Husarahagen. Malmö: The County Administrative Board Skåne (Länstyrelsen). .

THAM, H., KNUTSSON, L., PERSSON, C., RUNGE, J. & MALMQVIST, A. 2008c. Skötselplan för naturreservatet Häckeberga - Skoggård. Malmö: The County Administrative Board Skåne (Länstyrelsen). .

VERA, F. W. M. 2000. Grazing ecology and forest history. Wallingford: CABI Publishing.

WOXBOLM , L. 2007. Ädellöv - virkesegenskaper och användning. *Fakta Skog - Om Forsknig vid Sveriges Landbruksuniversitet,* 11**,** 7.

10 Appendix

10.1 Appendix A – Species list the THCV register

Sum of Assessed	Vitality					
Specie	Dying	Dead lying	Dead standing	High stump	Living	Total
Alder (*Alnus sp*)	1	1	3	2	32	39
Elm (*Ulmus sp*)	12	24	77	3	35	151
Elm? (*Ulmus sp*)			2		1	3
Apple (*Malus sp*)	1				36	37
Apple? (*Malus sp*)					1	1
Ash (*Fraxinus sp*)	3	3	7	4	220	237
Aspen (*Popolus sp*)		1			17	18
Hornbeam (*Carpinus betulus*)		2		1	68	71
Birch (*Betula sp*)		14	6	9	33	62
Beech, red (*Fagus sp*)					5	5
Beech (*Fagus sp*)	23	133	40	294	2694	3184
Beech, red beech (*Fagus sp*)					1	1
Douglas (Pseudotsuga menziesii)					1	1
Oak (*Quercus sp*)	45	103	125	55	2688	3016
Oak, Beech (*Quercus sp Fagus sp*)					1	1
Oak? (*Quercus sp*)		1				1
Wild Cherry (*Prunus sp*)	6	14	3	5	72	100
Spruce (*Picea sp*)		2	1		5	8
Hawthorn (*Cartaegus sp*)					6	6
Hazel (*Corylus sp*)					15	15
Weeping golden ash (*Fraxinus sp*)					1	1
Hanging beech (*Fagus sp*)					2	2
Horse chestnut (Aesculus hippocastanum)	1	6	4	11	787	809
Cherry (*Prunus sp*)					3	3
Lime (*Tilia sp*)	2	4	1	2	643	652
Lime? (*Tilia sp*)					2	2
Larch (*Larix sp*)					6	6
Maple (*Acer sp*)	1			4	172	177
Unknown	1	90	74	42	26	233
Guelder rose (*Viburnum opulus*)					1	1
Whitebeam (*Sorbus aria*)					104	104
Willow (*Salix sp*)		1	2	1	331	335
London plane (*Platanus acerifolia*)					6	6
Plum (*Prunus sp*)					3	3
Poplar (*Populus sp*)				1	14	15
Pears (*Prunus ap*)					2	2
Rowan (*Sorbus sp*)	1		1		3	5
Sallow (*Salix sp*)	1	1			11	13
Pine (*Pinus sp*)					1	1
Turkish hazel (*Corylus avellena*)					1	1
Sycamore (*Acer sp*)					13	13
Tyskönn (Sycamore (*Acer sp*))					1	1
Walnut (*Juglans sp*)					3	3
Sweet cheatnut (*Castanea sativa*)					1	1
Hovedtotal	98	400	346	434	8068	9346

10.2 Appendix B – Calculations of measurements

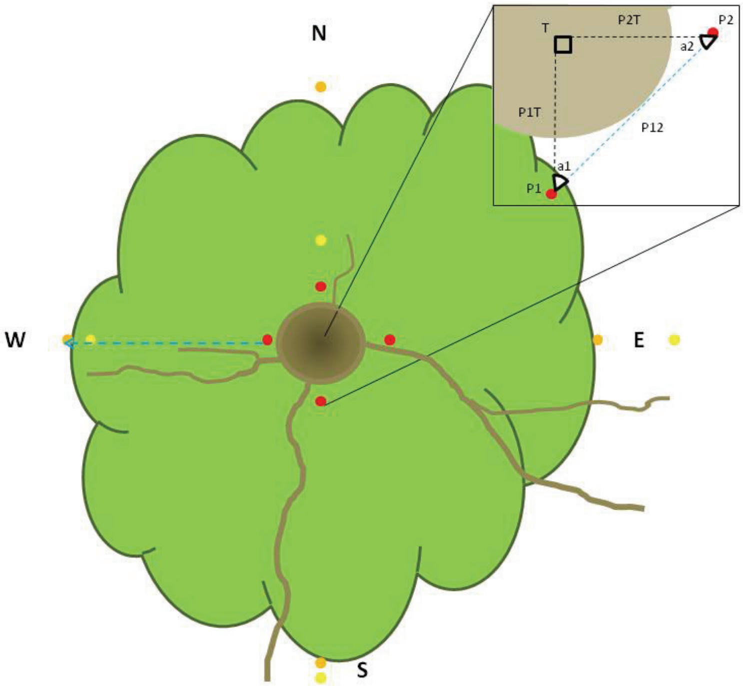


Figure 22 The figure from the methodology chapter of the measurements of the 32 oaks in the field.

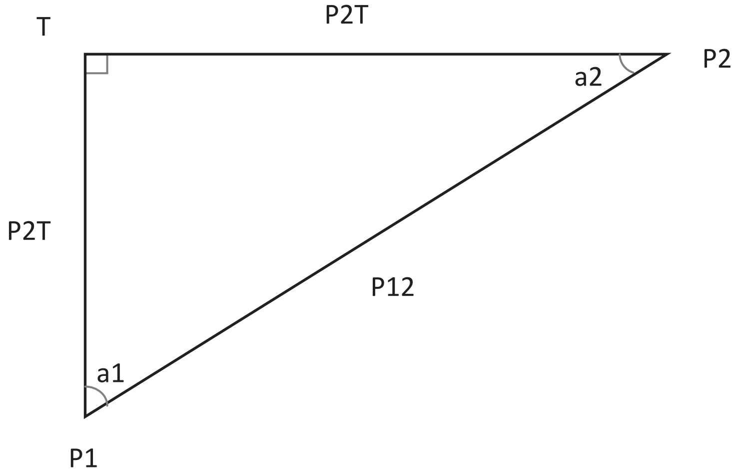
The further calculations made were made for the triangles' in the cutting:

Distances:

$$P1T = \sin(a2) * P12$$

$$P2T = \sin(a1) * P12$$

$$a1 + a2 = 90°$$



10.3 Appendix C – Oak photos

The 32 heritage oaks assessed during the field inventory in May 2012. Containing oak number and photo direction


No 961 southeast


No 932 southeast


No 898 south


No 775 south


No 840 southeast


No 766 east


No 768 south


No 756 east


No 755 north east


No 728 south


No 721 south


No 718 north


No 310 north


No 576 northeast


No 288 south


No 554 south


No 277 south


No 553 east


No 259 northeast


No 328 southeast


No 260 south east


No 206 west


No 182 north


No 167 south


No 119 north


No 115 east


No 107 east


No 88 southwest


No 79 southeast


No 10 southwest


No 62 west


No 9 south