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Sensitivity analysis of the habitat models used in the Heureka planning system



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Abstract

Forest management is getting more and more complex. New important considerations like biological diversity, environmental protection and social benefits have to be taken into account. Many novel approaches and initiatives have been prepared and applied in recent times. The Heureka Forestry Decision Support System is one example of this trend being a relatively new analysis program for forest management. One of the purposes with developing this program has been to be able to add new values into the traditional forest management. Issues like biodiversity and recreation are dimensions that traditionally haven't been able to take in consideration in forest management planning systems. This project focus on the Heureka habitat models where six different indicator species and their ecological requirements act as surrogates for biodiversity.

I have, by using sensitivity analysis, tested the performances of three out of six different habitat models used in Heureka with different levels of parameter values. These were the habitat models for Red Squirrel *Sciurius vulgaris,* Lesser Spotted Woodpecker *Dendrocopos minor* and a lichen Witch's Hair *Alectoria sarmentosa.* The first two models worked correctly while it seems like the model for *A. sarmentosa* had some bug that made my result not useful. In order to study the potential impact of regional characteristics I performed the sensitivity analysis in four regions of Sweden representing the north-south gradient in broad forest types.

I have chosen to present the result in Relative Areal Points (RAP). This means that the suitable habitat area according to the model with parameters representing the lowest demands for particular species and particular region always represented 100%. With increasing requirements the habitat areas decreases and are put in relation to the value representing 100%

The sensitivity analyses indicate that changes in parameter value may have great consequences in resulting effective habitat area for examined species. In particular change of mean stand age has big effect. Some regional differences can be observed. For *S. vulgaris* one can see a slight increase of Relative Areal Points the further north one get.

For *D. minor* one could suppose an increasing level of suitable habitat the further southward one got as deciduous proportion is an important factor and one can expect more deciduous component in the forests of south of Sweden than further north. Strangely I observed more of effective habitat area in Västernorrland than in both Örebro and Gävleborg.

Generally one can see a more dramatic outcome of changes of parameter values where effective habitat area is low when default values are used. This might indicate that one has to be careful when using the models on small areas.

As far as this degree project can indicate the habitat module in Heureka is a reliable tool to try to identify the amount of suitable habitats for the indicator species included but habitat module should be used with understanding of possible effects of the applied parameter values.

1. INTRODUCTION

Since mid-1800´s wood and wood products have been the main goals for Swedish forestry management (Wastenson 1990, Elmberg et al. 1992). This aim was strongly reflected in the Swedish forestry act of 1903 and 1979.

The income from forestry is a major part of Swedish net export revenue (about 50%) and stands for about 10 – 12 % of Swedish industries employment, turnover and added value. The forest industry is strongly oriented towards export. Sweden is after Canada the world's biggest exporter of paper, pulp and sawn timber products. The forestry's part of Swedish total export of goods is 11%. During the recession in 2008 the forestry stood for almost the entire national net export revenue (Link A: http://www.svenskfastighetsmarknad.se/2011-2/skogsmarknaden).

Recently, other values like biological diversity and recreation linked to forests have become more and more important both internationally and in Sweden. This development may be exemplified by the "Pan-European Forest Process" (previously known as the Helsinki Process) where the European countries and the European Community agreed on six common criteria, twenty-seven quantitative indicators and 101 descriptive indicators for sustainable forest management at the regional and national levels (Castañeda et al. 2001). Also, in the Montreal Process twelve countries outside Europe agreed on a set of 7 non-legally binding criteria and 67 indicators for sustainable forest management for national implementation. Participating countries (Argentina, Australia, Canada, Chile, China, Japan, Republic of Korea, Mexico, New Zealand, Russian Federation, Uruguay and USA) have agreed to review and consider possible elements for criteria and indicators at the forest management unit level (Anon. 1995). These new and broadened ideas were also reflected in §1 in the Swedish Forestry Act when it was re-written and enacted in 1994. The act now states that production and environmental goals should be valued the same.

Guidelines and directives on both national and international level point out a need for extended use of wood and bio-energy from the forest while, in the same time, green infrastructures for functional networks of areas with high biological values has to be secured (Andersson et al. 2011). Important economic values are often in conflict with ecological, social and cultural values in development of rural- and regional areas (Angelstam et al. 2011, Andersson et al. 2011).

Due to reasons listed above, the forest management without comprehensive ecological and social consideration is nowadays virtually impossible. Many attempts and efforts have recently been done to make it easier to assess non-monetary values as for example recreation, biodiversity, water- and air quality. Great efforts have been made in trying to find ways to solve this conflict of multiple preferences and several different models and tools have been developed (Bettinger 2009, Rompré et al. 2010, Nordström 2010, Půlzl 2012). An important factor in solving complex combined mathematical problems related to optimization in multi-purpose forestry have been the advances in computer programming that has been going on since the 1960's (Wikström et al. 2011).

One attempt to evaluate biodiversity is to use habitat modeling by trying to specify different species requirements as a proxy. Habitat models are based on particular species' needs of resources for survival and reproduction and are often spatially explicit. Different forest species can have quite different demands on their habitat. It may concern amount, type and/or quality of trees needed for protection from the predators, for breeding purposes or as substrate for food (Edenius and Mikusiński 2006). Habitat models do not give an exact picture of where a specific species occur but where there is a high probability to find it. Habitat models can be used as tools to predict probability of survival, reproduction and dispersal according to different management alternatives (Edenius and Mikusiński 2005). A suitable habitat may be defined as an area that fulfills the species needs for food, shelter and reproduction (Öhman et al. 2011).

For example Öhman et al. (2011) presented a spatial habitat model for use in the traditional forest planning process. It was based on two parts: stand-wise characteristic and spatial conditions related to species requirements. Stand-wise conditions were depending on the needs for the specific species such as stand age and tree species composition. These data may be found in forest databases. The second part concerned the spatial needs for the particular species. If both parts conditions were fulfilled the stand was treated as suitable habitat (Öhman et al. 2011).

Due to the occurrence of different natural processes including disturbances, ecosystems are usually dynamic and changeable and therefore associated species communities are able to adapt to changes within certain limits (Angelstam et al. 2003, Mikusiński et al. 2007). Thanks to that, the forest ecosystems can be used for production of timber and other products without losing species especially if landscape perspective is considered in planning (Angelstam et al. 2003). However there are limits for how big the reduction of suitable habitats can be and thereby trespassing these limits may lead to the situation that specialized species risk extinction. This can be described as critical threshold values (Angelstam et al. 2003). This means that although there is some suitable habitats left in the landscape one species can be doomed to disappear since the amount, distribution or both are insufficient to support its population (e.g. Carlson 2000). One can look upon the landscape like an archipelago. If the islands are too small or too far away such threshold values are trespassed and no functional habitat is left (Andrén 1994, Angelstam et al. 2003).

According to the Swedish Species Information Centre there are 4,127 red listed species in Sweden, of which more than half are forest dwellers (Link B: http://www.slu.se/artdatabanken/). And the situation is getting worse for many fungi, mosses, lichens and wood-living insects. That indicates that there is much to do to maintain and restore the biodiversity in Swedish forests. For doing this, effective and reliable tools are needed.

1.1 The Swedish Model

In an attempt to cope with the issues described above a multi-scaled model for handling biodiversity issues was introduced in Sweden's forests more than 30 years ago (Gustafsson and Perhans 2010). This so called Swedish Model, which goes beyond the Swedish Forestry Act, is partly based on set aside areas (e.g. nature reserves) and partly on different types of biodiversity considerations applied in the ordinary forest production management. A fundamental assumption of this model is that biodiversity is best promoted with a multi-scaled approach. Gustafsson and Perhans (2010) divide the model into three spatial levels where the lowest level encompasses individual trees and group of trees covering up to 0.5 ha. In the next level areas from 0.5 to 15-20 ha are included (i.e. encompassing parts or entire stands). Next level includes all areas above this size. This pioneer type of integrated approach is now spread around the world among countries like, Finland, Norway, Estonia, Lithuania, Canada, NW USA and Tasmania (Gustafsson and Perhans 2010).

Strength of the Swedish Model is that effective consideration is taken in the ordinary production forest. Due to economic and technical reasons, national parks and other protected areas where often established in low productive and remote places (Nilsson and Götmark 1992). In the Swedish Model biodiversity conservation is considered also in management of highly productive stands. Thereby, this includes biodiversity into everyday thinking among every person engaged in forestry. Simultaneously, it is assumed that biodiversity consideration in the production forests shall be planned in accord with existing protected areas so threatened and endangered species may also exist in production landscapes (Mikusiński et al. 2007). Still, forests in officially protected areas are considered as an essential part of the Swedish Model.

Sweden has a total land area of 40.8 million ha whereas 28.3 million ha (69%) is forest land. Mires and rock surface cover 3.1 million ha, 0.9 million ha are located in high mountains and subalpine coniferous woodlands and in total 1.8 million ha are woodlands in protected areas, such as national parks, nature reserves and other nature conservation areas. A total area of productive forest land is 22.5 million ha (Swedish National Forest Inventory, Forestry Statistics 2010).

National parks and nature reserves together comprise 4.3 million hectares, which corresponds to roughly 10 % of Sweden's total land area. Of that amount, 795,000 hectares consist of legally protected productive forest land. In addition, habitat protection areas account for more than 22,000 hectares and nature conservation agreements account for 32,000 hectares were over 49,000 hectares are productive forest land. Voluntary conservation areas comprise another 1.1 million hectares (Swedish National Forest Inventory, Forestry Statistics 2010).

On small-scale forestry holdings, some 54,000 key habitats are registered by the Swedish Forest Agency. They encompass approx. 167,000 hectares, of which 141,000 hectares are productive forest land (Swedish National Forest Inventory, Forestry Statistics 2010). Many of those habitats are voluntary set aside in the frame of mostly small-scale management plans that are made according to FCS or PEFC standards which stipulate that at least 5% of the productive area has to be devoted to nature conservation.

1.2 Indicator and umbrella species

To investigate and analyze the environment from the biodiversity perspective is a complex task. Different species have specific ecological demands necessary for their survival. Therefore, we need to seek management solutions that will profit several species simultaneously and here use of various types of surrogate species may be useful (Caro and O'Doherty 1999, Linell et al. 2000).

Incorporating biodiversity considerations into forest planning requires effective tools that assess the effects of different management scenarios. These tools may be based on simple measurements like the amount of conservation areas, the area of old forests, dead wood volume etc. calculated for particular scenario and each time step (Öhman et al. 2008, Edman et al. 2011, Öhman et al. 2011). However, the effects of forest management may also be measured from the perspective of specialized forest species with particular requirements concerning the quality and amount of habitat (Edenius and Mikusiński 2006, Öhman et al. 2008, Edman et al. 2011, Öhman et al. 2011).

The large number of different forest species and lack of specific knowledge demands that planning for conservation of species may be simplified by using suitable surrogate species with well-known demands concerning their habitat (Noss 1999, Jonsson and Jonsell 1999, Lindenmayer et al. 2000, Angelstam and Mikusiński, 2003). Such surrogate species should be an area demanding habitat specialists assumed to indicate that the community of ecologically similar species in a certain forest environment is relatively complete (Angelstam and Mikusiński 2003). For example occurrence of woodpeckers can be used to indicate a high degree of naturalness of forest meaning the presence of dead wood, old deciduous and large trees (Angelstam and Mikusiński 1994, Jonsson and Jonsell 1999, Noss 1999, Lindenmayer et al. 2000).

Often the concept of umbrella species is used to indicate the habitats suitability. Umbrella species can be defined as "species with such demanding habitat requirements and large area requirements that maintenance of it will automatically mean maintenance of many other species" (Simberloff 1998). Although critique has been raised against the idea that one single species could serve as an umbrella for all other species (Simberloff 1998, Lindenmayer et al. 2002, Bifolchi 2005, Shreeve and Dennis 2011,) there is increasing evidence confirming the usefulness of surrogate species (i.g. Lambeck 1997, Fleishman et al. 2000, Roberge et al. 2008a, Roberge et al. 2008b). Here, the method presented by Lambeck (1997) is particularly interesting. He proposed that a subset of species (called focal species) in a landscape defines attributes that must be present to meet the requirements of the other, less demanding species to occur there.

In Sweden lichens, wood fungi and mosses have been extensively used as indicators for forests with high values on a stand level (E.g. Gustafsson et al. 1999, Bader et al. 1995, Angelstam and Mikusiński 2003). On a landscape scale, different combinations of sedentary birds may cover many of the demands of different other species (Angelstam et al 2004, Venier and Pearce 2004). Here, woodpeckers seem to have particular position (Roberge et al. 2008a). For example, it has been estimated that conservation measures directed towards White-backed Woodpecker (*Dendrocopos leucotos*) in Sweden would benefit about 200 other threatened species (Edman et al. 2011).

1.3 Habitat models

A strategy to try to predict the presence or absence of a certain species by using correlations of distributions and environmental factors can be found as early as mid-1920s (Guisan and Thullier 2005). As computerizing made this kind of empirical species distributions models easier to perform they increased in the 1970s (Guisan and Thullier 2005). The results of these models, often presented as habitat suitability maps, are useful tools for resolving practical questions in applied ecology and conservation biology (Guisan and Thullier 2005).

Edman et al. (2011) categorizes habitat models in different classes where the simplest models predict occurrence of species only on the area of habitat in the landscape. By incorporating the spatial configuration of habitat patches one goes further as structural and functional connectivity are included. Meta-population models add the temporal aspect of habitat use and dispersal among populations while demographic models focus on the colonization and abandonment by individuals. Edman et al. (2011) also mentions that it is ideally that the targeted species, if to be used in conservation planning, have an umbrella species function.

Generally it would often be best if there was as large area and as many suitable habitats as possible. Even the spatial configuration of the habitat where a specific species is expected to live may matter. Often a round shape of habitat patch is better than thin, narrow one because it minimize the border- and buffer zones (Simberloff and Abele 1982, Sands 2005). Hunter (2002) also states that border zones should change gradually rather than have an abrupt changeover to another type of environment.

In early 1980's US Fish and Wildlife Service developed a series of models in the purpose that in some way quantify different qualities of habitat (Bettinger et al. 2009). Many different models have been developed since then. Often these models are based on Habitat Suitability Index (HSI) for one particular species. HSI can be calculated for a single stand as well as for complete landscapes or water catchment areas. Normally HSI is a value between zero and one where the digit zero stands for a non-habitat for the particular species and the digit one represents a habitat that is optimal. Usually a HSI-model uses several variables. Those variables are such that has been judged by expert knowledge as important or found by ecological empirical studies as significant for the specific species to live and breed in the specific habitat. For Downy Woodpecker *(Picoides pubescens)* for example*,* a model was developed that consists of two variables. One was a function of the basal area of all trees in the stand and the other is the number of snags over 15.2 cm (6 inches) diameter at breast height. For White-tailed Deer (*Odocoileus virginianus*) the model was more complex and included six variables. Two of the variables (proportion of agricultural land and distance from agricultural land to forest or protective bushes) demanded analysis of spatial data i.e. made this model spatially explicit (Bettinger et al. 2009).

In the above models, all the variables are given a value between zero and one. Those are summarized and divided with the number of variables. The result is a weighted HSI between zero and one. It's possible to give one variable greater influence and reduce the influence of another. In the example above with the Downy Woodpecker one could give the variable for basal area 70% and the variable for snags 30% by multiplying the values with 0.7 and 0.3 (Bettinger et al. 2009).

Similar modeling has been applied to tackle biodiversity considerations in Heureka forestry planning system. Heureka is a relatively new analysis program for forest management that has been created in Sweden in response to the requirements of sustainable forestry planning that in addition to traditional products (e.g. timber) should encompass other values like recreation or biodiversity (Wikström et al. 2011). Habitat models for six species have been used in Heureka as a tool for assessing the impact of forestry operations on biodiversity. The amount of habitat for particular species under different management scenario has been used as currency to assess this impact.

The aim of this degree project is to investigate how variables and the parameter value used in habitat models in Heureka Forestry Decision Support System influence the result in terms of the assessed amount of suitable habitat that further should be used for planning purposes. This has been done by performing sensitivity analysis in order to detect critical threshold values that influence the relationship between different environmental values specified in each of the investigated models. Moreover, the potential influence of regional differences in the level of habitat suitability was investigated.

2. MATERIAL AND METHODS

To perform sensitivity analysis several different computer programs and applications have been used. In this chapter these are briefly described. Also, the detailed method description is provided.

2.1 Heureka system

Computer technology, hardware as well as software, have had a rapid development the last 40 years or so. This has led to computer programs that developed from handling specific and well defined problems towards more complex and wider questions. Heureka Forestry Decision Support System follows this trend as a newly developed computer program for forest management that should be able to consider new demands linked to trend towards multi-purpose forestry. From the same kernel different economic, ecosystem and social models can be reached, allowing for a problem to be approached from a number of different angles. Today, the system can handle economic values, silvicultural treatments and harvesting, timber production, forest fuels, biodiversity, recreation and carbon sequestration (Wikström et al. 2011).

Already from the beginning the aim of Heureka has been to develop software for users both within and outside the research community and make a computer program for both applied planning as well as research. The target group included a wide range of different users and needs, all from the small-scale forest owner to large companies and authorities (Wikström et al. 2011).

Heureka consists of six different sub-programs or applications. These are:

- **StandWise,** for stand-level analysis, an interactive simulator including visualization in 2D and 3D
- **PlanWise**, for forest-level planning and analysis, including a optimization tool
- **PlanEval,** for multi-criteria decision analysis, to help comparing plans generated in PlanWise
- **RegWise**, for regional scenario analysis
- **Ivent,** is an application for field inventory - plot wise sampling of single-tree data (for Windows mobile devices)
- **PlanStart**, is used for project initiation and data preparation (mainly import of data from different data sources)

Although my study considers the habitat models used in Heureka the analysis was not made using the Heureka program per se. The habitat models is an external module of Heureka but can be reached from the program. In this project separate stand-alone modules of the habitat models has been used. The data is not exported from Heureka but manually adjusted to fit (see appendix 7.1 for details). By kind permission by Peder Wikström I have had direct access to the habitat models and therefore I was able to run these models outside Heureka using ArcGis 9.3.1.

2.2 Biodiversity module in Heureka

The model for species' habitat suitability in Heureka is designed to provide a coherent framework based on habitat suitability modeling for assessing biodiversity scores. The models are intended to be used primarily at landscape scale (>1000 ha). Biodiversity module in Heureka is, in its present version, based on habitat suitability models for six focal species taxonomically representing mammals (1), birds (3), insects (click beetle) (1) and lichen (1).

These are:

Sciurius vulgaris
Red Squirrel (Swedish: ekorre)
Dendrocopos minor
Lesser Spotted Woodpecker (Swedish: mindre hackspett)
Bonasa bonasia
Hazel Grouse (Swedish: järpe)
Perisoreus infaustus
Siberian Jay (Swedish: lavskrika)
Harminius undulatus
(Swedish: violettbandad knäppare)
Alectoria sarmentosa
Witch's Hair (Swedish: garnlav)

The different species were chosen to cover species with small area demands as well as species that need several stands for survival and breeding. Also the ability to disperse has been considered. The limiting factors linked to forest variables has been identified and valued for every species. Demands of forest type, substrate/habitat requirement, space use and movement capability has been identified. The approach is based on the focal species concept and focuses on factors that might limit the species occurrence.
(Link C: http://heurekaslu.org/mw/images/6/64/Heureka_Habitat_models.pdf).

To explain how the model is constructed one can consider the model for Hazel Grouse as an example. It needs Norway Spruce (*Picea abies*) for shelter and deciduous trees (preferably *Alnus*) for food. Both these attributes have to exist in one stand as the Hazel Grouse don't move over long distances. Forest older than 20 years that consists of at least 25% spruce and 15 – 40% deciduous has been given Habitat Suitability Index = 1 i.e. top score. If the forest fulfill the first two criteria but have 5 – 15% deciduous the HSI = 0.5. If none of the criteria is fulfilled the HSI = 0 i.e. the forest is treated as a non-habitat.

However, it is not enough that the single stand is a suitable habitat. For a stand to get HSI 1 or 0.5 there has to be at least 20 ha suitable habitat in vicinity relevant for the species i.e. within a radius of 565 m (100 ha). Finally the area is added and the effective habitat area is calculated as a measurement of the suitability of the given forest landscape for Hazel Grouse. The habitat models for the remaining bird species and red squirrel are constructed in a similar way, whereas model for *Harminius undulatus* does not have any spatial component and the one for witch's hair has edge effect accounted for.

Although analyzes are performed on pixel or stand level the models are intended to be used on landscape scale (> 1 000 ha).

2.3 SLU Forest Map

The source of information of forest characteristics used for running the habitat models in this study was SLU Forest Map, earlier called kNN-Sweden, developed and produced by the Remote Sensing Laboratory, Forest Resource Management, Swedish University of Agricultural Sciences. The kNN (k Nearest Neighbor) approach used to produce these data is a method to classify objects (pixels) according to its neighboring objects (Reese et al 2003). This method was used to classify Swedish forest landscapes based on satellite images (Landsat) combined with data from National Forest Inventory (Riksskogstaxeringen).

It contains mean values over segments in generalized classification data for standing volume per hectare for pine, spruce, birch and other deciduous, average stand age and average height of trees. The dataset is adjusted so that average stand size is about two hectares in southern Sweden and about ten hectares in the north (Granqvist Pahlén et al 2004). The data covers almost the whole country and the recommendation is not to use it for analyses of areas <100 hectares to keep the standard deviation under 10 – 15% SLU Forest Map classifies forest land in three classes as it is classified in the official road map from the national land survey bureau. Forest land includes productive forest area, forest covered wetlands as well as areas of subalpine birch on higher altitudes. This includes non-productive land that is situated inside the segment (stand). (Mats Nilsson pers. comm. 2013-01-23).

2.4 The analysis

Sensitivity analysis is an accepted method to investigate the performance of a given model. It is a formalized procedure to identify the impact of changes in various model components on model output (Newham et al. 2003). Sensitivity analysis is an integral part of simulation experimentation and may influence model formulations. It is commonly used to examine model behavior. A common approach to sensitivity analysis is to explore the effects of changing parameters, one at the time, on a target output parameter (Beres et al. 2001). The general procedure is to define a model output variable that represents an important aspect of model behavior. The values of various inputs of the model are then varied and the resultant change in the output variable is monitored. Large changes in the output variable imply that the particular input variable is particularly important in controlling model behavior.

To investigate how variables used in the models influence the result in terms of the assessed amount of suitable habitat I performed sensitivity analysis using forest data from SLU Forest Map (described above). Data from this database have been already used for testing the Heureka system. The data was downloaded from the SLU web site (Link D: SLU 2011). To obtain a broader geographical coverage and get a representation of different types of forest landscapes and forest types, data from four different counties was chosen. Those where: Skåne (county code 12), Örebro (county code 18), Gävleborg (county code 21) and Västernorrland (county code 22), see Fig. 2.1 and table 2.1 below.

For practical reasons the selected areas followed the raster from the Swedish map "Terrängkartan". Areas chosen were:

- 12 Skåne blad 3d sv
- 18 Örebro blad 11f sv
- 21 Gävleborg blad 15f no
- 22 Västernorrland blad 18h no

The southernmost site was in Skåne. The landscape is overall dominated by agricultural land and relatively high percentage of deciduous trees in the forest. Stands are usually small. In the whole county of Skåne agricultural land stands for 70% of the area and the presence of small forest lots surrounded by agricultural land are relatively common. The site is located in the northern part of Skåne where there is some more forest land, forest cover on the site is 61% The climate zone is very good for agriculture with temperature sum more than 1 300 day-degree and is very humid (Wastenson 1990).

Site two is located in the northern part of Örebro County where the clay dominated agricultural land in the southern part borders into forested moraine hills in the north. Altitude is about 150 meters above sea level. The site has high proportion of spruce. Climate is relatively chilly with temperature sum between 900 and 1 300 day-degree (Wastenson 1990).

The third site is located in western part of Gävleborg County. Here is agricultural land concentrated around lakes and rivers. Forest land is normally dominated by pine. It has the lowest proportion of deciduous among sites in this study. Climate is relatively chilly with temperature sum between 900 and 1 300 day-degree (Wastenson 1990).

The northernmost site is situated in eastern part of Västernorrland, not so far from the Baltic Sea. Forest is an equal mix of spruce and pine. It has also a relatively high proportion of deciduous trees.
Climate is dry in summer to slight humid with temperature sum > 900 day-degree (Wastenson 1990).

Tables over age distribution, deciduous- and spruce proportion in the four sites is added in Appendix 7.2

First, some initial testing of the model was performed to get an idea of how long every runtime lasted in relation to the area being tested. Then it was decided that an area of 625 km^2 (25 x 25 km) from every county would be used in the sensitivity analyses.

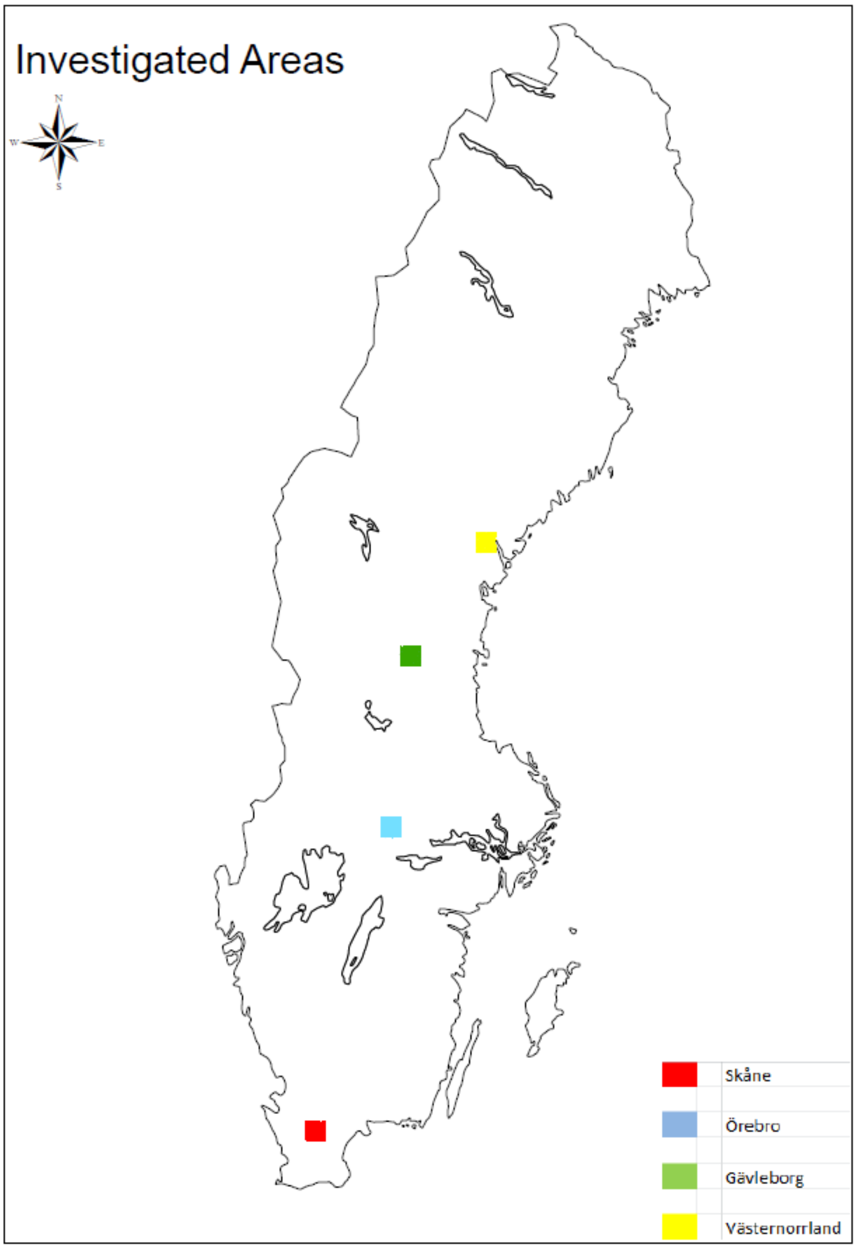

Figure 2.1. Map of Sweden with investigated areas.

Table 2.1. Characteristics of study plots. Percentages of spruce and deciduous trees are based on data from SLU Forest Map

	Skåne	Örebro	Gävleborg	Västernorrland
Forest cover (%)	61	71	79	83
Spruce volume (%)	17.5	40.2	27.1	48.8
Deciduous volume (%)	71.2	19.2	6.9	18.1

The attribute tables from SLU Forest Map for every selected area were adjusted to fit the habitat models developed for Heureka. The adjustment concerned mostly names of the columns in the attribute table.

Three of the six focal species representing mammals, birds and insects were initially selected for sensitivity analyses. These were the following:

- Red Squirrel *S. vulgaris*
- Lesser Spotted Woodpecker *D. minor*
- Witch's Hair *A. sarmentosa*

The sensitivity analysis was performed by changing the different values used in the models (see table 2.2) in both directions from the default value (i.e. higher and lower than default values). For example for Lesser Spotted Woodpecker the forest age was lowered or raised with 10 and 20 years so that one e.g. got runtimes for the following stand ages as minimum thresholds 40, 50, 60, 70 and 80 years. In the same way the figures for spruce respective deciduous proportion was lowered and raised with 10 respective 20 percent units. The models for Red Squirrel and Lesser Spotted Woodpecker also contain a calculation for "half-good" habitat. This habitat get Habitat Suitability Index = 0.5 (See table 2.2 for details).

Table 2.2. Table over input values in sensitivity analysis. The column in the middle is the default value.

			Default values		
Sciurus vulgaris			↓		
Age criteria for habitat score	≥ 50	≥ 60	≥70	≥ 80	≥ 90
Spruce prop 0,5	≥0.10 and <0.30	≥0.20 and <0.40	≥0.25 and <0.50	≥0.30 and <0.60	≥0.40 and <0.70
Spruce prop 1,0	≥0.30	≥0.40	≥0.50	≥0.60	≥0.70
Dendrocopos minor					
MeanAge	≥ 40	≥50	≥60	≥70	≥80
DecidProp 0,5	≥0.10 AND < 0.30	≥ 0.20 AND < 0.40	≥0.25 AND < 0.50	≥ 0.30 AND < 0.60	≥0.40 AND < 0.70
DecidProp 1,0	≥0.30	≥0.40	≥0.50	≥0.60	≥0.70
Alectoria sarmentosa					
MeanAge	≥80	≥ 90	≥100	≥110	≥ 120
SpruceProp	≥0.60	≥0.70	≥ 0.80	≥ 0.90	≥1.00

As only one variable was adjusted at the time (age or spruce/deciduous proportion) this resulted in 25 runs per species and area. This gives 25 x 3 x 4 = 300 runs. For Red Squirrel and Lesser Spotted Woodpecker every run resulted in three output-files. One for HSI = 1, one for HSI = 0.5 and one aggregated that includes both HSI = 1 and HSI = 0.5. For Witch's Hair only one file with HSI = 1 was created. This gives 2 x 100 x 3 + 100 = 700 habitat suitability maps.

Even if there is a possibility to derive many different variables from the output files this work is limited to the "effective habitat area" (EHA) of suitable habitat that is also the main output from Heureka biodiversity module. It is defined as the total area with Habitat Suitability Index = 1 plus total area with Habitat Suitability Index = 0.5 divided by 2. By doing this, we account for the lower quality of habitat in the latter case. This way of calculating effective habitat area has been applied in the case of Red Squirrel and Lesser Spotted Woodpecker. For Witch's Hair there only exist data for HSI = 1 and therefore this calculation were unnecessary.

I have chosen to show the results of sensitivity analyses as Relative Areal Points (RAP). This way of present data might be explained in the following way: On the Y-axis the HSI with the lowest demands for particular species and particular region always represented 100%.

For Red Squirrel that will be age >= 50 and spruce prop > 10. That gives for Skåne 8,700.5 hectares of effective habitat area (see table 3.1). With increasing requirements the effective areas decreases and are put in relation to 8,700.5 hectares. Corresponding figures for Lesser Spotted Woodpecker in Skåne are age >= 40 and deciduous percentage > 10 and gives 27,099.5 hectares as 100% Note that in both these cases spruce respective deciduous prop between 10% and 30% are considered as "half good" habitat and there area is reduced with half.

3. RESULTS

While reviewing the results and figures below it is important to note also that the habitat areas being the base for calculating RAP for the different investigated regions differ remarkably (consult tables with areas accompanying the figures). For example, for the Lesser Spotted Woodpecker figures corresponding to 100% are 3,269 ha and 28,000 ha in Gävleborg and Skåne, respectively.

3.1 Sciurus vulgaris

The sensitivity analysis shows that cut-off values for both age of stands and proportion of spruce are largely affecting the effective habitat area indicated by the habitat model in relation to the default value (Figures 3.1 – 3.4, Tables 3.1 – 3.4). However, effect of changing the minimum age of stands treated as suitable for the species has greatest effect on the results. In all regions 100% RAP corresponded to at least several thousand hectares of EHA even in the case of the highest level in the term of spruce proportion (max. 22,000 ha in Örebro with spruce proportion >30%), min 2,953 ha in Skåne with spruce proportion >70%). The comparison with the default parameter values in terms of age indicated that EHA declined several times the 100% RAP from the lowest cut-of values (i.e. age >50 years). Further increase of minimum stand age resulted in rapid decline of EHA in comparison to default values. In cross-regional comparison Skåne has been much more extreme than other counties in terms of EHA decline with higher stand age. In this county, the total EHA using default values was very low.

In contrast to age, the change of parameter value concerning the proportion of spruce was much less dramatic for all cut-off levels for age (Tables 3.1 – 3.4). In great majority of cases the change of EHA in comparison to default value was within + - 100% (usually below + - 50%). Only Gävleborg region demonstrated higher levels (118 – 208 %) of increase in EHA in the case of lowest cut-off value of spruce proportion (i.e. >30%).

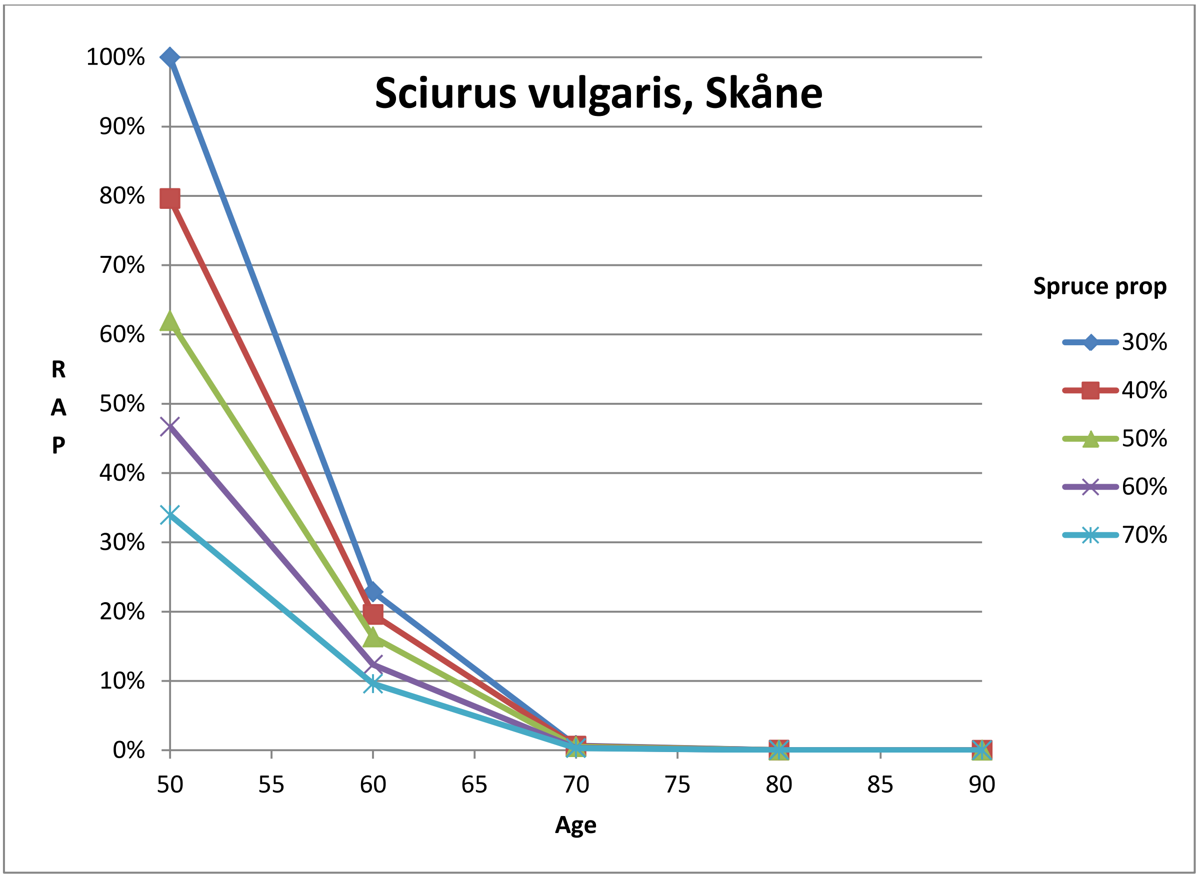

Figure 3.1 Relative Areal Points for *S. vulgaris* in Skåne.

Table 3.1 Area and relative change of the amount of effective habitat for *S. vulgaris* in Skåne. Spruce prop 50 and Age 70 as default.

	Sciurus vulgaris, Skåne								
	Spruceprop 30		Spruceprop 40		Spruceprop 50	Spruceprop 60		Spruceprop 70	
Age	Areal (Ha)	Change	Areal (Ha)	Change	Areal (Ha)	Areal (Ha)	Change	Areal (Ha)	Change
50	8700,5	61%	6927,5	28%	5393,5	4062,5	-25%	2953,7	-45%
60	1988,3	40%	1705,0	20%	1421,4	1073,1	-25%	834,5	-41%
70	58,1	31%	52,3	18%	44,3	29,6	-33%	26,1	-41%
80	1,9	0%	1,9	0%	1,9	1,0	-50%	1,0	-50%
90	0		0		0	0		0	

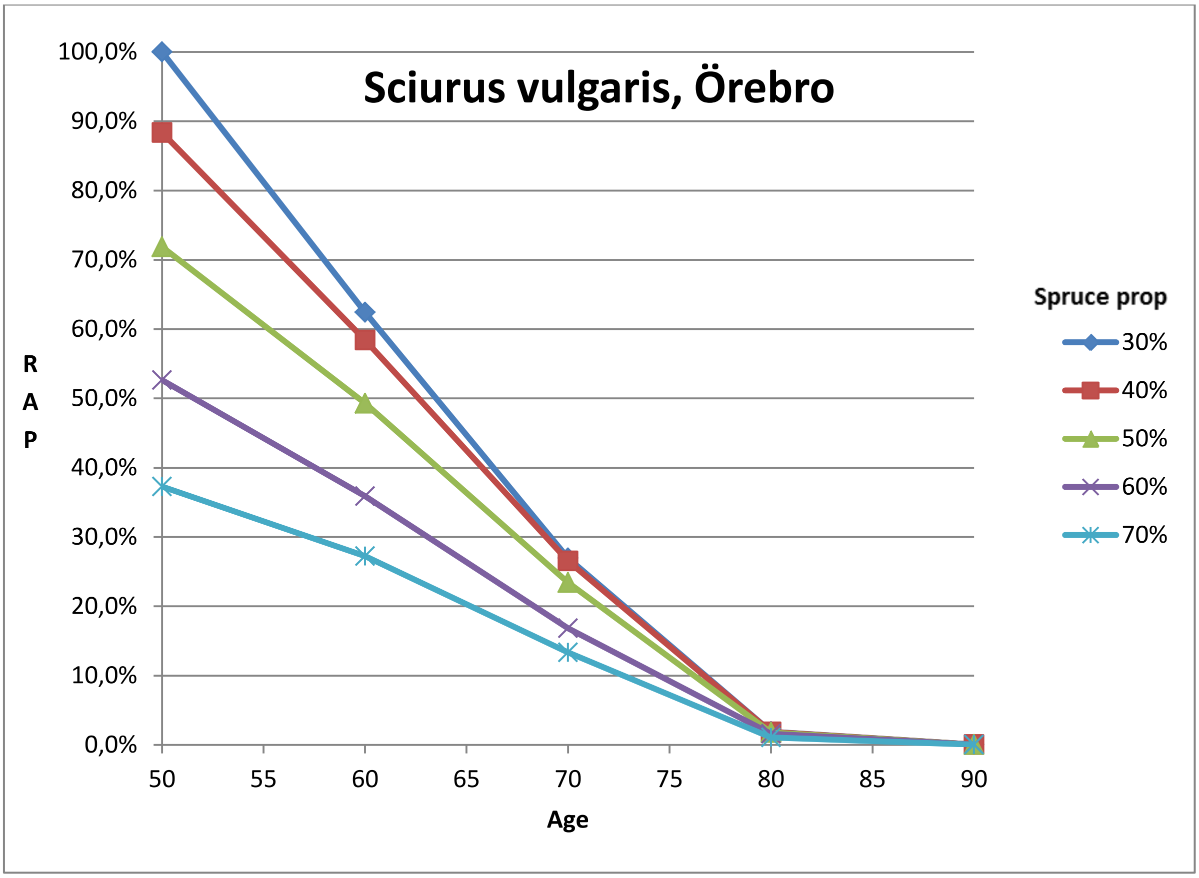

Figure 3.2 Relative Areal Points for *S. vulgaris* in Örebro.

Table 3.2 Area and relative change of the amount of effective habitat for *S. vulgaris* in Örebro Spruce prop 50 and Age 70 as default.

	Sciurus vulgaris, Örebro								
	Spruceprop 30		Spruceprop 40		Spruceprop 50	Spruceprop 60		Spruceprop 70	
Age	Areal (Ha)	Change	Areal (Ha)	Change	Areal (Ha)	Areal (Ha)	Change	Areal (Ha)	Change
50	22178,3	39%	19599,3	23%	15943,4	11675,1	-27%	8267,2	-48%
60	13848,7	27%	12954,8	18%	10935,4	7963,1	-27%	6044,4	-45%
70	5981,0	15%	5889,8	13%	5199,3	3733,9	-28%	2962,7	-43%
80	422,5	6%	415,4	4%	397,9	354,1	-11%	235,6	-41%
90	12,6	0%	12,6	0%	12,6	11,2	-11%	6,3	-50%

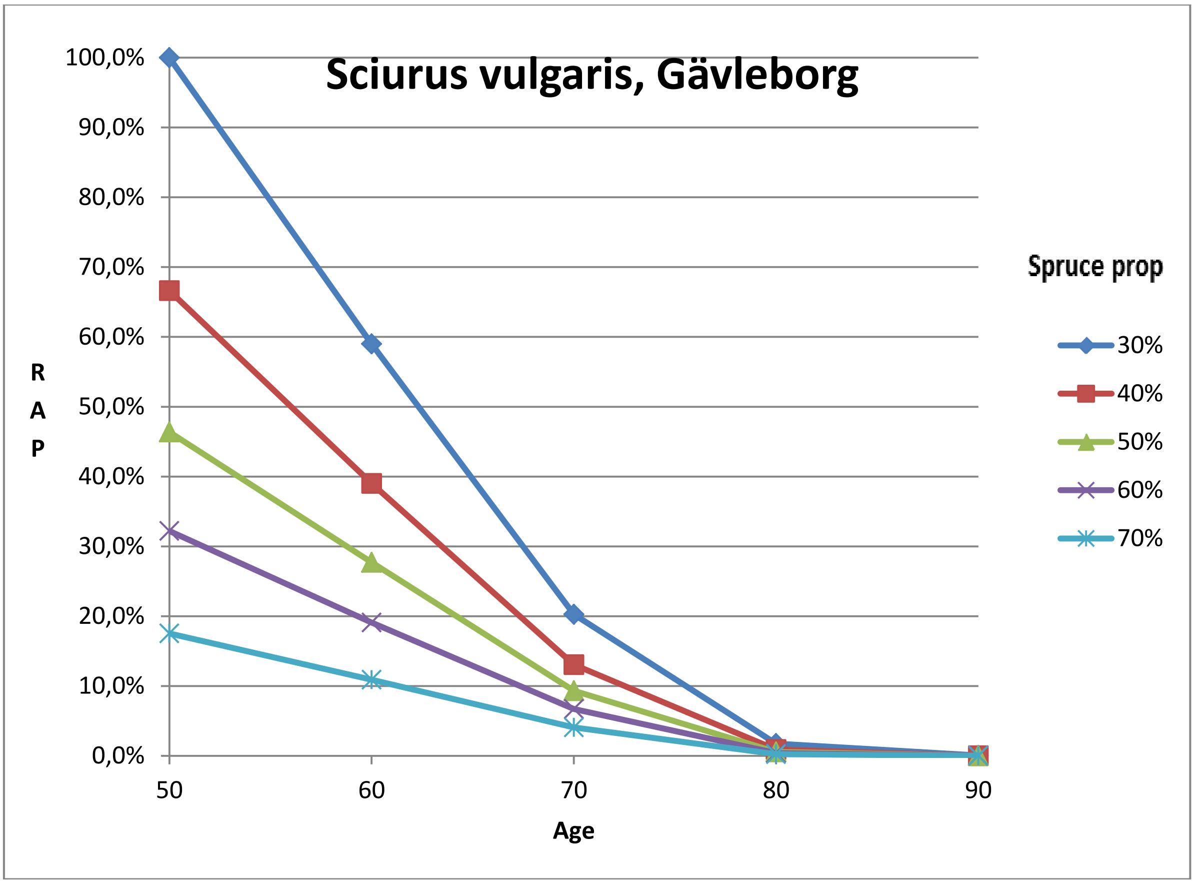

Figure 3.3 Relative Areal Points for *S. vulgaris* in Gävleborg.

Table 3.3 Area and relative change of the amount of effective habitat for *S. vulgaris* in Gävleborg. Spruce prop 50 and Age 70 as default.

	Sciurus vulgaris, Gävleborg								
	Spruceprop 30		Spruceprop 40		Spruceprop 50	Spruceprop 60		Spruceprop 70	
Age	Areal (Ha)	Change	Areal (Ha)	Change	Areal (Ha)	Areal (Ha)	Change	Areal (Ha)	Change
50	18304,1	116%	12194,4	44%	8488,7	5894,8	-31%	3207,6	-62%
60	10796,8	113%	7139,5	41%	5072,9	3493,3	-31%	1992,6	-61%
70	3708,0	118%	2390,2	40%	1703,8	1228,1	-28%	742,8	-56%
80	318,9	208%	164,5	59%	103,4	70,4	-32%	41,4	-60%
90	7,7	-	0,0		0,0	0,0		0,0	

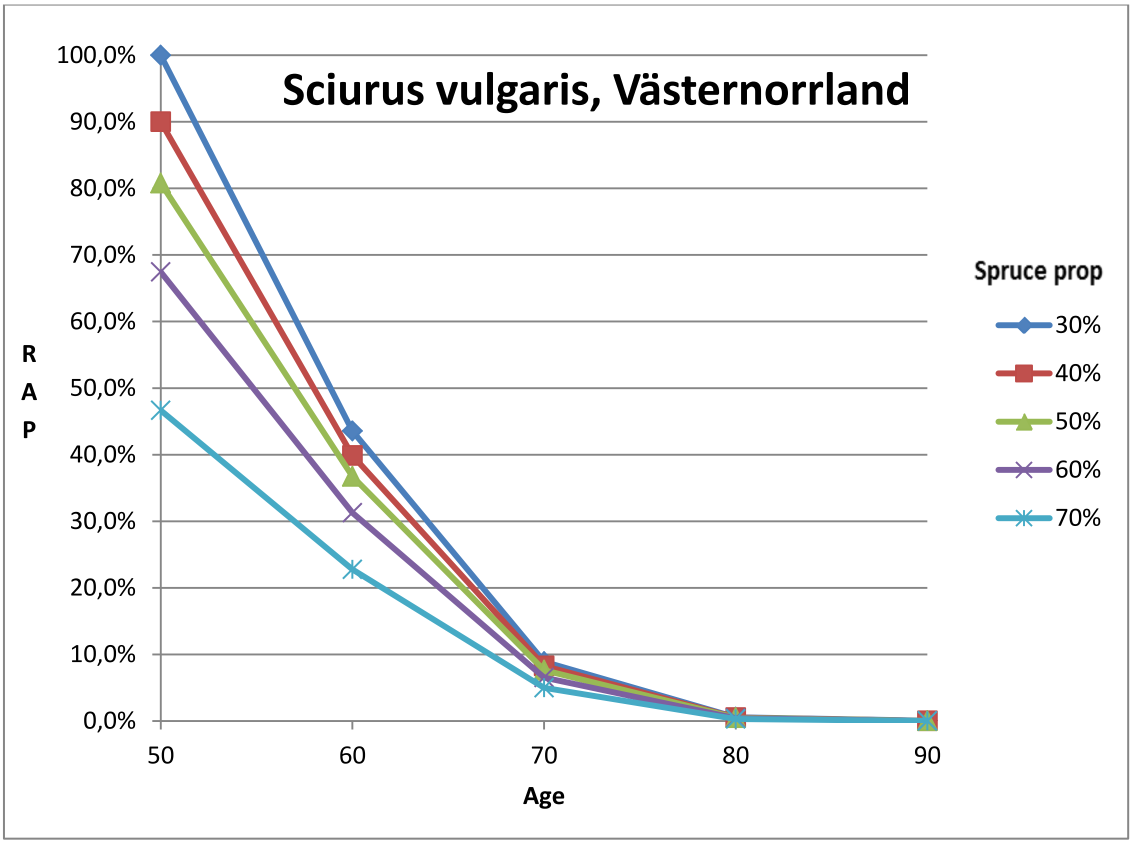

Figure 3.4 Relative Areal Points for *S. vulgaris* in Västernorrland.

Table 3.4 Area and relative change of the amount of effective habitat for *S. vulgaris* in Västernorrland. Spruce prop 50 and Age 70 as default.

	Sciurus vulgaris,Västernorrland								
	Spruceprop 30		Spruceprop 40		Spruceprop 50	Spruceprop 60		Spruceprop 70	
Age	Areal (Ha)	Change	Areal (Ha)	Change	Areal (Ha)	Areal (Ha)	Change	Areal (Ha)	Change
50	17545,7	24%	15793,3	11%	14175,4	11833,4	-17%	8185,7	-42%
60	7642,8	19%	6996,3	9%	6443,4	5486,9	-15%	3995,8	-38%
70	1560,1	17%	1451,0	8%	1339,1	1145,8	-14%	873,7	-35%
80	99,6	15%	91,5	6%	86,3	72,0	-17%	53,2	-38%
90	8,6	12%	7,7	0%	7,7	3,6	-54%	2,7	-66%

3.2 Dendrocopos minor

The sensitivity analysis for Lesser Spotted Woodpecker shows that cut-off values for both age of stands and proportion of deciduous are largely affecting the EHA (Figures 3.5 – 3.8, Tables 3.5 – 3.8). Even here the effects of changing the minimum age of stand have great effect on the EHA while the effect of changing values for deciduous proportion is less but still considerable.

100% RAP correspond to several thousand ha of EHA in all regions. From nearly 27,100 in Skåne to almost 3,300 in Gävleborg. As mentioned above, please note that the EHA for Örebro and Gävleborg below is low and explain the remarkable figures for these two regions.

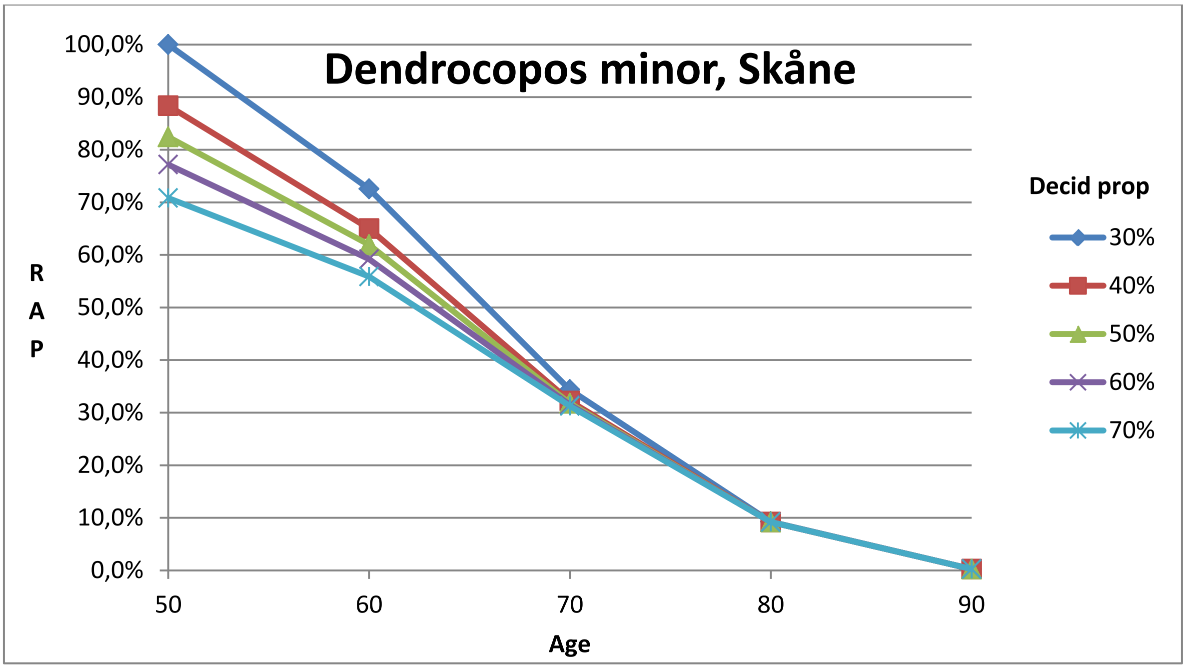

Figure 3.5 Relative Areal Points for *D. minor* in Skåne.

Table 3.5 Area and relative change of the amount of effective habitat for *D. minor* in Skåne. Deciduous prop 50 and Age 70 as default.

	Dendrocopos minor, Skåne								
	Deciduous prop 30		Deciduous prop 40		Deciduous prop 50	Deciduous prop 60		Deciduous prop 70	
Age	Areal (Ha)	Change	Areal (Ha)	Change	Areal (Ha)	Areal (Ha)	Change	Areal (Ha)	Change
50	27099,6	21%	23954,1	7%	22344,5	20916,4	-6%	19190,5	-14%
60	19663,6	17%	17614,3	5%	16784,4	16044,3	-4%	15145,4	-10%
70	9311,9	8%	8731,2	1%	8607,8	8540,0	-1%	8467,6	-2%
80	2511,3	1%	2496,5	0%	2494,1	2494,0	0%	2493,5	0%
90	71,2	1%	70,3	0%	70,3	70,3	0%	70,3	0%

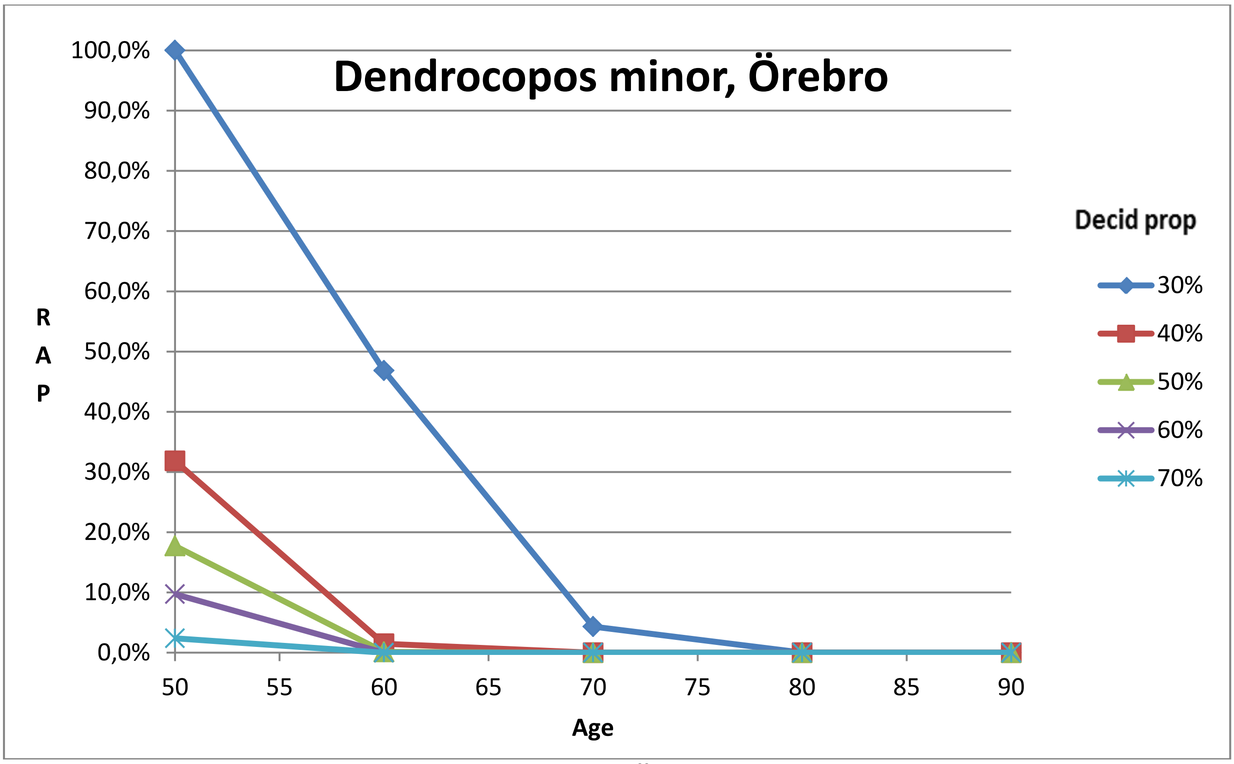

Figure 3.6 Relative Areal Points for *D. minor* in Örebro.

Table 3.6 Area and relative change of the amount of effective habitat for *D. minor* in Örebro. Deciduous prop 50 and Age 70 as default.

	Dendrocopos minor, Örebro								
	Deciduous prop 30		Deciduous prop 40		Deciduous prop 50	Deciduous prop 60		Deciduous prop 70	
Age	Areal (Ha)	Change	Areal (Ha)	Change	Areal (Ha)	Areal (Ha)	Change	Areal (Ha)	Change
50	8214,7	464%	2615,7	80%	1457,0	799,9	-45%	197,3	-86%
60	3848,7	38997%	122,4	1143%	9,8	0,5	-95%	0,0	-100%
70	356,4		0,4		0,0	0,0		0,0	
80	1,7		0,0		0,0	0,0		0,0	
90	0,4		0,0		0,0	0,0		0,0	

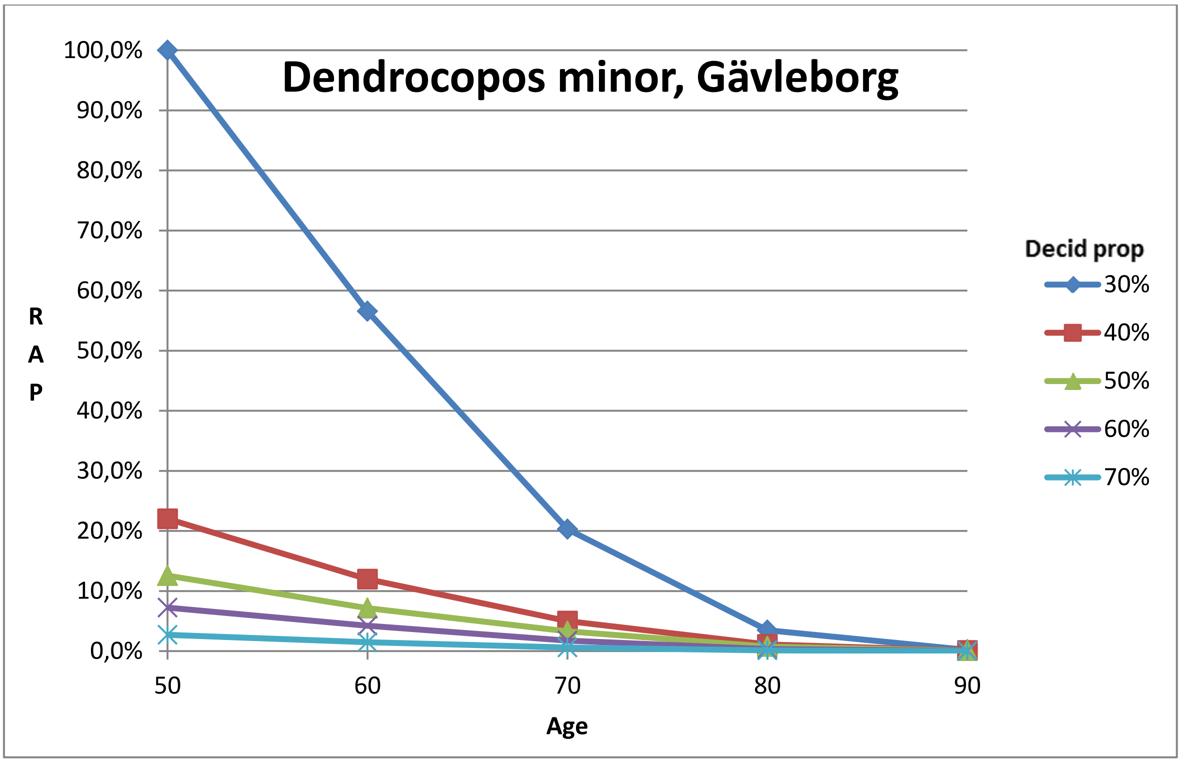

Figure 3.7 Relative Areal Points for *D. minor* in Gävleborg.

Table 3.7 Area and relative change of the amount of effective habitat for *D. minor* in Gävleborg. Deciduous prop 50 and Age 70 as default.

	Dendrocopos minor, Gävleborg								
	Deciduous prop 30		Deciduous prop 40		Deciduous prop 50	Deciduous prop 60		Deciduous prop 70	
Age	Areal (Ha)	Change	Areal (Ha)	Change	Areal (Ha)	Areal (Ha)	Change	Areal (Ha)	Change
50	3269,7	695%	719,7	75%	411,2	236,7	-42%	88,9	-78%
60	1849,1	691%	391,6	68%	233,7	137,9	-41%	48,5	-79%
70	663,6	515%	163,6	52%	107,8	57,7	-46%	20,3	-81%
80	114,2	353%	36,8	46%	25,2	11,2	-56%	4,2	-83%
90	7,2	232%	3,7	71%	2,2	1,8	-17%	0,0	-100%

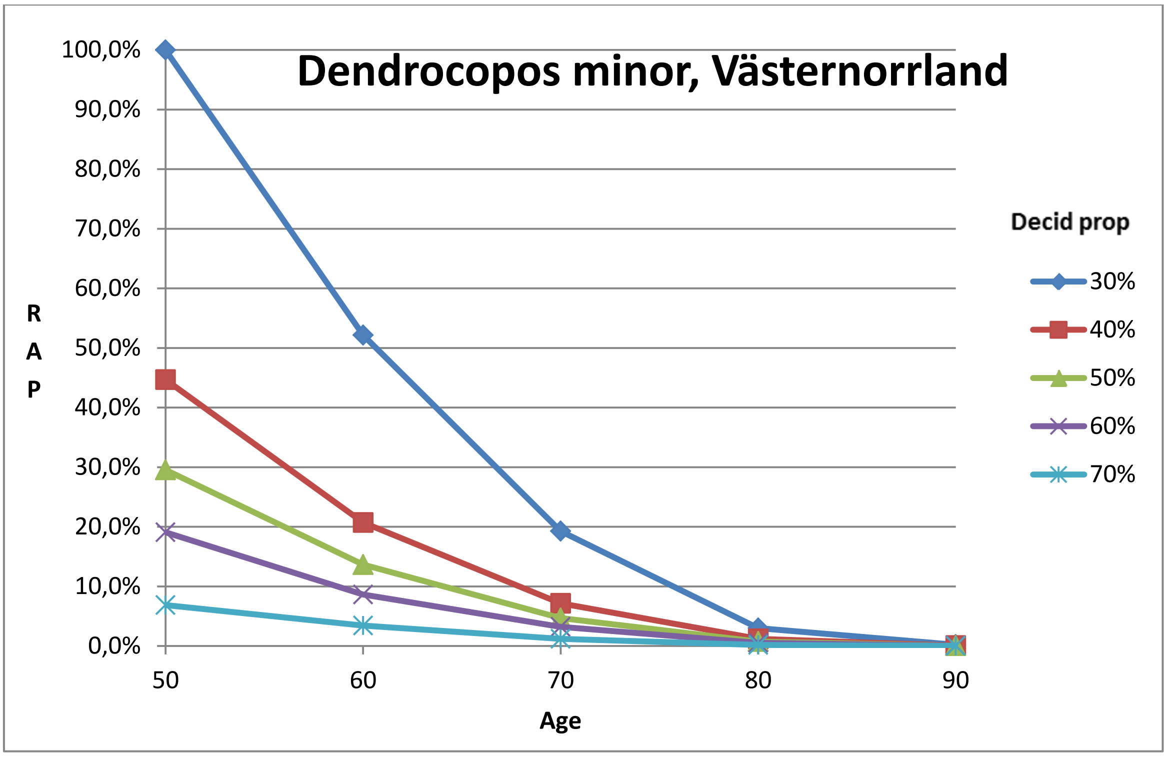

Figure 3.8 Relative Areal Points for *D. minor* in Västernorrland.

Table 3.8 Area and relative change of the amount of effective habitat for *D. minor* in Västernorrland. Deciduous prop 50 and Age 70 as default.

	Dendrocopos minor,Västernorrland								
	Deciduous prop 30		Deciduous prop 40		Deciduous prop 50	Deciduous prop 60		Deciduous prop 70	
Age	Areal (Ha)	Change	Areal (Ha)	Change	Areal (Ha)	Areal (Ha)	Change	Areal (Ha)	Change
50	14351,0	238%	6411,4	51%	4241,7	2739,4	-35%	983,5	-77%
60	7485,1	282%	2973,7	52%	1958,1	1239,1	-37%	493,5	-75%
70	2765,5	310%	1027,4	52%	674,6	459,7	-32%	170,3	-75%
80	429,7	305%	170,3	61%	106,1	74,9	-29%	24,3	-77%
90	28,1	262%	10,9	40%	7,8	5,8	-25%	1,0	-88%

3.3 *Alectoria sarmentosa*

The result of analysis for Witch's Hair was quite confusing. Not a single stand in any of the regions fell out as suitable. It seems like the version of the habitat module for *A. sarmentosa* that I had access to was not correctly debugged. As mentioned earlier this modules are built to work integrated in the Heureka system while I got modules for running in ArcGis. It was supposed that the modules handed to me would be the same as the incorporated ones. Unfortunately that seems not to be the case. If one manually reads the databases and search for stands that might fulfill the demands (age and spruce proportion) one could see that there are suitable areas that the model should have found. Tests made later of another version also result in suitable areas.

4. DISCUSSION

The purpose of this degree project was to investigate the performance of the habitat models used in the Heureka forest decision support system. This was done by using sensitivity analysis. The methodology of sensitivity analyses has proven to be a useful tool in assessing effects of environmental processes and status (Newham et al. 2003, Venier and Pearce 2004, Alvarez et al 2013). The application of sensitivity analysis to the outcome of habitat modeling, although highly recommended (Ashley Steel et al. 2009, Venier and Pearce 2004) seems not to be a routine procedure. More commonly the sensitivity is applied to data used in modeling rather to the model itself (e.g. Stoms et al. 1992, Manton et al. 2005, Edman et al. 2011). In this respect my study that applies sensitivity analysis to parameter value is rather unique.

As the figures above show the results for both Red Squirrel and Lesser Spotted Woodpecker are logical and somewhat what was expected; the more the requirements increase the fewer suitable habitats there are. Generally one can see a more dramatic outcome of changes of parameter values where EHA is already low when default values are used. While studying the diagrams one might see that when EHA for default values is 1,000 ha or more it seems that the model is more stable. This might indicate that one has to be careful when using the models in areas with generally low amount of habitat in question. If the default values give very low amount of EHA lowering cut-off values is advised. In the case of Lesser Spotted Woodpecker and particularly Red Squirrel, it seems that lowering the minimum age of stands will be the best solution here since this parameter appear to be more sensitive.

My results show that in all regions default values in the Heureka system indicated that generally a very little fraction of forests provide suitable habitat (from none at all in Örebro for Red Squirrel and only 44,3 ha of totally 38 525 ha forest area for Lesser Spotted Woodpecker in Skåne). This confirm the general notion that forestry in Sweden as a very intensive cause depletion of habitat for specialized species (Manton et al 2005, Angelstam et al. 2011). Use of Heureka's biodiversity module may improve our possibilities to tackle the conservation dimension in forestry by be able to predict consequences of different management strategies.

The change in parameter value had a profound effect on the amount of effective habitat for the two studied species and may have great consequences on the EHA. In particular change of mean stand age has big effect. This calls for caution among users especially when analysis is done on areas with low amount of suitable habitat. According to this study it is recommended to change mean stand age in small steps to avoid strange or inaccurate result according to passing critical thresholds. This is especially important when the input data represent small areas. Small areas could depend on the structure of stands, distribution of environmental factors important for the actual model (e.g. age, tree species distribution) or that the investigated area itself is small and more prone to random effects.

For Red Squirrel suitable habitat older than 80 years seems to be very rare in the data used to feed the models (i.e. kNN estimates). The sensitivity of HSI models in this study to change in cut-off values concerning the age is linked to the abrupt slope in the forest age distribution curve in these data with very few forests stands being older than 80 years (see fig. 7.1-7.4). Such a distribution, partially linked to the deficiencies of kNN discussed below but mostly based on the production cycle in forestry largely affected the results of sensitivity analysis.

Some regional differences can be observed. For Red Squirrel one can see a slight increasing of RAP the further north one get. That was expected considering that stands of older spruce are more common to the north.

For Lesser Spotted Woodpecker one could suppose an increasing level of suitable habitat the further southward one got as deciduous proportion is an important factor and one can expect more deciduous in the south of Sweden than further north. Strangely one can observe more of EHA in Västernorrland than in both Örebro and Gävleborg. That may seem confusing especially as the relative deciduous volume is slightly higher in Örebro than Västernorrland (19.2% respective 18.1 %). EHA for 100% RAP was 8,214.7 ha in Örebro, 3,269.7 ha in Gävleborg and in Västernorrland 14,351 ha. EHA with default values provided none habitat for Örebro, only 107.8 ha in Gävleborg and 674.6 ha in Västernorrland. However, Västernorrland has the highest forest cover and therefore general amount of deciduous component is higher. Moreover, higher forest cover may also imply that landscape scale effects causing much higher functionality of deciduous environments in this plot in comparison to the ones in Gävleborg and Örebro (Angelstam and Mikusiński 2003, Mikusiński and Edenius 2006). On the other hand, plot located in Skåne with lowest forest cover thanks to the fact that forests are dominated by deciduous trees still provides quite a lot of suitable habitat for the species.

Another thing that may influence in this matter is that in the south stands are generally smaller and not so seldom isolated forest lots in an agricultural landscape while stands are generally bigger in the north and often located in continuous forest areas. So it would be easier to find enough of suitable area in the surroundings in the north. So good knowledge of structure of size and spatiality of the investigated area is crucial to be able to make correct analyze of the result. One also should have in mind that forest cover in Skåne is 61% while it is 83% in Västernorrland.

It is important to remember that my analysis was mostly oriented towards the estimation of how sensitive Heureka's models are to changes in parameter value. The regional differences observed in this study are of seconday importance especially taking into account the fact that just one square in each region cannot be treated as fully representative for the region. Still however, some general differences among regions were expressed by my results give indication on effects on studied HSI.

The sensitivity analysis performed in this study has several deficiencies. One is that I just tested models for only two out of six species. Another is that I didn't try to validate my result in any mathematical statistic significant way.

Manton et al (2005) points out that sensitivity analyses shall be done to evaluate input data when using remote sensing in Habitat Suitability Index (HSI) modelling. Land cover data might need to be combined with other landscape information to get an effective tool for planning for functionality and connectivity of suitable habitat. Remote sensing based cover data does not indicate many important forest variables such as dead wood and foliage diversity (Manton et al. 2005).

In this study only one source of data have been used that have high level of uncertainty itself especially in terms of spatial context i.e. particular pixels are not necessarily representing habitat present in particular spot. The SLU Forest Map aggregate pixels to stands on 2 – 10 ha with mean values. This may be particularly important for two variables used in my analysis namely percentage (volume) of deciduous trees – low quality at fine resolution and age in the case of spruce – low quality for older forest. When aggregate pixels up to 2 ha one could think that single standing deciduous trees falls out and will be missing. This would lead to underrepresenting. Another consequence of working with mean values is that extreme values tend to disappear. Everything drags to the middle. (Mats Nilsson pers. comm. 2013-01-23). Aggregate mean values up to 10 ha segments or more would likely aggravate this.

Reese et al. (2003) says that users have to be aware of accuracy of the estimates and the minimum mapping unit. "Forest variable estimates produced using the kNN method usually have low accuracy, if accessed on a pixel (around 30 m) basis. In addition, the accuracy is limited for stands with high stem volumes". Due to Landsat's limited information of denser and older forest it tends to overestimate lower values and underestimate higher values of forest variables. Accuracy of wood volume for different tree species is less than for age and total wood volume (Reese et al. 2003).

On the other hand both models are summing up the habitat quality over relatively large areas; in the study I've looked on 625 km^2 – the scale allowing for landscape studies.

Another issue is the simplicity of models based just on a few parameters. As mentioned above, important variables as dead wood and foliage diversity are not included in SLU Forest Map and are not taken in consideration. It is also quite possible that in some landscape where the amount of habitat for certain species according to Heurekas´s biodiversity module is zero or close to zero species actually occurs. This may be linked to the fact that models of indicator or umbrella species is just models that point out the probability of occurrence and not actual presence. As Barry and Elith (2006) points out models are simple approximations of the true probability surface and an attempt to summarize complex distributional patterns with a reduced set of predictor variables. Models will always contain some degree of mismatch between the prediction and the actual conditions.

5. CONCLUSIONS

The sensitivity analyses indicate that changes in parameter value may have great consequences in result of effective habitat area for examined species. In particular change of stand age has great effect. Some regional differences can be observed.

Generally one can see a more dramatic outcome of changes of parameter values where Effective Habitat Area is low already when default values is used indicating generally low amount of habitat in the landscape. Therefore, I argue, that one has to be careful when using the models in small areas. If the default values give very low amount of EHA lowering cut-off values is advised (e.g. stand age).

My results enable the future users of Heureka´s habitat module to critically examine possible effects of the changing parameter values on the results. Good knowledge of structure of size and spatiality of the investigated area is crucial to be able to make correct analyze of the result as well as knowledge and insight of forces and deficiencies of the input data.

Finally, I would like to stress once more that habitat models are just a methods to assess, with uncertainty, probability of species occurrence and not necessarily the real occurrence. Since module is used to compare different scenarios over time I argue that the most important is to see the direction of changes rather that absolute number of individuals.

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6.2 Internet documents

Link A http://www.svenskfastighetsmarknad.se/2011-2/skogsmarknaden). 2012-12-18

Link B: Artdatabanken http://www.slu.se/artdatabanken/ 2013-11-12

Link C: Edenius, L. Mikusiński, G. Framework for building models for species habitat suitability assessment in the biodiversity module of Heureka system http://heurekaslu.org/mw/images/6/64/Heureka_Habitat_models.pdf 2013-11-13

Link D: SLU Skogskarta http://skogskarta.slu.se/ 2011-01-31

6.3 Personal messages

Nilsson, Mats, Researcher. Remote Sensing Laboratory, Forest Resource Management, Swedish University of Agricultural Sciences, E-mail correspondence [2013-01-23]

Wikström, Peder, former researcher at SLU, Umeå, now consultant at Peder Wikström Skogsanalys. [2013-02-15]

7. APPENDIX

7.1 Technical details

The habitat models are developed and adjusted to run on data from Heureka. This analysis is made in ArcGIS on data direct downloaded from SLU Forest Map. Because of that some columns in the attribute tables had to be added. No changes of original dataset has been done but new columns has consistency been added even if that in most cases resulted a copying of data from an old column to a new one with a new name.

This models were supposed to be exactly the same modules that is included in Heureka but here as incorporated separate tools included in ArcGIS toolbox.

The conditions that had to be fulfilled to run the models were:
ArcGIS v. 9.3.1
License level has to be ArcInfo
Spatial Analyst has to be activated under Extensions

Columns added to SLU Forest Map dataset is:
MeanAge, which equals Age_mean in SLU Forest Map.
Volume, which equals Voltot_mea in SLU Forest Map.
ResultId, which equals FID in SLU Forest Map. As far as I understand this column only needs a unique number.
VolLeaf wich is the sum of the mean value of all deciduous (Birch, Decid, Oak, Beech).
VolSpruce which equals Spruce_mean in SLU Forest Map.
AGOSLAG Where all fields are set to value 1

All the new fields are set to the format Double.

7.2 Some data over the sites

Skåne

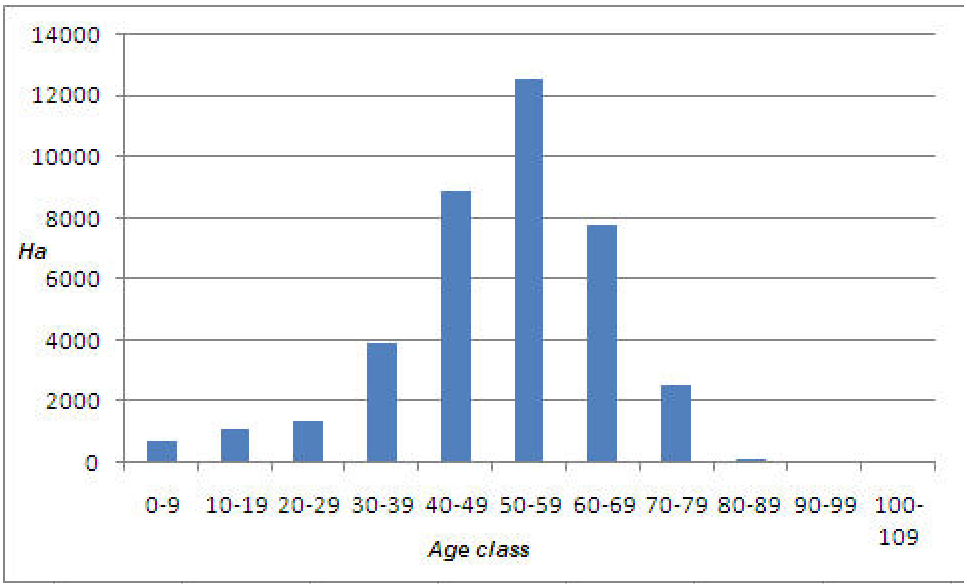

Figure 7.1. Age distribution in Skåne.

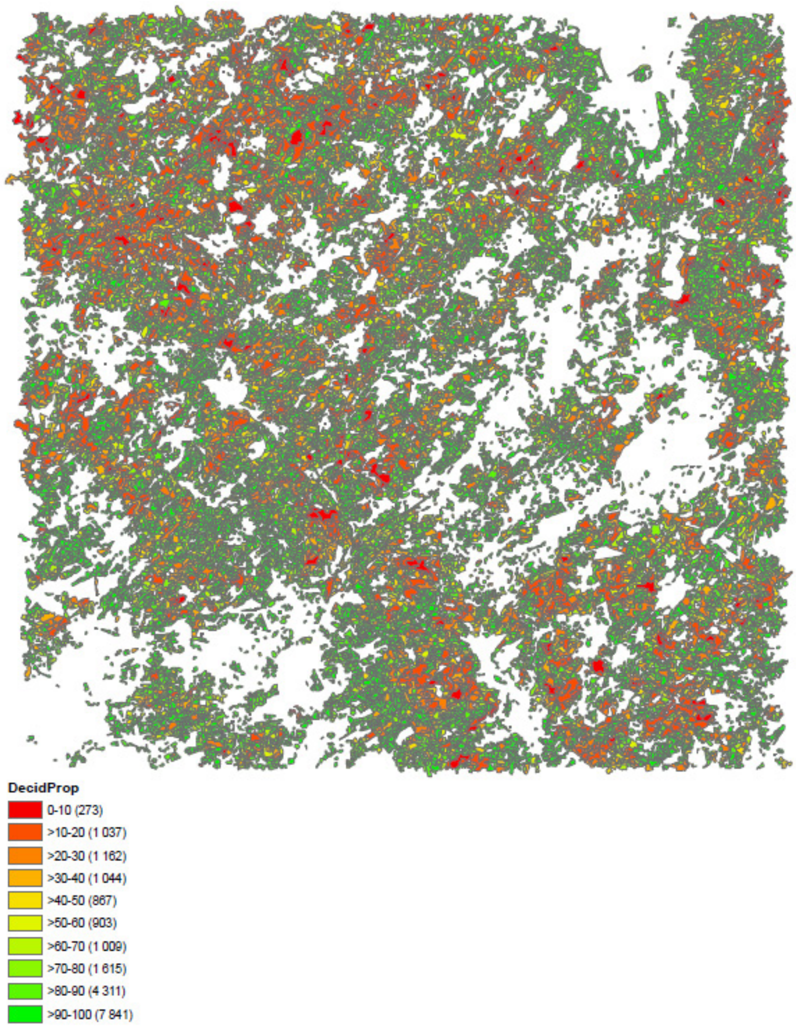

Figure 7.2 Distribution of deciduous in Skåne.

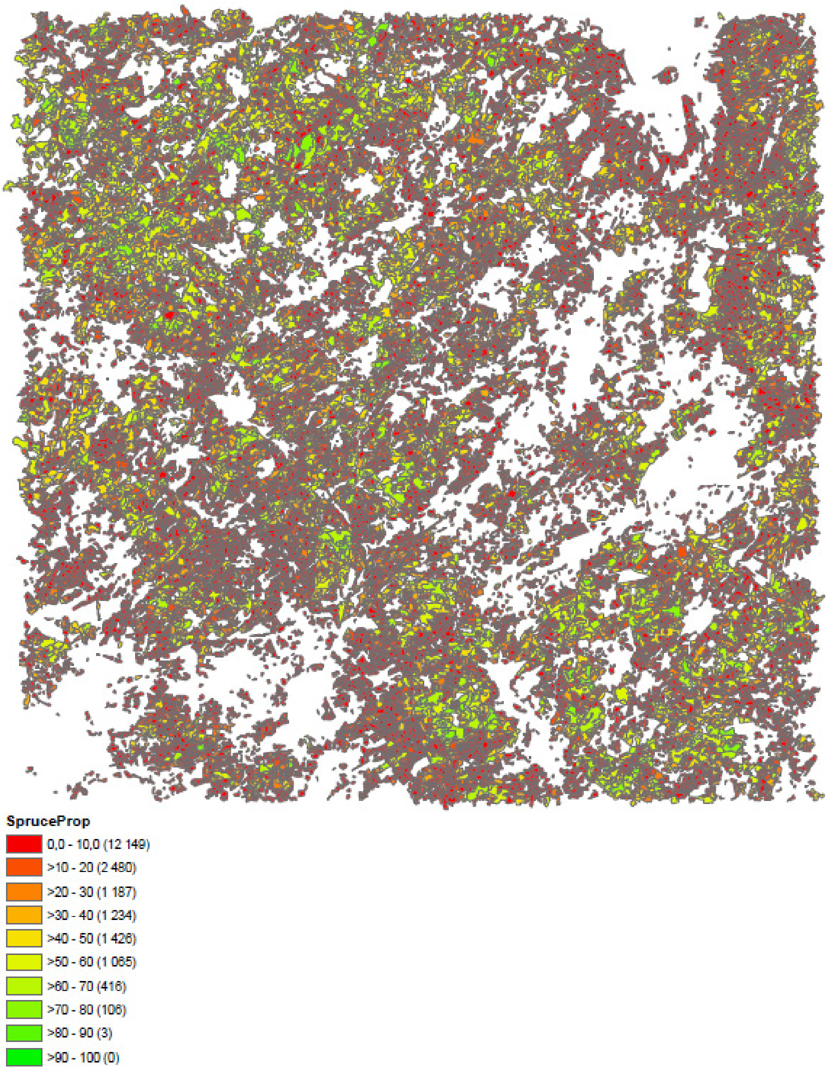

Figure 7.3 Distribution of spruce in Skåne.

Örebro

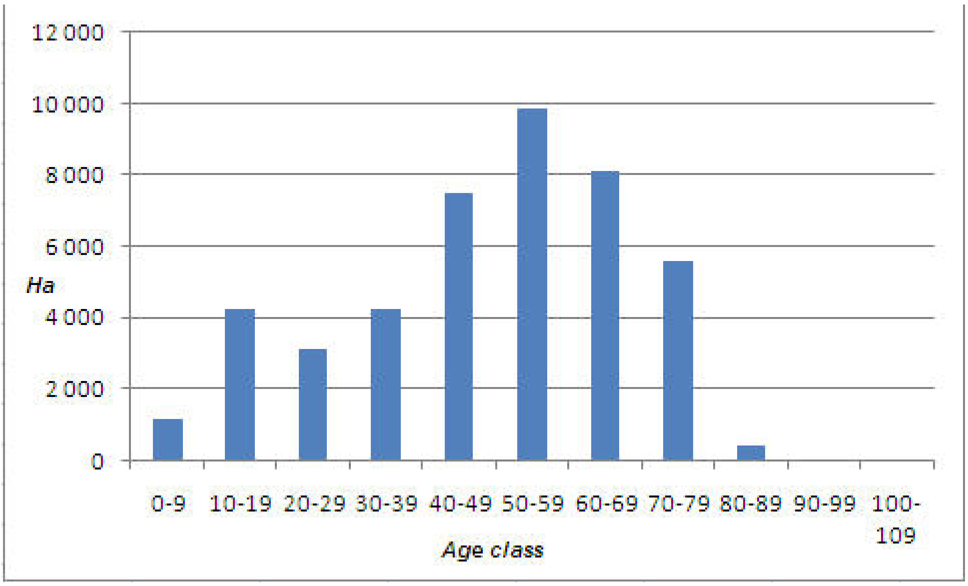

Figure 7.4 Age distribution in Örebro

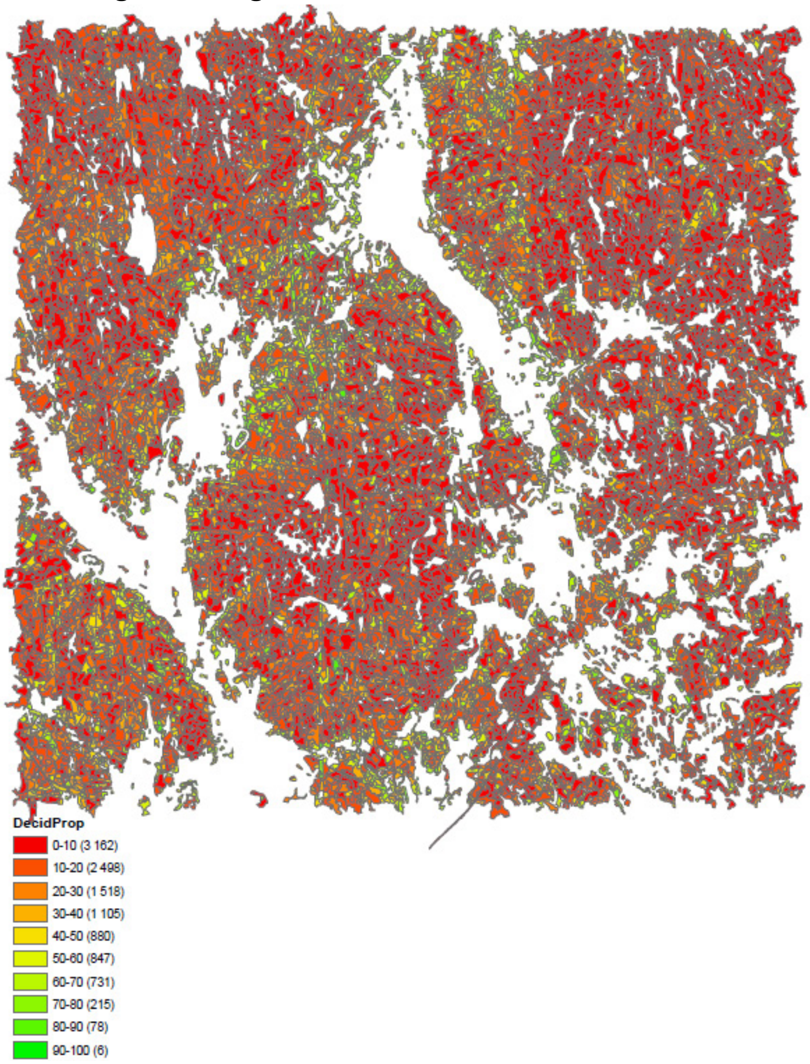

Figure 7.5 Distribution of deciduous in Örebro.

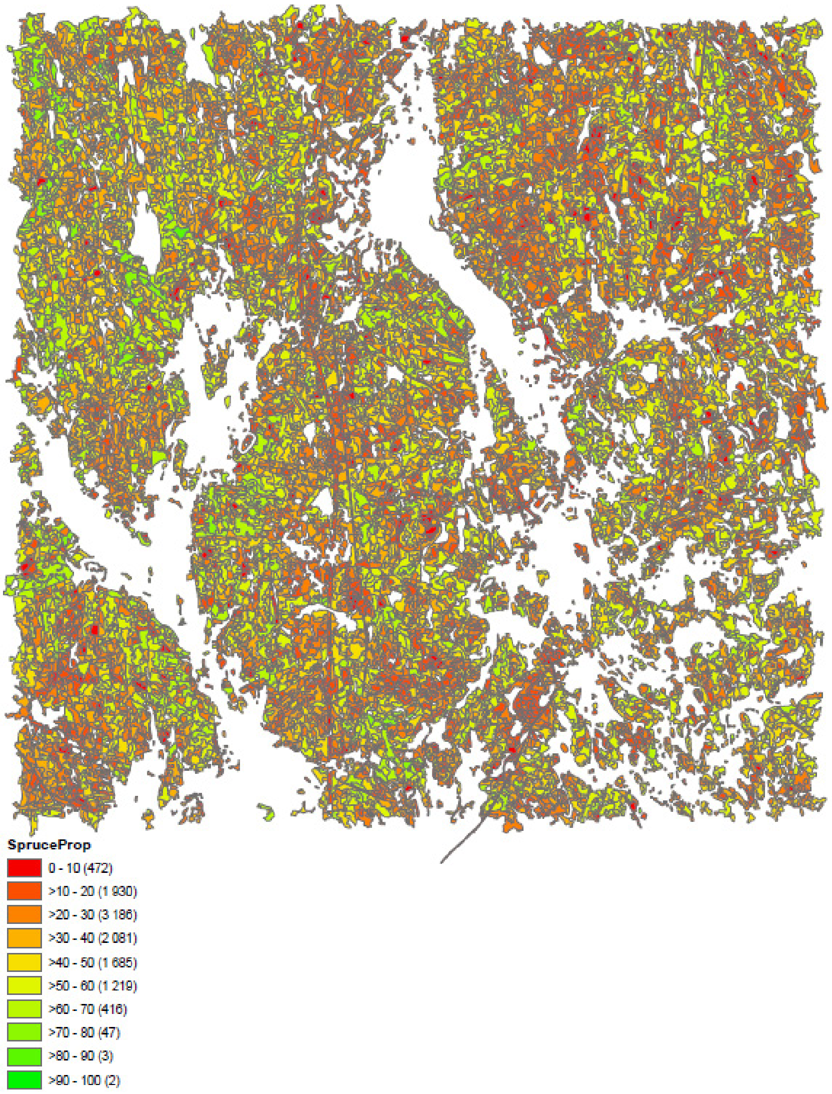

Figure 7.6 Distribution of spruce in Örebro.

Gävleborg

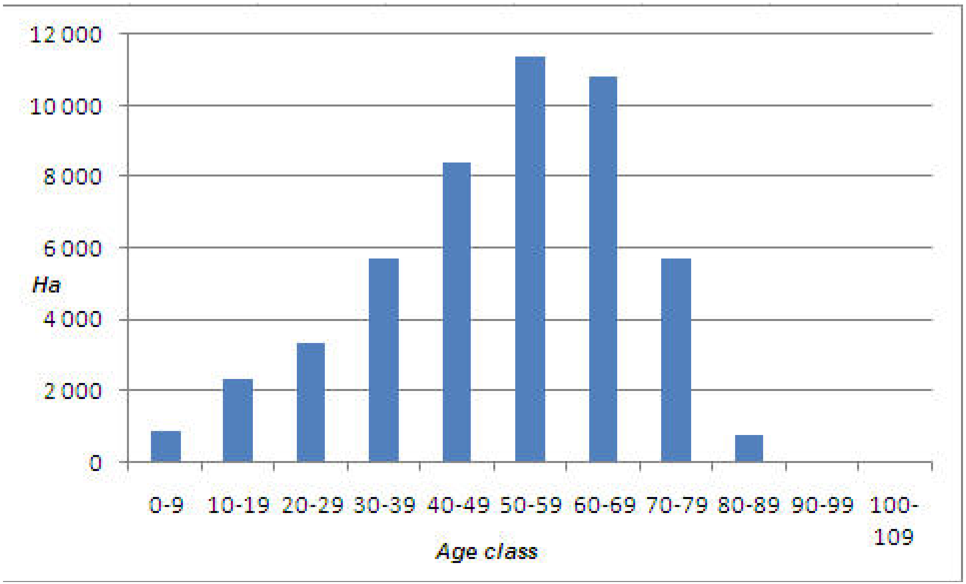

Figure 7.7. Age distribution in Gävleborg

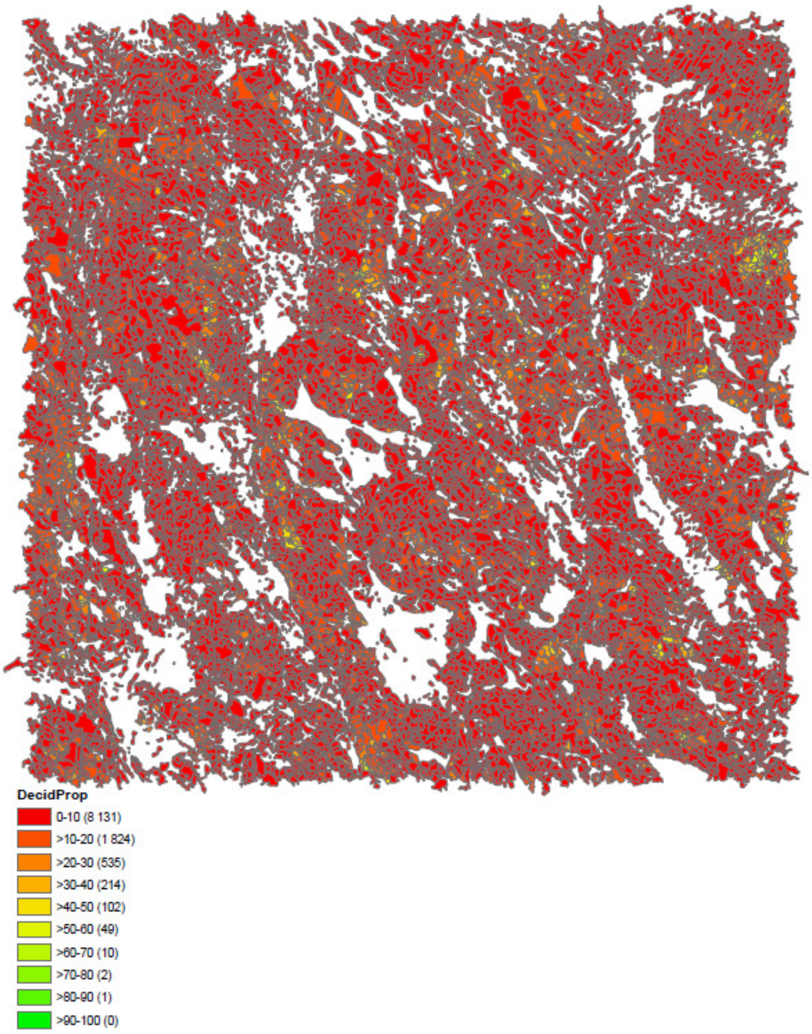

Figure 7.8 Distribution of deciduous in Gävleborg

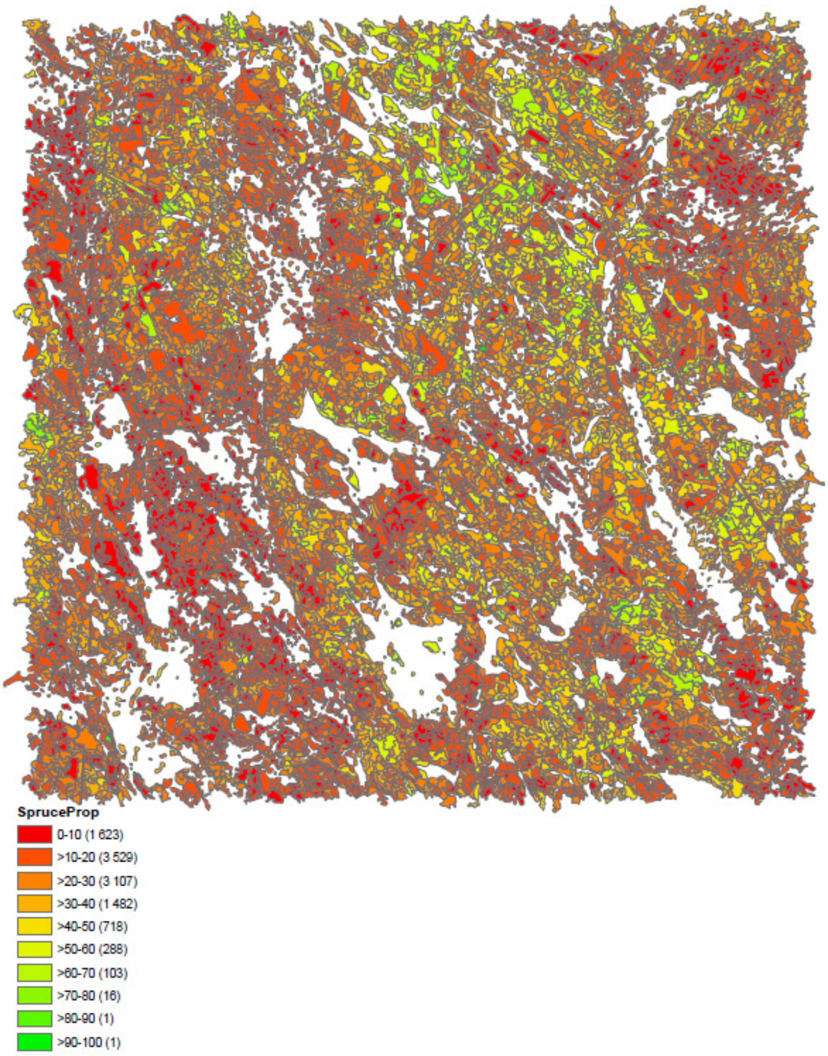

Figure 7.9 Distribution of spruce in Gävleborg

Västernorrland

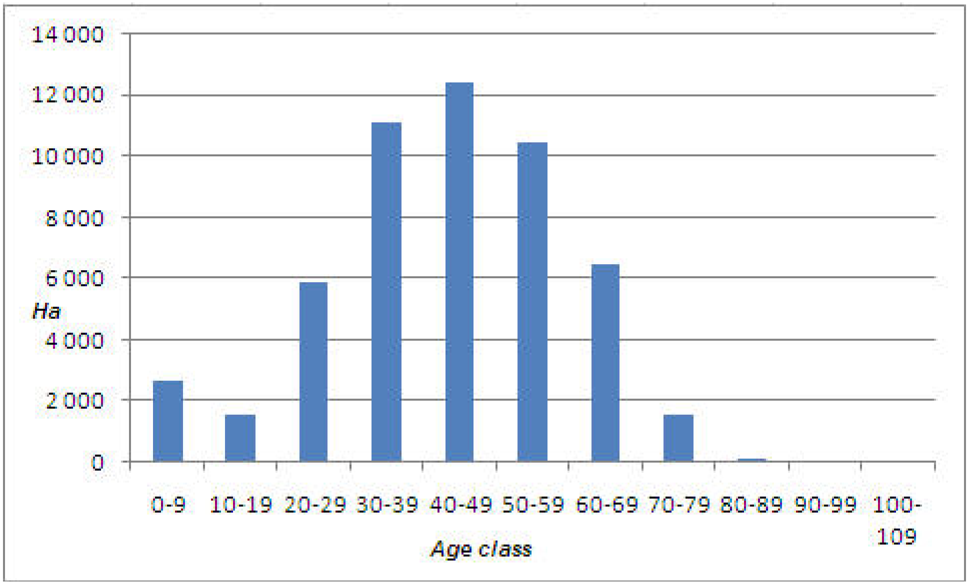

Figure 7.10. Age distribution in Västernorrland

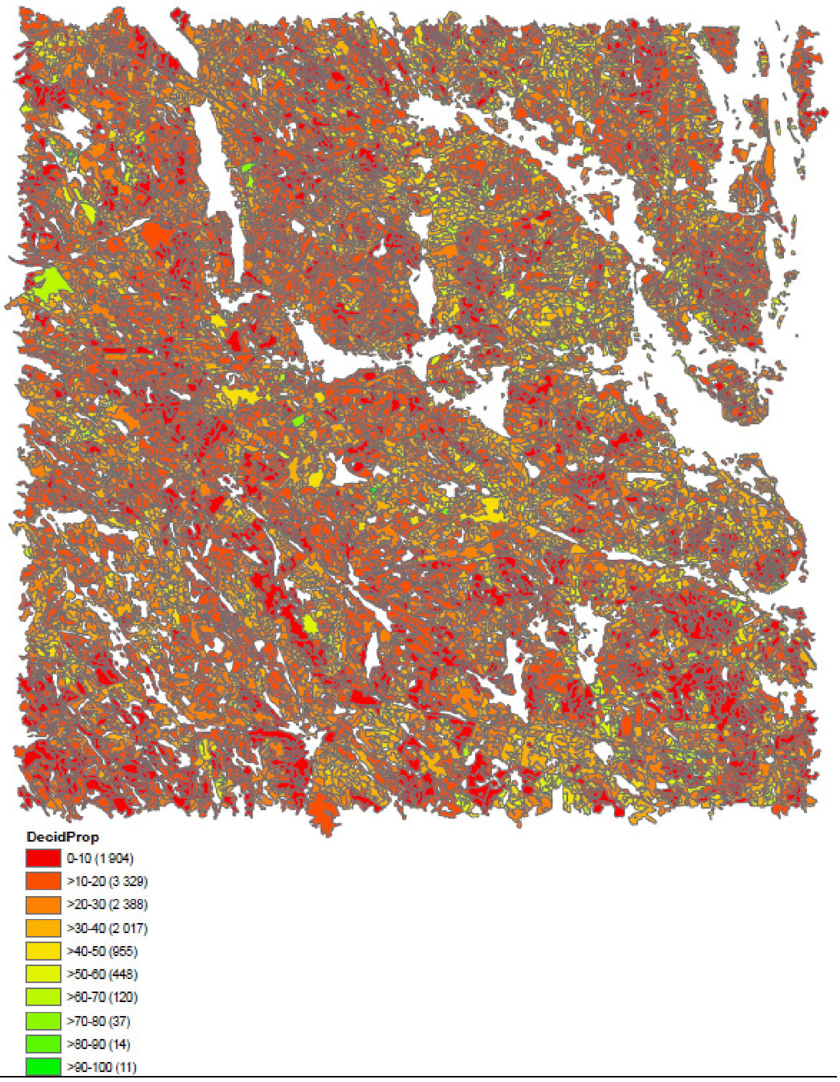

Figure 7.11 Distribution of deciduous in Västernorrland

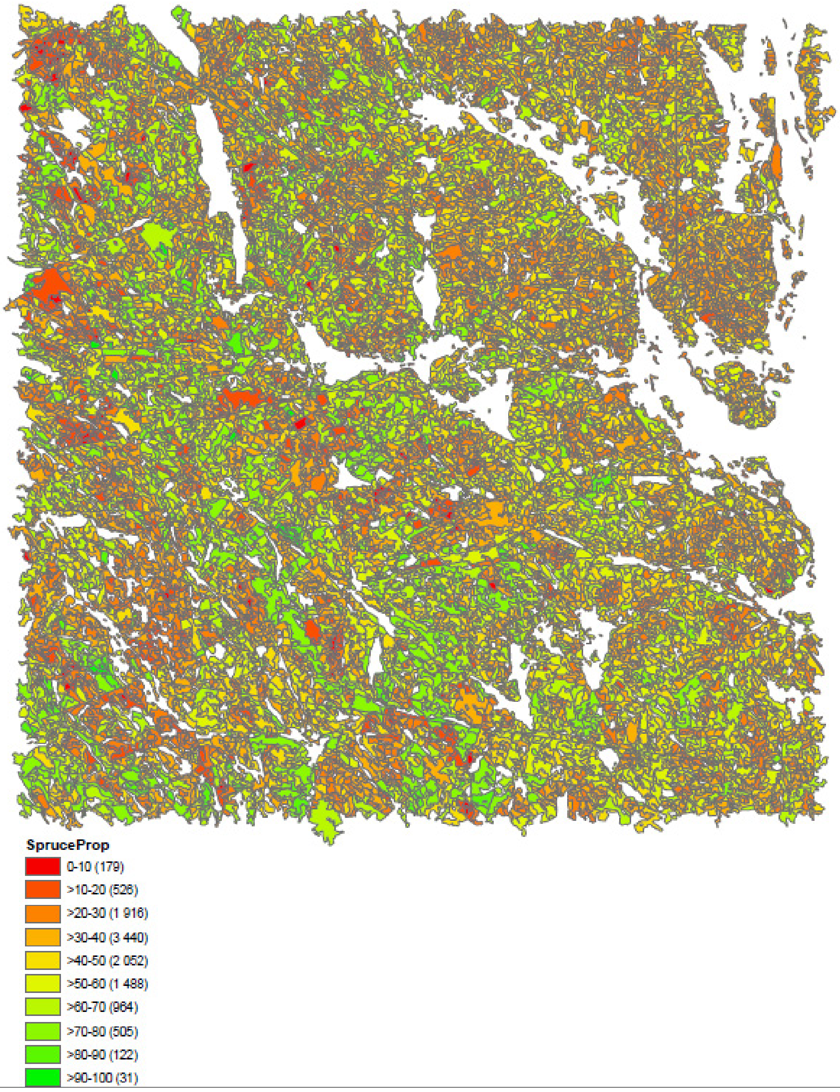

Figure 7.12 Distribution of spruce in Västernorrland