Changes in landscape configuration and occupancy of northern goshawk and Ural owl territories

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Summary

Landscape fragmentation is one of the processes strongly related to human activities. During this process, an area is divided into smaller pieces and usually, these pieces have different predestination. As a result natural areas lose their connections, which are vital for animals and plants. Finland is mainly covered with forest that is also affected by landscape fragmentation. Thus, forest species are under threat and biodiversity can be reduced to a critical level. Monitoring of the biodiversity is usually a complicated and long process, but for facilitating research indicator species are often used. Examples of these are the northern goshawk and Ural owl. In this research the relationship between these species occupancy and landscape configuration in Suupohja area was investigated and tested. A strong connection was found between Northern goshawk occupancy and the mature spruce forest. Furthermore, a connection between decreasing species population and increasing amount of low-stocking forest was observed. Changes in the protected areas in Suupohja were also studied for the period 2009-2013. As a result, a decrease in human activities and an increase in the amount of mature forest due to natural growth were found, which confirms the security of this area and its name of protected areas.

Language: English

Key words: landscape fragmentation, landscape configuration, natural reserve, species distribution, Northern goshawk, Ural owl

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Abbreviations

AG – northern goshawk (*Accipiter gentilis*)

GDP – Gross Domestic Product

NR – Natural reserve (Protected areas)

SU – Ural owl (*Strix uralensis*)

1. Introduction

It is very hard to find a place in Europe, which is not affected by human activities. It is clear that the development of civilization requires more space for settlements, food production and other human activities. As a result, the landscape has changed drastically around the whole continent. Especially, these changes have affected areas located around centers of human activities, such as settlements. Each year the big cities require more and more area for urban expansion. For instance, in Finland the number of cities increased by 57 % between 1950 and 1998 (Heikkilä & Järvinen, 2002), which means more area is required for people to live on.

The fast growing population and the development of the countries expanded the transport networks, so that the density of these networks is high. This is one of the examples of impact through human activities causing landscape fragmentation, which is a result of transforming large habitat patches into smaller fragments of habitat. Very often these small fragments are isolated from each other and as a result, they are losing connectivity. These connections are, however vitally important for ecological systems. The access of the species to different types of habitat is important for a functional lifecycle (European Environment Agency (EEA), 2011).

Moreover, scientists believe that a major factor for the decline of species populations, the modification of native plant and animal communities, and the changes in ecosystems, is the destruction and fragmentation of the landscape. Removal of native vegetation and breaking up the habitat patches into smaller pieces are causes for destroying the microclimate in the ecosystem. Possible changes are increasing access to sunlight (in, for example, the case of forest clearing), changes in wind speed, rising air and ground temperature, etc. These changes are affecting biological processes that are vital for the animal and plant community. The changes can affect the food chain, deprive the animals of their homes and destroy their habitual way of life in the ecosystem (Sodhi & Ehrlich, 2010).

It is clear that different species have different requirements for the landscape they are living in and they select the most suitable habitats for their living. The species studied in this thesis are the northern goshawk and the Ural owl. These species are similar in their requirement of the mature mixed spruce forest for their success (Burgas, Juutinen & Byholm, 2016).

The objective of this thesis is monitoring changes in the landscape configuration in the time period from 2009 to 2013 and investigating relationships between these changes and species distribution at Suupohja, Western Finland. That's why research is concentrated on assessing changes mainly in the forest cover. This thesis is the initial stage of more global research about relationships between the landscape configuration and biodiversity in Western Finland. For this thesis two hypotheses were composed, which reflect the main objectives of this study:

1. There is no decrease in the amount of the spruce forest accompanied by an increase in agricultural and urban areas in protected areas (NR).
2. There is a strong relationship between the amount of spruce forest and occupancy of northern goshawk (AG) and Ural owl (SU) territories.

2. Theory background

2.1 Landscape fragmentation

According to common understanding, landscape fragmentation is a process that is mainly related to human activities. By definition, this is the process of changing or transforming the natural landscape into smaller pieces. One can imagine a sheet of squared graph paper and color pencils. For some reason, it was decided that the right part of the paper will be in red color, the center in blue and the left part in yellow, but at the same time, the biggest part of paper was left in its original state with the white color. Now, on the paper four different colors (categories) are present on our list (Figure 1). Beside the originally white color on the paper is a piece of ground with some uniform nature vegetation (white color), where a farm was built. So, as a result, the natural vegetation for houses (red color squares) was cleared, an artificial lake was made for irrigation (blue squares) and, finally, the land was converted into an agricultural area (yellow squares). The original uniform white becomes natural vegetation. This is a simple example of landscape fragmentation.

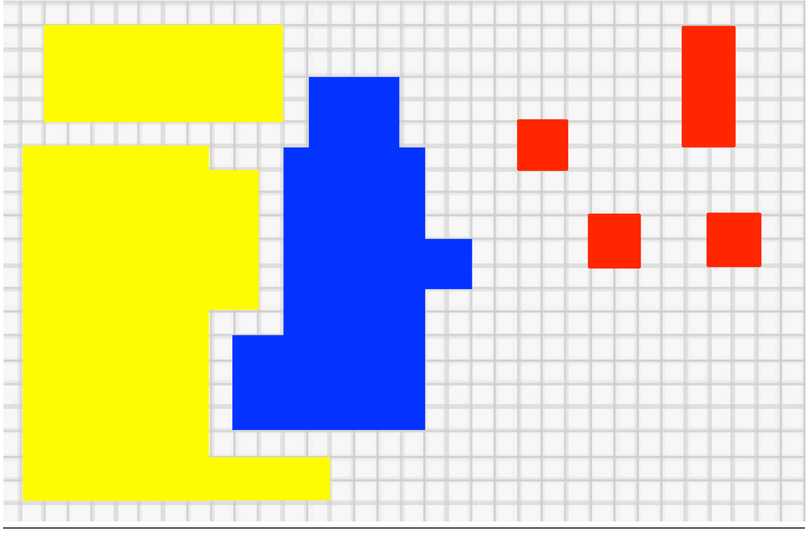

Figure 1. Simple model of the landscape fragmentation (red color – houses, blue – water, yellow – agricultural fields)

However, in this example the explain edge effect that could be present in the landscape fragmentation process was not clear. This effect arises when two different habitats have a common border. For instance, mature forest and agricultural area have one border, but obviously environmental conditions in these landscape classes are different. Some species can extract benefits from this edge effect, but it can be a trigger for species invasion from the other ecosystem and may create competition between species (Bannerman, 1998).

According to Sodhi and Ehrlich (2010), the fragmentation process has three interrelated stages. At the first stage, removal of the original habitat takes place (e.g. original vegetation), the second stage is the subdivision of the remaining habitat into fragments (direct fragmentation) and the final stage occurs with the introduction of new habitats in the places where original vegetation is lost. Moreover, the process of landscape fragmentation is dynamic and continuous.

At the same time, Fahrig (2003) divided landscape fragmentation into four stages and concluded that these stages are more quantitative and, as a result, can be used for assessing landscape fragmentation. According to this research, fragmentation has a stage of a reduction in the amount of habitat, an increase in the number of patches, a decrease in the size of the patches and, finally, an increase in patch isolation. However, it is very common that in the assessment of landscape fragmentation, scientists used one, two or three, but not all four effects. Moreover, it is understandable that different stages have different impacts on the biodiversity, so this may lead to contradictory results.

Socio-economic drivers are the main reasons for landscape fragmentation. A common opinion among scientists is that the landscape is more fragmented around urban centers. This theory is supported by geographic economic theories, which indicate a decrease in economic activities with an increase in the distance from the population centers. This means that an area will be more fragmented if it has a high population density, higher GDP, volume passenger density and quantity of goods loaded and unloaded per capita (EEA, 2011).

But the effects of fragmentation are visible not only around urban centers. It is clear that human activities are spread out according to people’s needs. Except for urban development, other drivers behind the landscape fragmentation are the industrialization, the intensive agriculture, and forestry, as well as the expansion of transport networks. Scientists have summarized the effects of landscape fragmentation into three parts: a decrease in habitat area, a reduction in the size of the habitat and isolation of habitats from each other. All these effects are considered equally negative when it comes to the impacts on species (de la Guerra et al., 2002).

2.2 Island biogeography theory

Many scientists rely on the island biogeography theory in assessing landscape fragmentation. Robert MacArthur and Edward Wilson formed this theory in 1967. This simple model depicts the relationship of habitat characteristics (islands) and distances to other suitable habitats (mainland) for species (in the original case the role of species was played by birds).

The distance effect is essential in the island biogeography theory: closer islands are easily colonized by a larger number of species compared to islands farther away. Islands located large distances from the mainland are affected by the distance effect and as result, they have a low immigration rate.

The size of the island is also important. A bigger habitat can be more suitable for a larger amount of species. Thus, more species can colonize the habitat and coexist in one environment. Therefore, larger habitats have lower extinction rates, which makes the habitat appropriate for a larger population of the species. This phenomenon is called area effect and is illustrated by the species-area curve. According to Figure 2, the number of species is expected to double as the island size increases tenfold. This is an example of the increasing population of amphibian and reptile species on Caribbean islands with increasing size of islands (Withgott & Laposata, 2015).

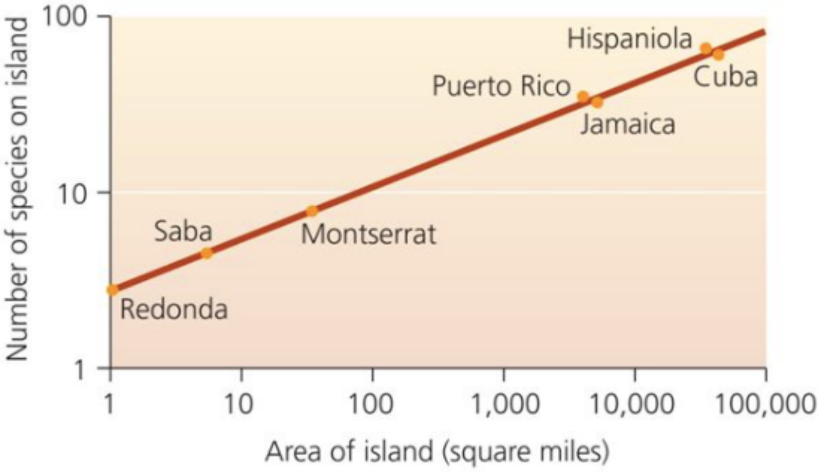

Figure 2. The species-area curve for Caribbean islands (Withgott & Laposata, 2015)

Island biogeography theory can be applied for inland habitats. In this case, for example, forest patches can play the role of the "islands", which is suitable for some species and the "sea" in this situation will be forest clear cuts, urban or agricultural areas. In the later studies, scientists adapted this theory to new circumstances. Landscape fragmentation, as well as the environment around these patches directly affects habitat patches. Hereby, the location of patches became an important factor in the newly fragmented landscape. The isolation of some patches can be a trigger for a higher extinction rate and, as a result, low species richness in a single patch (Sodhi & Ehrlich, 2010).

For assessing landscape fragmentation, scientists created a common pattern of landscape modification. The complexity model for these processes was created by McIntyre and Hobbs in 1999 but has later been modified a few times. The concept model for landscape modification (Figure 3) is based on the stages of change in natural vegetation.

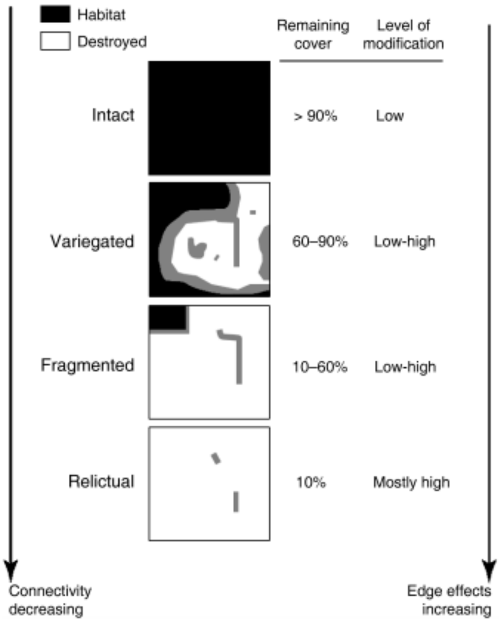

Figure 3. Conceptual model of landscape modification states (Fischer & Lindenmayer, 2007, modified from McIntyre & Hobbs, 1999)

2.3 Landscape fragmentation and its impact on species richness

As mentioned before, the effects of landscape fragmentation are drastic for natural habitats: loss of natural vegetation, reduced patch sizes, increasing distances between patches (which can be a reason for the isolation of habitats) and, as a result, increasing sizes of the new habitat (which has replaced the original one). It is clear that landscape fragmentation affects various ecosystem services. Moreover, increasing landscape fragmentation can be a trigger for a "domino effect". In the European Environmental Agency report (2011) scientists collected known effects of landscape fragmentation (Table 1). However, it is important to notice, that cumulative effects of this process are less studied. At the same time, researchers mention that landscape fragmentation is increasing the accessibility for people to some landscapes, making them more attractive.

Table 1. Effects of landscape fragmentation on the environment and various ecosystem services (modified from EEA, 2001)

Theme	**Consequences of the landscape fragmentation**
Land cover	• Land occupation for road surface • Soil compaction, sealing of soil surface • Alterations to geomorphology (e.g. cuts, embankments, dams, stabilization of slopes) • Removal of vegetation, alteration of vegetation
Local climate	• Modification of temperature conditions (e.g. heating up of roads, increased variability in temperature) • Accumulation of cold air at road embankments (cold-air build-ups) • Modification of humidity conditions (e.g. lower moisture content in the air due to higher solar radiation, stagnant moisture on road area due to soil compaction) • Modification of light conditions • Modification of wind conditions (e.g. due to aisles in forests) • Climatic thresholds
Emissions	• Vehicle exhaust, pollutants, fertilizing substances leading to eutrophication • Dust, particles (abrasion from tires and brake linings) • Oil, fuel, etc. (e.g. in case of traffic accidents) • Road salt • Noise • Visual stimuli, lighting
Water	• Drainage, faster removal of water • Modification of surface water courses • Lifting or lowering of groundwater table • Water pollution

Flora and fauna	• Death of animals caused by road mortality (partially due to attraction of animals by roads or railways: 'trap effect') • Higher levels of disturbance and stress, loss of refuges • Reduction or loss of habitat; sometimes creation of new habitat • Modifications of food availability and diet composition (e.g. reduced food availability for bats due to cold air build-ups along road embankments at night) • Barrier effect, filter effect to animal movement (reduced connectivity) • Disruption of seasonal migration pathways, impediment of dispersal, restriction of recolonisation • Subdivision and isolation of habitats and resources, breaking up of populations • Disruption of metapopulation dynamics, genetic isolation, inbreeding effects and increased genetic drift, interruption of the processes of evolutionary development • Reduction of habitat below required minimal size, loss of species, reduction of biodiversity • Increased intrusion and distribution of invasive species, pathways facilitating infection with diseases • Reduced effectiveness of natural predators of pests in agriculture and forestry (i.e. biological control of pest more difficult)
Landscape scenery	• Visual stimuli, noise • Increased penetration of the landscape by roads, posts and wires • Visual breaks, contrasts between nature and technology; occasionally vivification of landscapes (e.g. by avenues with trees) • Change of landscape character and identity
Land use	• Consequences of increased accessibility for humans due to roads, increase in traffic volumes, increased pressure for urban development and mobility • Farm consolidation (mostly in relation with construction of new transport infrastructure) • Reduced quality of agricultural products harvested along roads • Reduced quality of recreational areas due to shrinkage, dissection, and noise

As seen from table 1, the impact of landscape fragmentation on a species can even be lethal in some cases. Mainly, however, these effects are not immediate and take some time after the destruction of established connections. Therefore, habitat loss is more critical for population and biodiversity loss than fragmentation, because the presence of some specific habitat can be vital for a species and can be used roughly as an indicator for presence or absence (Björklund, 2015). Moreover, it is important to have an idea which species are living in a specific area and what their minimum habitat requirements are (such as the minimum size of the habitat) (Fahrig, 2009). As known from the island biogeography theory, patch size is very important and small patches are losing their species richness faster. This is shown in an experiment provided by scientists (under direction of Dr. Thomas Lovejoy) in Amazon, where an amount of forest was cleared by people who needed space and who left 11 mature forest fragments in three different sizes: 1 ha, 10 ha and 100 ha (Withgott and Laposata, 2015). During the experiment, scientists found that to slow down the species loss, the fragments should be 1000 times bigger and that even a 100 ha fragment is not enough, so after 15 years half of the local species richness was lost. Nevertheless, scientists found that growing young forest along the border of the fragments and connecting fragmented forests with other habitats can change the situation and recolonize the isolated patches. However, during the experiment edge effects were noted in the fragments. Among these were increased wind disturbance, elevated tree mortality, invasion of disturbance-adapted butterflies, altered species composition of leaf-litter invertebrates, lower relative humidity, reduced canopy height, reduced soil moisture, increased air temperature, reduced understory-bird abundance, increased sunlight and invasion of disturbance-adapted plants. These effects are strongly reduced species richness of plants and animals. Moreover, during an experiment in USA was found that reduced area, increased isolation, and increased proportion of edge habitat reduced the number of predators and herbivores, whereas an increased proportion of edge caused higher predation that had the effect of reducing bird fecundity (Haddad et al., 2015).

Changes in the landscape configuration and fragmentation can lead to drastic changes in the conditions of the ecosystems. Furthermore, it is a trigger for the destruction of a natural food chain, as the absence of food creates competition among predators due to the changing physical conditions of the habitat. In this case, the predators are changing their food diet (if possible) or start to predate on other predators (Björklund, 2015). All together, these changes can lead to the extinction of the predator population. That’s why management of fragmented landscapes is so important and requires knowledge of the vulnerable conditions and species.

2.4 Study species: northern goshawk and Ural owl

Northern goshawk and Ural Owl (Figure 4) are common predatory birds in Finland. Food preferences for these predators are differ: the goshawk preys on different types of birds, which is the main diet for this species and Ural owls prey on small mammals. Nevertheless, goshawk could also prey on the small mammals, too. (Byholm et al., 2012). The typical breeding density of this species is 2-4 pairs per 100 squares kilometers (Väisänen et al. 1998).

a) b)

Figure 4. Northern goshawk (a) and Ural owl (b) (photos by Ronald Kube and Jari Peltomäki)

Northern goshawk and Ural Owl have similar preferences for their habitat: mature coniferous forests or, to put it simple, old grown forests (Goffette et al., 2016). Usually, the goshawk nesting area is among large trees and dense canopies. Young, dense forest is not suitable for goshawks due to their requirement for space to maneuver (Smith & Keinath, 2004). Northern goshawks and Ural owls try to avoid predator competition and have a “prey distance” of one kilometer from the nests of each other’s nests. (Byholm et al., 2012).

As predators, these species are susceptible to changes or destructions in the habitat, which are ruining their habitual lifestyle (Byholm et al., 2007; Lundberg & Westman, 1984). These changes entail a decrease in population. An occurrence of the breeding seasons of the Ural owls is dependent of the variation in the lifetime reproductive success of the females. However, the main factor affecting the probability of laying eggs is food supply. Moreover, Ural owls pairs is trying to breed every year, but environmental conditions combined with individual differences could be the reason for unsuccessful breeding in some years. This is means that the “every year checking effect” could be broken, when the absence of species could be caused by behavior features, but not by a decrease of the spruce mature forest or an impact from human activities. (Pietiäinen, 1989; Saurola, 1989)

2.5 Forestry in Finland

According to the Finnish Forest Association (2016), 75% of the country's land area is occupied by forest. Moreover, 11% of the land is used for other forestry purposes. If this huge amount of forests is divided on all people who live in Finland, we will have over four hectares of forest per person. The same resource asserts that private individuals own around 60% of this forest, 26% of the forest is owned by the state and 14% is the property of private companies. Traditionally, in Finland private forest is transmitted from generation to generation and is a pride for the family (Ministry of Agriculture and Forestry, 2015).

The main trees in the Finnish forests are pine (67%), spruce (22%), birch (10%) and other broadleaved trees (1%). The large amount of pine is the result of the regeneration of forests in the 1950s, when it was common to use pine seeds. According to Parviainen and Västilä (2011), species composition in Finland changes slowly and more than half of the forests are homogeneous in composition.

Forests have an important economic value for Finland because the forest industry produces approximately 20% of all export products (paper and paperboard, wood pulp, softwood, sawn wood, etc.). Moreover, wood fuels power more than a quarter of the energy consumption and the forest industry is one of the main employers in Finland (Finnish Forest Industries, 2016).

It is important that the forest is not only recognized as a source of income in Finland. By statistics provided by the Ministry of Agriculture and Forestry of Finland, 36% of all threatened species in the country live in forests. This means more careful management of the forests is required because they are important for the biodiversity. Thus, part of the forests in Finland is protected and has the status of the conservation areas (13% of the total area of forest). The biggest area of protected forest is located in the northern part of Finland. Moreover, the proportion of strictly protected forests (5,2% of all forests) is bigger than any other European country (Metla, 2012). Managing and establishing protected areas is an objective of Metsähallitus, which is a state-run enterprise. General objectives for this organization are a sustainable forest management, protection of the natural recourses and conservation of the biodiversity (Metsähallitus, 2016).

The establishment of new protected areas is an ongoing process (Figure 5). According to the National Forest Strategy 2025, Finland is planning to increase the amount of conservation areas in private forests. Currently, the majority of the protected areas are located in state-owned forest. As mentioned in the Forest Act (1996), which is the main law regulating forestry in Finland, "forests shall be managed and used in such a manner that the general conditions for the preservation of habitats important for the biological diversity of forests are safeguarded". Likewise, this document requires the owner to ensure that time of forest regeneration does not exceed 10-25 years after the harvest of wood, and to only use domestic tree species (pine, spruce, birch) for this process. Also, the Forest Act is regulating the harvest of forest in protected areas.

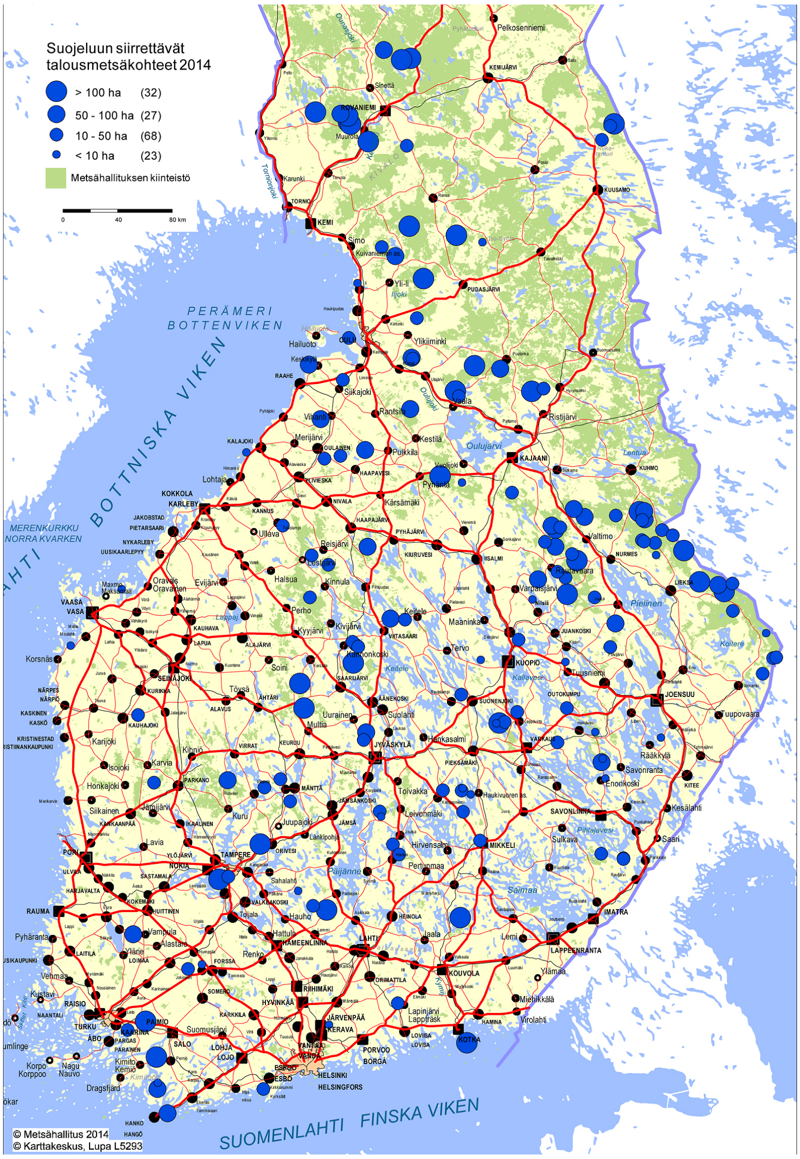

Figure 5. Protection of forests. Blue dots refer to newly protected areas and green color mark area owned by Metsähallitus (Finnish Forest Association, 2014)

All these efforts to strengthen the position of the forest are the consequences of historical issues with Finnish forests. As we see in figure 6, the clearing of forests was at least on the same level as the growth and in some cases even higher than the amount of growing forest in 1960-63. According to Lier and Parviainen (2013), the biggest impact on forests was seen in Southern Finland in the beginning of the 20th century, where 50-75% of the forests were converted to agricultural lands through slash-and-burn cultivation. As was mentioned before, a large number of the threatened species are living in the forests. Moreover, as was noted earlier, Northern goshawk and Ural owl also require forests for their success. Thus, removal of the forests lead to loss in the biodiversity of the forest species and a decline in the number of forest species. A slowdown of this process was achieved only in the 1990s. Still, an assessment of the threatened species in 2010 showed that the decline has been slowed down or stopped for 81 species, but has continued for 108 species. This is the result of the more than seven different programs for the conservation of nature that were adopted by the Finnish government from the 1970s (Parviainen & Västilä, 2011).

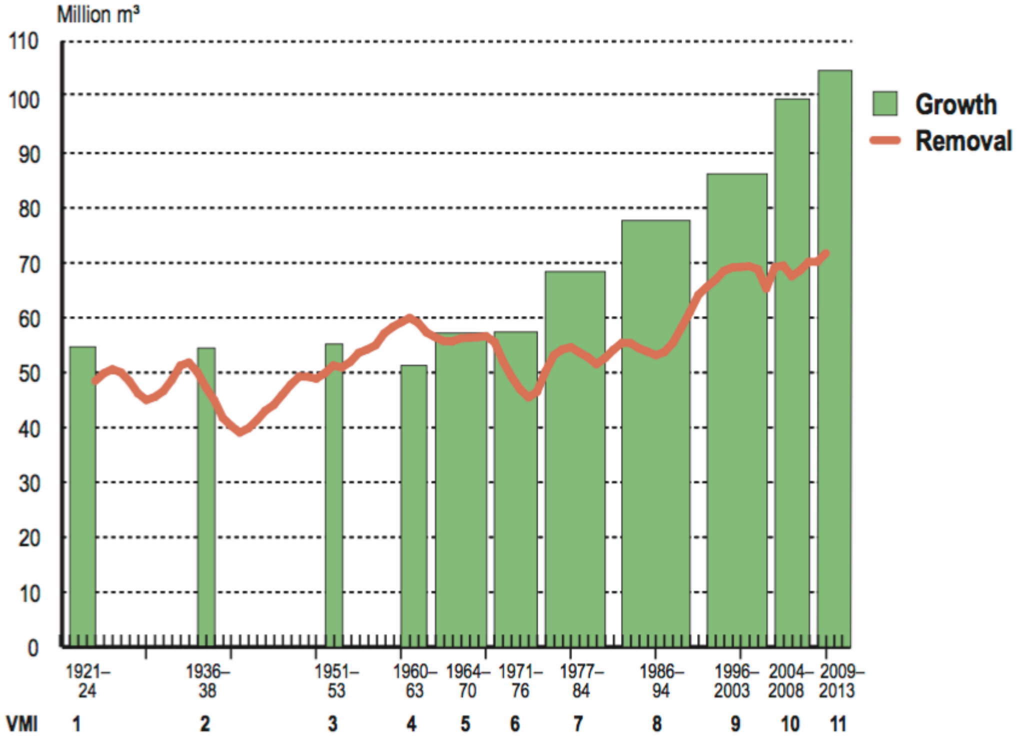

Figure 6. Forest growth and removal, 1920 - 2013 (Natural Resource Institute Finland, 2016)

3. Materials and methods

3.1 Study area and landscape measurements

All data were collected in Western Finland, in the area called Suupohja (Figure 7). This is a subdivision of Southern Ostrobothnia, which includes four whole municipalities and three parts of other municipalities. A large part of this area (75%) is covered by Norway spruce, pine and birch. Due to the intensive forestry practice in Suupohja, the forest is fragmented (Burgas, Juutinen & Byholm, 2016). Also, forests in the Suppohja area are mainly private-owned (Fabritius, 2010). Study area located in the cross section of the southern and middle boreal vegetation zones (Ahti et al., 1968).

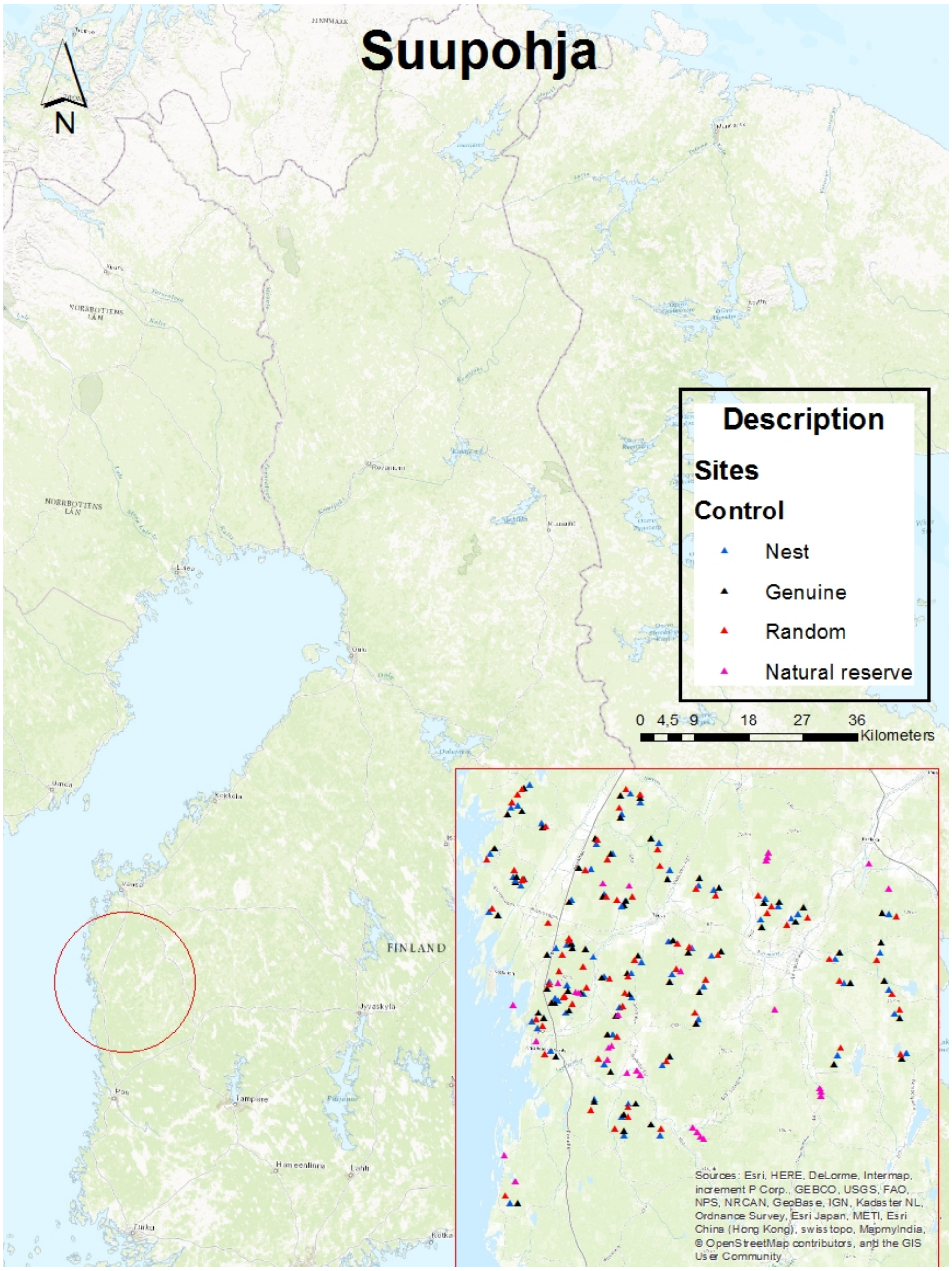

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Figure 7. Suupohja area (Western Finland)

3.2 Data source and data design

Daniel Burgas and Patrik Byholm were established study plots in 2006-2008 as a part of research project (Burgas et al., 2014). Later, Patrik Byholm collected data about the Northern goshawk occupancy during two different years: 2009 and 2013. All the data was divided into different categories: for northern goshawk (AG) and Ural owl (SU). Also, data was collected in the protected areas (NR) for control purpose. All species samples were gathered and divided into following types: nests sites, suitable places for nests and random sites (see detail in table 2). According to this, the samples for AG and SU were divided into three groups separately: nest, genuine and random. As a result, seven data groups were used for the study (N=34 for AG, N=35 for SU and N=30 for NR).

Table 2. Data categorization

Site type	Description
AG Nest	Site where northern goshawk are present
AG Genuine	Site which is suitable for northern goshawk, but species are absent
AG Random	Absolutely random site in the forest which relatively close to AG Nest and AG Genuine
SU Nest	Site where Ural owl are present
SU Genuine	Site which is suitable for Ural owl, but species are absent
SU Random	Absolutely random site in the forest which relatively close to SU Nest and SU Genuine
NR	Site located in protected area (natural reserve)

In order to investigate the landscape configuration in the study area, a map based on Multi-source National Forest Inventory data (pixel size of 20m×20m) was created. This data was collected by Natural Resources Institute Finland (Luke) in 2009 (Luke, 2009) and 2013 (Luke, 2013). Based on Björklund et al. (2015) and Santangeli et al. (2013) were defined five classes of forest (Table 3) and regrouped all data (using ESRI product ArcMap) into these classes for both time periods.

Table 3. Categorization of the landscape classes

Given value	Name of the landscape class	Volume of the trees	Age of the forest
1	Mature spruce forests	≥ 120 m^3ha^{-1}	≥ 70 years
2	Other mature forests	≥ 120 m^3ha^{-1}	≥ 70 years
3	Young forests	from 60 to 119 m^3ha^{-1}	< 70 years
4	Low-stocking forests	0 to 59 m^3ha^{-1}	< 70 years
22	Mature pine-dominated forests	≥ 120 m^3ha^{-1}	≥ 70 years (had to comprise of ≥ 50% pine)

All data that did not fit into the previously defined classes was regrouped into the following categories: Water bodies (given value 5), Agricultural areas (6), Urban areas (7) and Open bogs, marshes and meadows (41). Urban areas include houses, built-up areas, roads, infrastructure, etc. These landscape classes were derived from the Corine Land Cover 2006 database (pixel size of 25 m× 25 m) (CLC2006-Finland, 2010) and were subsequently corrected using the Corine Land Cover 2012 database (pixel size of 20 m× 20 m) (CLC2012-Finland, 2014).

For all the seven types of sites (AG Nest, AG Genuine, AG Random, SU Nest, SU Genuine, SU Random, NR) were created four types of buffer zones on the maps for both years, marking the distances 50, 100, 250 and 500 meters from the sites. Using this material, were calculated proportions of the landscape for 237 sites by using the four types of distances, using the formula:

$$P_{2009,2013} = \frac{H_{n,year}}{S} \times 100 \, ,$$

where $H_{n,year}$ is value of the explored habitat type for different years (2009 and 2013), and S is size of the buffer area.

Data was extracted from ArcMap and reorganized by using the application Geospatial Modeling Environment (Beyer, 2012). All data was reorganized in the way where every single buffer zone (circle) has data of the landscape configuration changes separately. Additionally, the proportions of the differences in the landscape classes were calculated comparing the results from 2013 and 2009 with each other according to the formula:

$$P_{dif} = \frac{H_{n,2013} - H_{n,2009}}{S} \times 100 \, ,$$

where $H_{n,2013}$ and $H_{n,2009}$ are values of the explored habitat type, and S is size of the buffer area.

3.3 Statistical analyses

First, the data was checked with correlation analysis, seeking relationships between the factors in the mature spruce forest data. Numbers for different buffer zones was checked pair by pair (e.g. 50 m and 100 m, 50 m and 250 m, etc.). This was done in order to study the strength of the relationships between variables.

Ural owls (SU) weren’t used for the more in-depth investigation, due to the peculiarities in the breeding behavior of this species that were described in the background theory part. Instead, collected data of the northern goshawk (AG) occupancy was used as indicator of biodiversity and changes in the mature spruce forest in the study area. For AG nests, a simple coding system was formed, indicating absence (0), presence (1) or species moving from nest to nest (2). The last category describes the possibility that AG moved from the nest (or bred in 2009) to another nest for some reason, but the newly occupied nest is located within 50-350 meters from the original one. Later six categories were formed, which included different combinations in the relationships of the 2009 and 2013 data in order to achieve better modeling relations between the changes in the configuration of required landscape and the changes in AG occupancy (Table 4).

Table 4. Categorization of the distribution of the northern goshawk

Combination of the distributions from 2009 and 2013	Description	Code for model	N
0 - 0	Stable empty nest	0	8
1 - 0	Newly empty nest	1	11
1 - 1	Stable occupied nest	2	4
1 - 2	Changed to other nest	3	3
2 - 0	Newly empty other nest	4	5
2 - 2	Stable other nest	5	3

This model shows whether the mature spruce forest and other mature forest can explain the changes in the AG distribution. That is, if changes occur, how big these changes are and how significantly important they are. Additionally, the differences in abundance of the low-stocking forest, which is not suitable for AG were statistically analyzed. These forests would have a negative affect on AG distribution contrary to mature forests.

Moreover, similar statistical modeling was used for investigating changes in protected areas (NR). In accordance with the 1^{st} hypothesis of this research, there are no increasing in areas with human activity and negative changes in the mature spruce forest.

All analyses were done using ANOVA tests in R 2.10.1 with MASS library (R Core Team, 2014). An ANOVA test, or the one-way analysis, is used for investigation significant differences between the mean value and the other seven groups of AG data. In this investigation the "null" hypothesis that different groups of data aren't significant different between each other was tested. If ANOVA test showed the significant differences (p-value of 5% or lower is considered to be statistically significant), "null" hypothesis was refuted.

4. Results

4.1 General changes in the landscape configuration

The changes in the landscape configuration between 2009 and 2013 are big, as seen in figure 8, where the grey color shows area where no changes could be seen and other colors are habitats, which differ in 2013. However, the changes in the landscape configuration in Suupohja occur mainly in the forest cover. Prevalence of different shades of green shows this visually. Moreover, it is easy to see that mainly the areas around the AG, SU and NR sites changed in comparison to 2009.

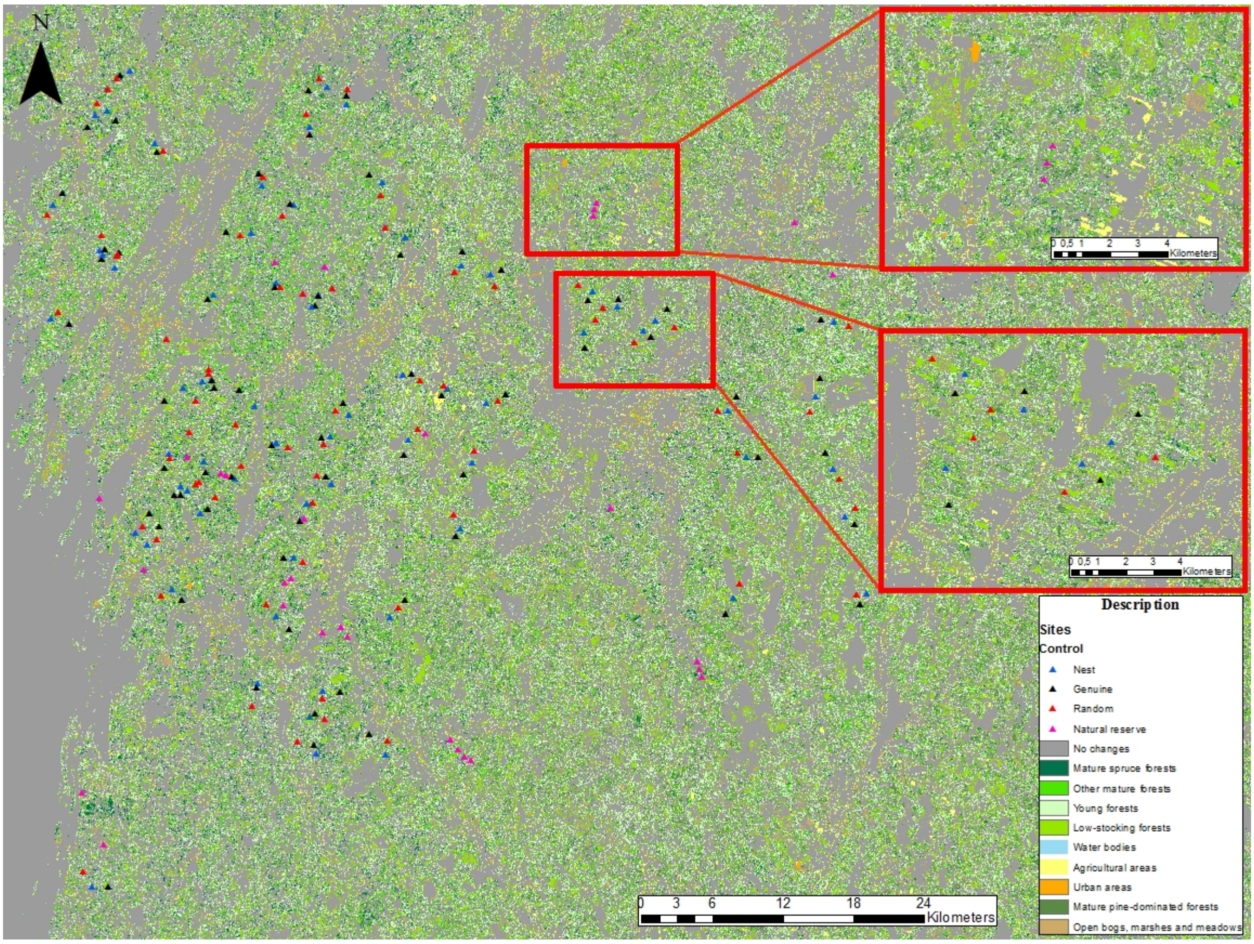


Figure 8. Changes in the landscape configuration between 2009 and 2013

Changes in landscape configuration are occurring in all four different types of buffer zones around sites (50 m, 100 m, 250 m and 500 m). The biggest buffer zone in this research has been used for comparing the changes on the biggest possible scale for visually understanding changes in landscape configuration. Figure 9a shows 500 m buffer zones in 2009 and 2013, where small squares are different types of landscape patches (size of one square is 20 m×20 m). There are changes in landscape configuration, but not surprisingly, they are mostly in the forest cover as evidenced by visual differences in the shades of green color. This is shown in figure 9b, where the proportions of the patches show that the proportions of young forest and low-stocking forest have decreased. At the same time, however, the proportion of mature pine-dominated forest has increased. The proportion of mature spruce forest is on the same level as before (Figure 9b). This is a good starting point for an investigation.

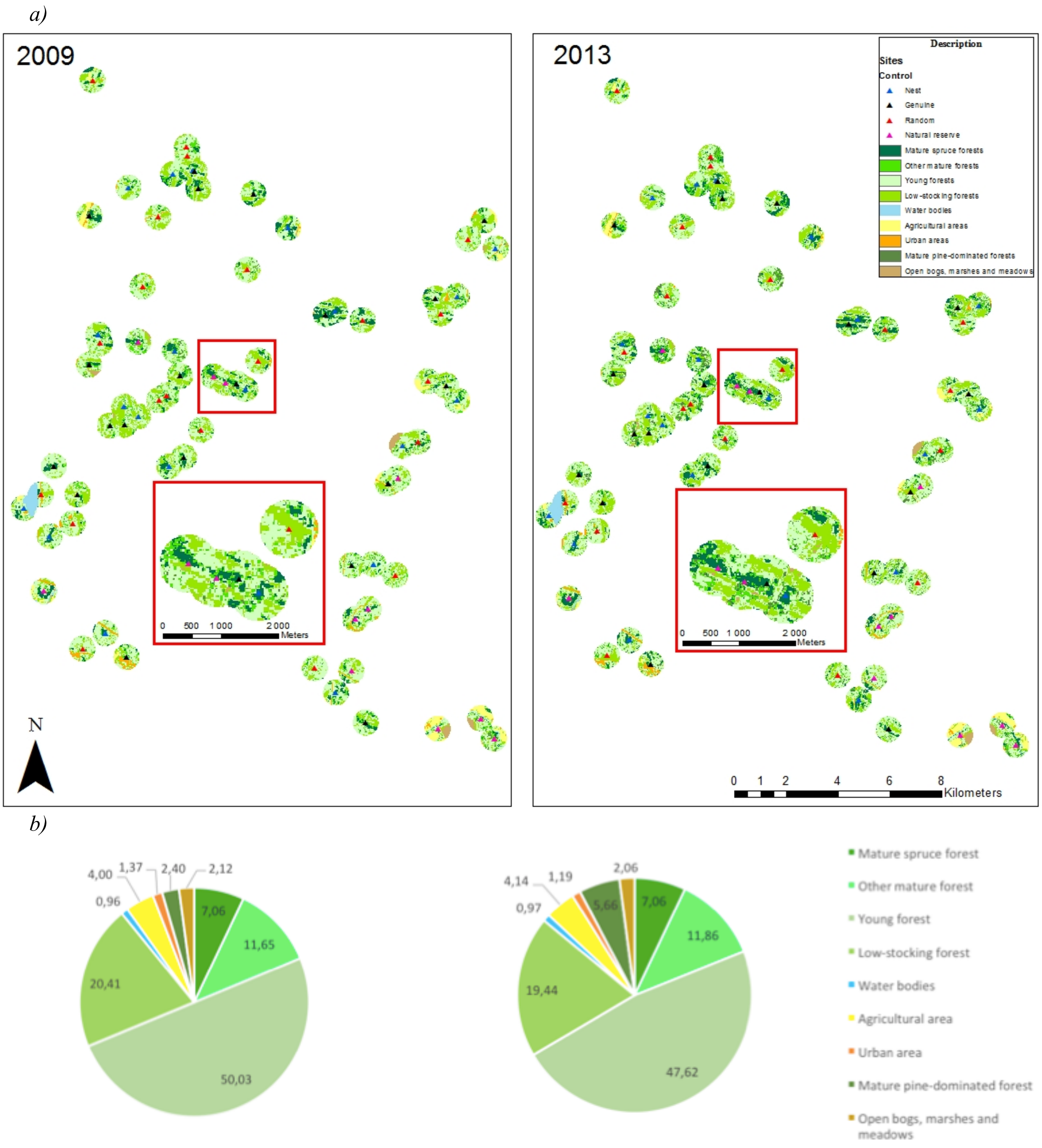
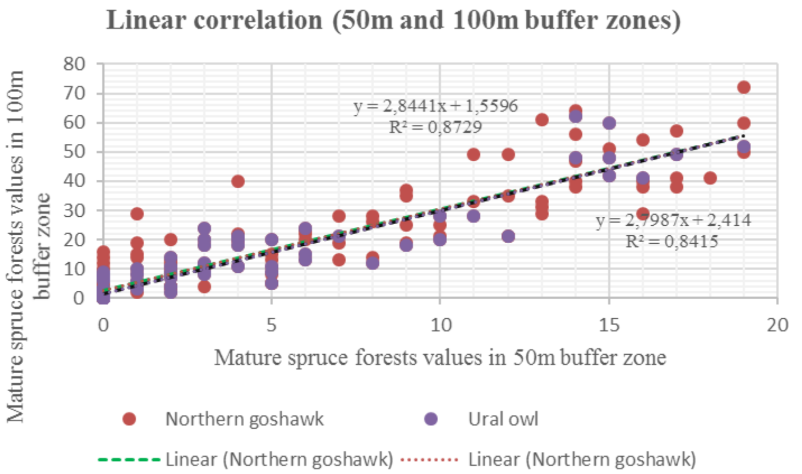


Figure 9. Landscape configuration (a) and proportions of landscape configuration (b) for 2009 and 2013 in 500m buffer zones

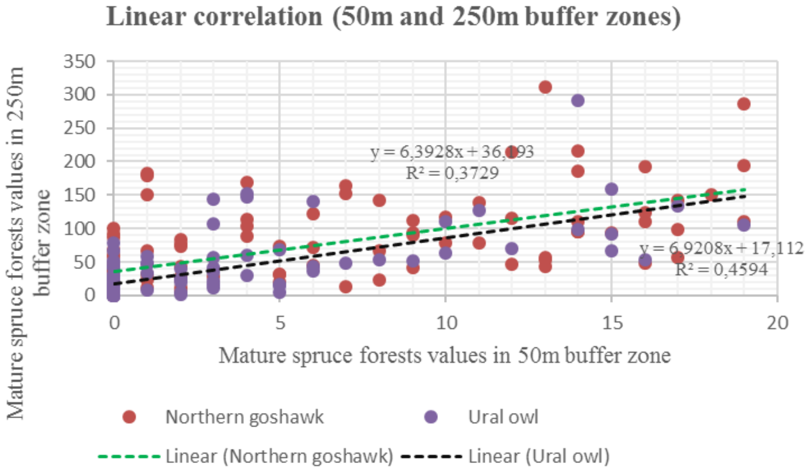
4.2 Correlation analysis of data

Correlation analyses of the 2009 data (values of the maturity spruce forest) show that the data between the buffer zones (in AG and SU sites) is linearly correlated. According to Figure 10, buffer zone radii of similar size (Figures 10a, 10d, 10f) correlated better than short and long radii

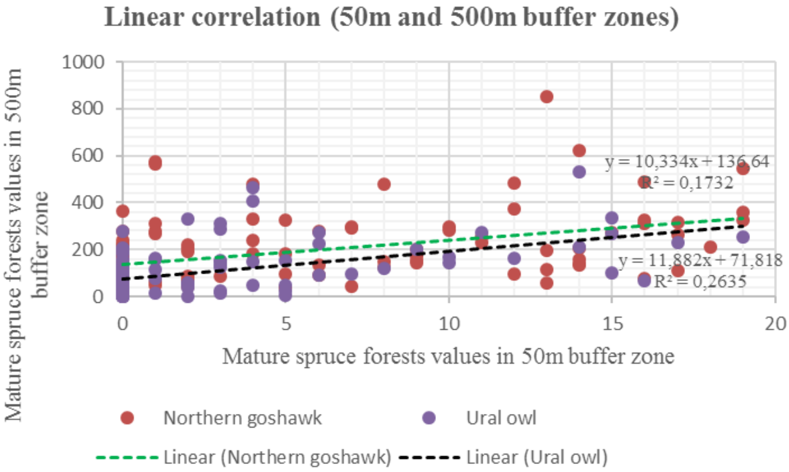
(Figure 10b, 10c, 10e). Correlation tests that were done for all three types of sites (AG, SU and NR) confirm better correlation for “neighboring” buffer zones (Table 3). Results of the correlation tests shows that data has a low quantity of “mistake values” and is reliable. Correlation graphs for the control data NR can be found in Appendix A.



a)



b)



c)

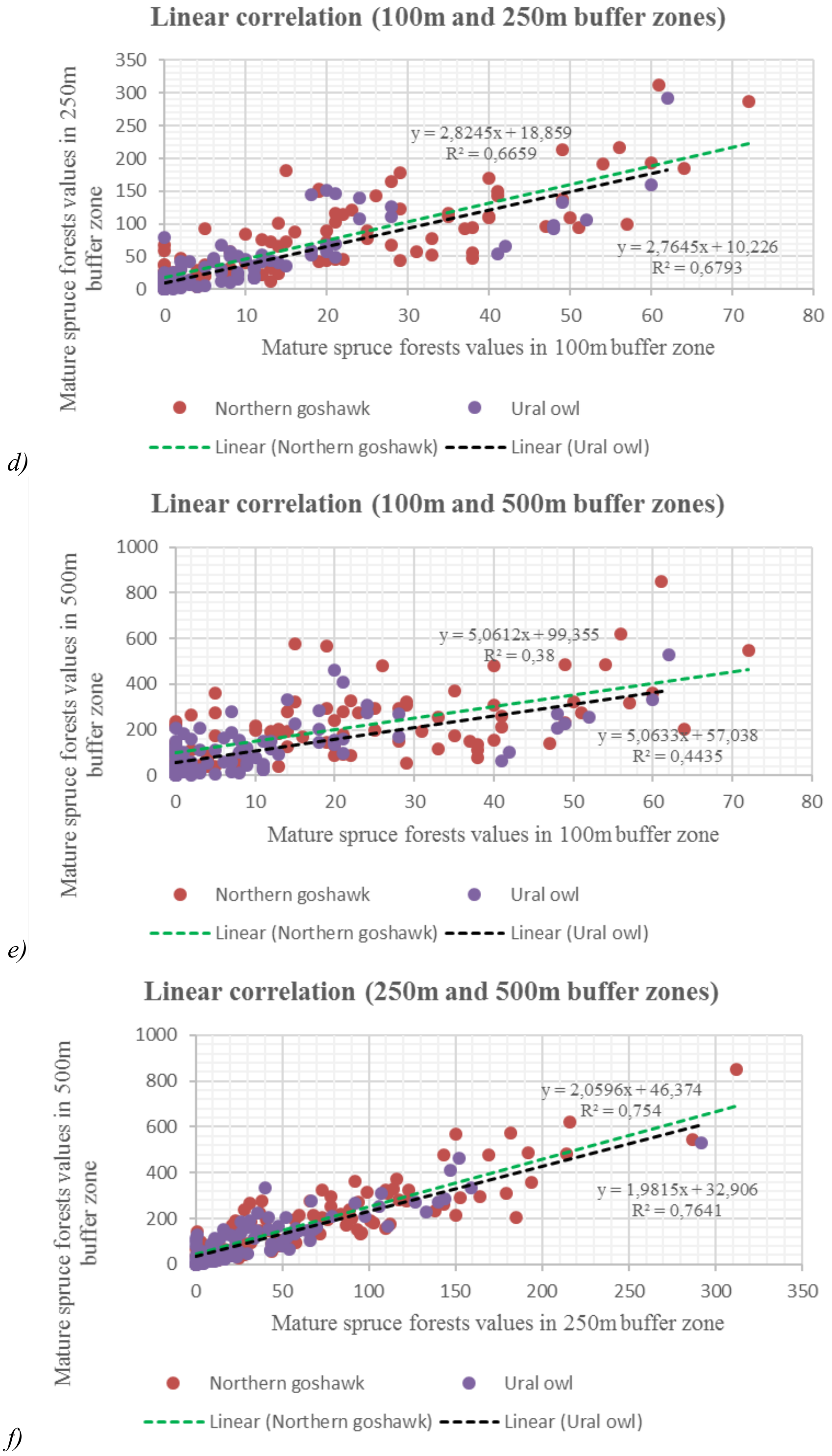


Figure 10. Correlations graphs in 2009 data (northern goshawk and Ural owl sites) between different buffer zones

Table 3. Results of the correlation test of the mature spruce forest data in 2009

Type of data	Pair of buffer zones	Correlation test results
AG	50 m and 100 m	r = 0,898, N = 34, p < 0,001
AG	50 m and 250 m	r = 0,611, N = 34, p < 0,001
AG	50 m and 500 m	r = 0,416, N = 34, p < 0,005
AG	100 m and 250 m	r = 0,816, N = 34, p < 0,001
AG	100 m and 500 m	r = 0,617, N = 34, p < 0,001
AG	250 m and 500 m	r = 0,868, N = 34, p < 0,001
SU	50 m and 100 m	r = 0,934, N = 35, p < 0,001
SU	50 m and 250 m	r = 0,677, N = 35, p < 0,001
SU	50 m and 500 m	r = 0,513, N = 35, p < 0,005
SU	100 m and 250 m	r = 0,824, N = 35, p < 0,001
SU	100 m and 500 m	r = 0,666, N = 35, p < 0,001
SU	250 m and 500 m	r = 0,874, N = 35, p < 0,001
NR	50 m and 100 m	r = 0,915, N = 30, p < 0,001
NR	50 m and 250 m	r = 0,716, N = 30, p < 0,005
NR	50 m and 500 m	r = 0,745, N = 30, p < 0,005
NR	100 m and 250 m	r = 0,83, N = 30, p < 0,001
NR	100 m and 500 m	r = 0,775, N = 30, p < 0,001
NR	250 m and 500 m	r = 0,875, N = 30, p < 0,001

4.3 Changes in landscape configuration

The raw results are presented in Appendix B. From this table can be seen, that in all buffer zones there are quite large changes in the mature spruce forest and young forest. The decreasing in last one can be explained by the natural grow of forests. Furthermore, in NR sites is no decrease in mature spruce forest, mature pine-dominated forest and other mature forest. This means that the changes are due to the natural growing of forests. Moreover, it is means that our GIS map is reliable from the logical point of view and shows natural processes of the changes (growing forest).

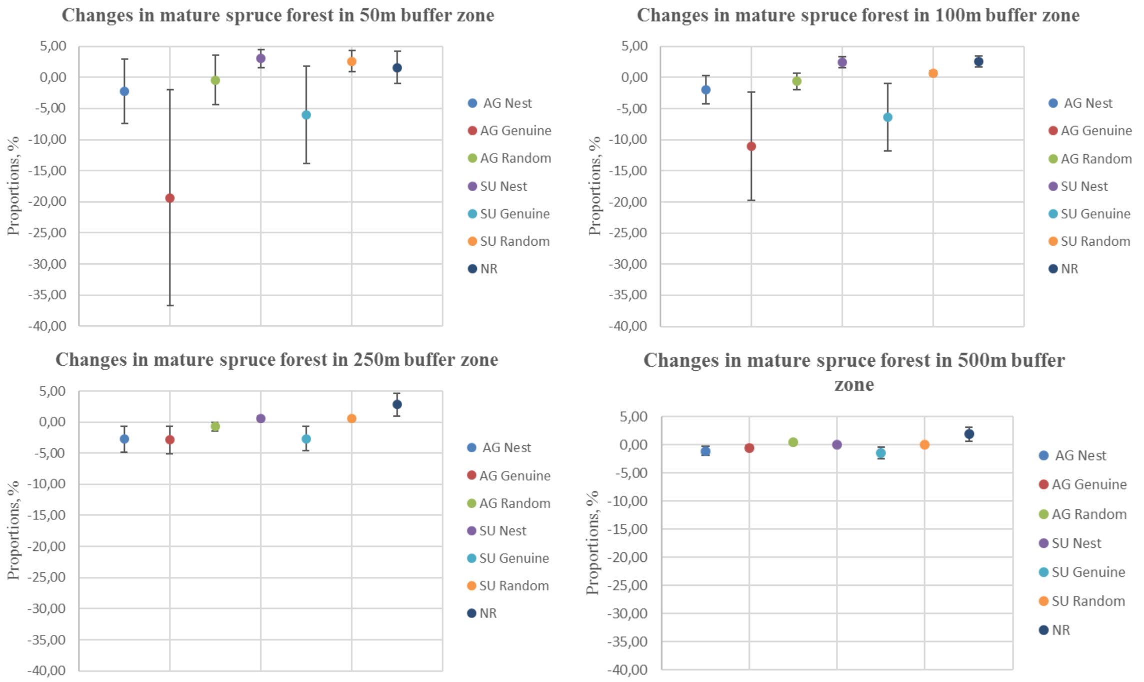


Figure 11. Changes in mature spruce forest (and SD) in northern goshawk (AG), Ural owl (SU) and protected sites (NR)

The changes in the mature spruce forest are presented in figure 11 for all seven types of sites. It can visually be seen that the bigger changes mostly occur in the smaller buffer zones. According to figure 11, the most negative changes occur in the AG Nest, AG Genuine and SU Genuine sites. Moreover, Genuine sites for both species have decreasing trend, this is especially visible in comparison to the NR sites, which look more stable. This is means that suitable sites for AG and SU are decreasing in size more than expected. However, everywhere, except for in the 500 m buffer zone for AG, Genuine sites are losing more forest than Nest sites. This is verified through the statistical analysis where a significant decrease of the mature spruce forest in AG Genuine sites was found in the 50 m and 100 m buffer zones (t=-3,266, p=0,001 and t=-2,530, p=0,01 respectively). It should also be noted that the same trend was found in the 250 m buffer zone for AG Nest (t=-2,239, p= 0,03). At the same time, the SU Nest sites look somewhat stable on the graph and in the 50 m and 100 m buffer zones almost on the one level with the NR sites. An increasing amount of mature spruce forest occur in protected areas. This is confirmed by the statistical analyses (Table 4), as there are significant differences in mature spruce forest values between different types of sites (p < 0,05). Moreover, in two of the buffer zones (250 m and 500 m) the increase in the cover of mature spruce forest in NR sites is significantly high (t=3,103, p=0,002 and t=3,031 and p=0,003 respectively). This strongly indicates the 1st research hypothesis is correct when it comes to the absence of decreasing or stagnant mature spruce forest in protected areas.

Table 4. Results of the statistical analyses when comparing the mature spruce forest values in buffer zones with F-test

Buffer zones	$F_{6,230}$	p
50m	4,542	0,0002
100m	3,827	0,0012
250m	3,007	0,0076
500m	2,464	0,0250

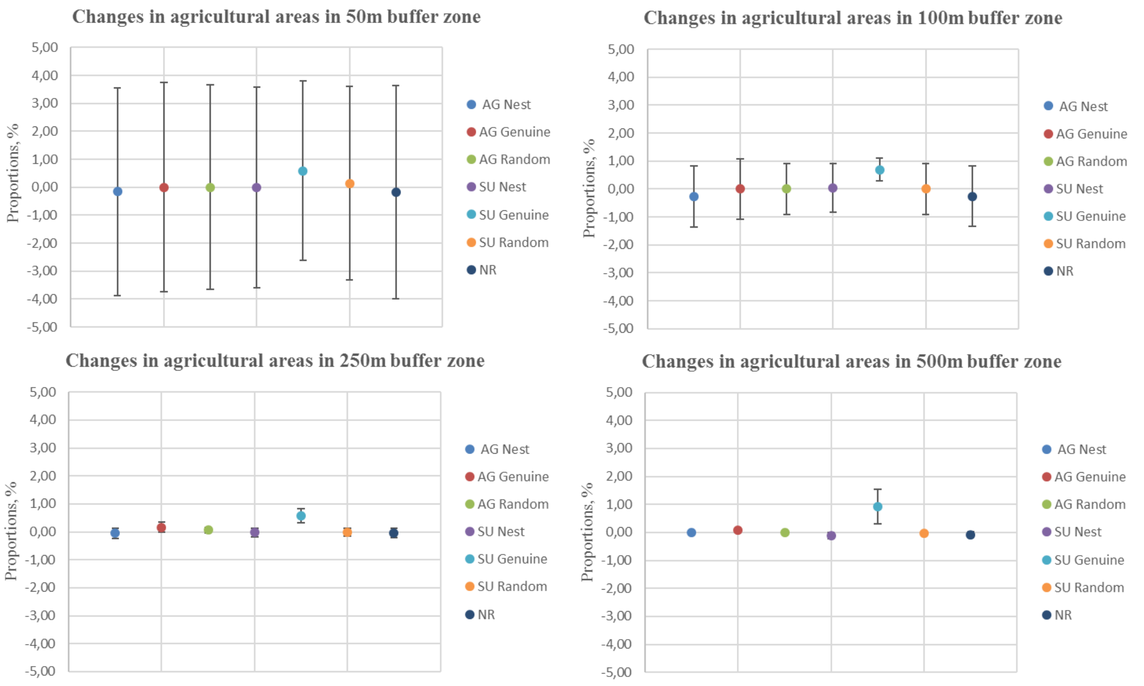


Figure 12. Changes in agricultural areas (and SD) in AG, SU and NR sites

According to figure 12, agricultural areas have increased in SU Genuine sites in all buffer zones. Nevertheless, the statistical analyses haven't shown any significant differences when it comes to changes in agricultural areas between the sites in any buffer zones (Table 5, p > 0,1).

Table 5. Results of the statistical analyses when comparing the agricultural area values in buffer zones with F-test

Buffer zones	$F_{6,230}$	p
50m	1,061	0,39
100m	0,996	0,43
250m	0,739	0,62
500m	1,197	0,31

However, in the in-depth analyses with t-test, a significant increase in agricultural areas was found in SU Genuine sites for the 50 m and 100 m buffer zones (t=2,107, p=0,04 and t=2,126, p=0,035 respectively). In NR sites no changes in agricultural areas could be seen.

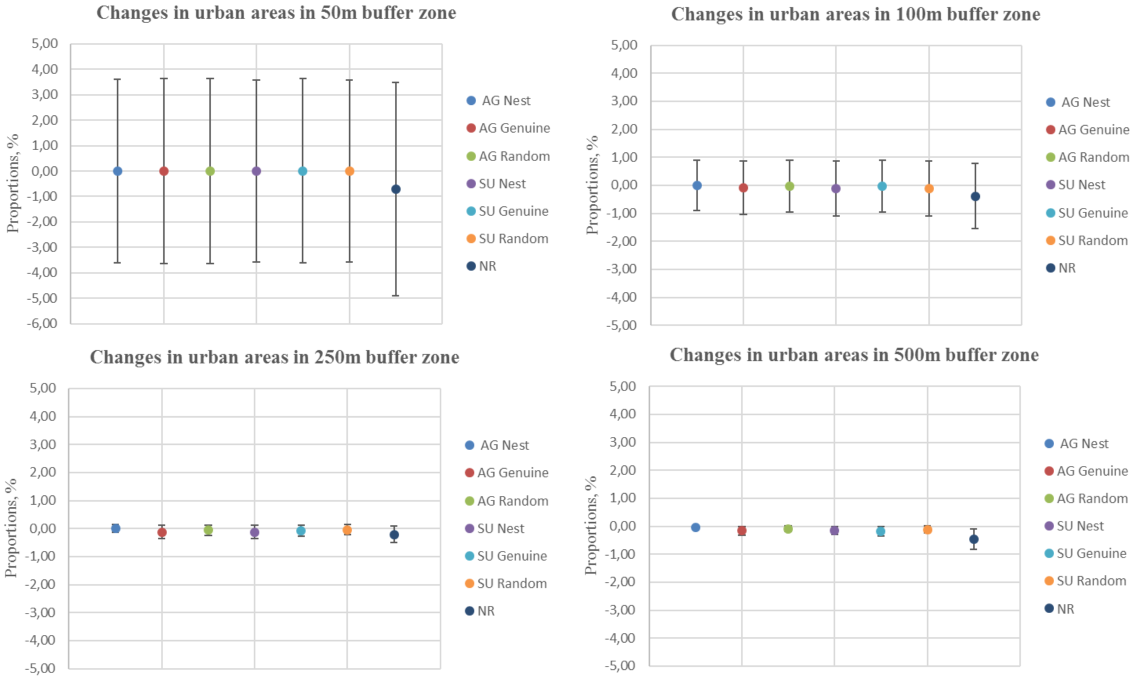


Figure 13. Changes in urban areas (and SD) in AG, SU and NR sites

Changes in urban areas can only be seen visually in protected areas (Figure 13), the other sites do not show any large visual differences in the amount of urban areas. When analyzed statistically, significant differences in urban areas were only found in the 500 m buffer zone ($F_{6,230}$=2,168, p=0,047), where the urban areas have decreased. Moreover, detailed analysis with t-test showed a significant decrease in urban areas in the NR sites for all buffer zones, except 100 m (for 50 m: t=-2,053, p=0,041 and for 250 m: t=-2,322, p=0,021), and a high significant decrease in the 500 m buffer zone (t=-3,244, p=0,001). Statistical analysis of agricultural and urban areas strongly favored the 1st research hypothesis when it comes to the absence of increasing of these types of landscape patches in NR sites (see all results in Appendix B).

4.4 Change in the northern goshawk occupancy and landscape configuration over time

Relationships between the distribution of northern goshawk and changes in the mature spruce forest in different buffer zones are presented in figure 14. “Newly empty nests” have, according to this graph, a strong relationship with decreasing amounts of spruce forest (see results in Appendix C).

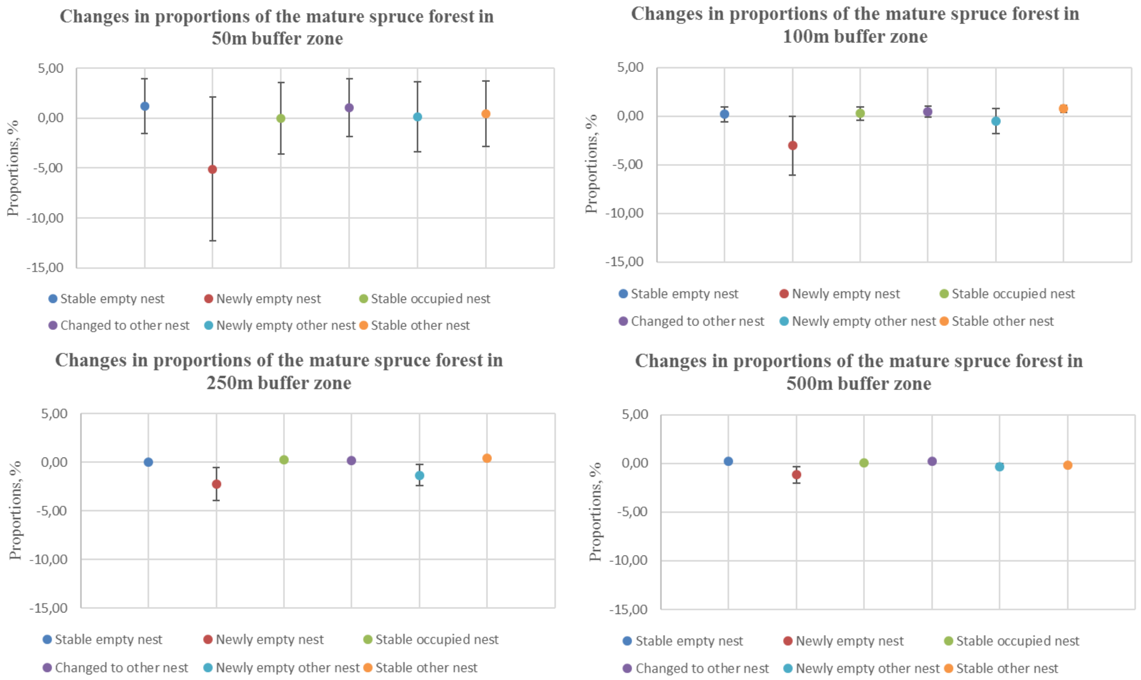


Figure 14. Changes in mature spruce forest (and SD) in relation to northern goshawk occupancy

Despite a clear trend shown in figure 14 with decreasing of the mature spruce forest in “Newly empty nests”, a statistical analysis on the AG occupancy didn’t show any significant differences in the amount of mature spruce forest in any buffer zones. Nevertheless, detailed analyses showed the same trend in “Newly empty nests” in decreasing mature spruce forest. This was significant for 50 m (t=-2,311, p=0,03) and slightly significant for the remaining buffer zones (100 m: t=-1,732, p=0,09; 250 m: t=-1,716, p=0,09 and 500 m: t=-1,878, p=0,07). In a similar analysis for the other mature spruce forests, there were no significant differences, but a slight decreasing amount of the other mature forest in “Changed to other nest” sites could be seen visually (see Appendix D).

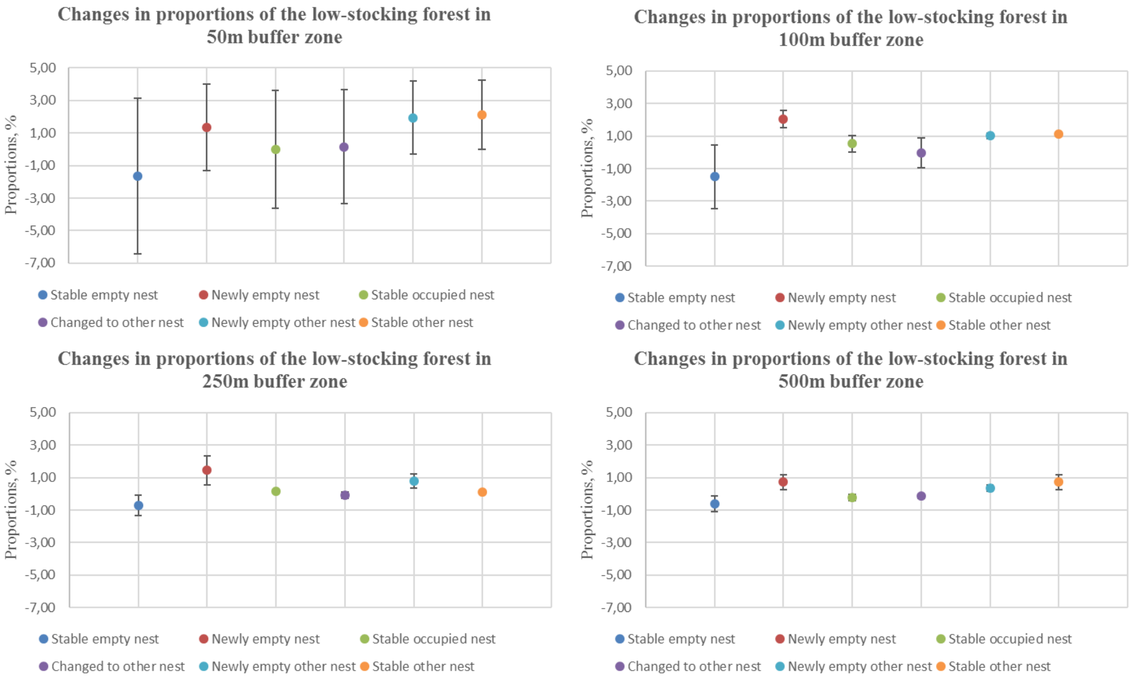


Figure 15. Changes in low-stocking forest (and SD) in relation to northern goshawk occupancy

The amount of low-stocking forest that potentially could have an influence on AG distribution was also analyzed. According to figure 15, low-stocking forest increased in “Newly empty nest” in all buffer zones except 500 m. However, during statistical analysis no significant differences in the low-stocking forest were found in any buffer zones. More detailed analyses showed a significant increase in the amount of low-stocking forest in the 50 m buffer zone for “Newly empty nest” (t=2,237, p=0,033) and for “Stable other nest” (t=2,863, p=0,008). Moreover, a significant increase was observed in the 500 m buffer zone for “Stable other nest” (t=2,092, p=0,04).

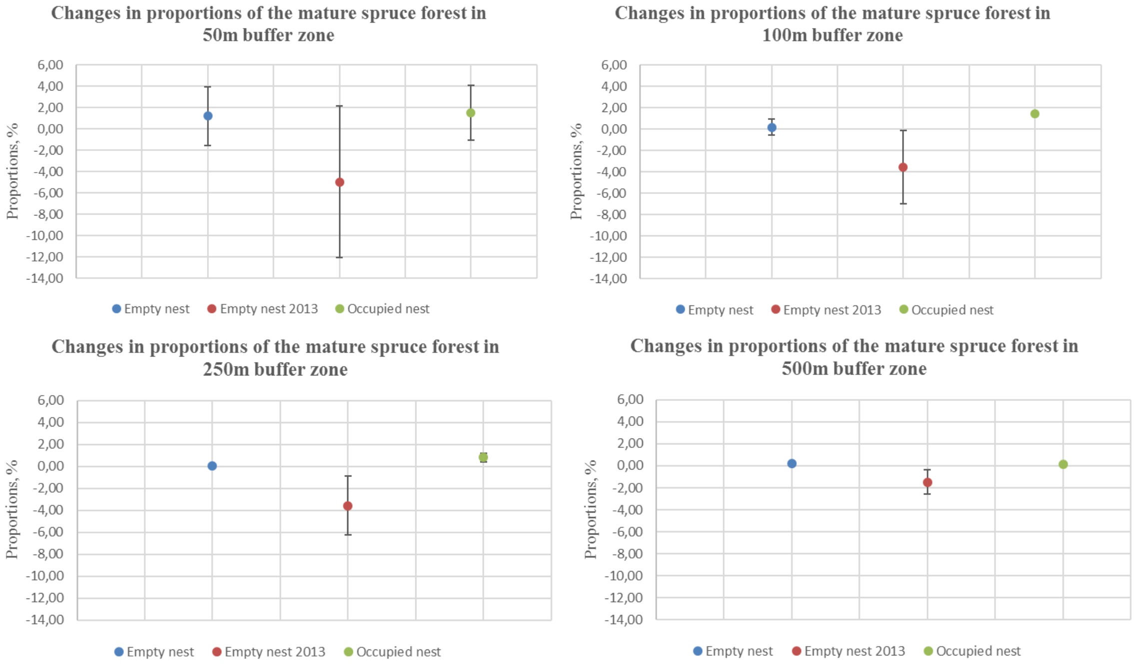


Figure 16. Changes in mature spruce forest (and SD) in relation to northern goshawk occupancy (modified coding)

To generalize the results on goshawk occupancy data was sorted into new categories: “Stable other nest” was added to “Occupied nest”, “Newly empty nest” was added to “Empty nest 2013”, “Changed to other nest” was added to “Occupied nest”, “Stable occupied nest” became “Occupied nest”, “Newly empty other nest” – “Empty nest 2013” and “Stable empty nest” became “Empty nest” (see Appendix E). According to figure 16, “Empty nest 2013” show a trend to decrease amount of mature spruce forest in all buffer zones.

Statistical analyses with the new coded factor of AG occupancy showed nearly significant differences in the amount of mature spruce forest in the 50 m buffer zone ($F_{2,31}$=2,719, p=0,09) and strong significant differences in the 100 m and 250 m buffer zones ($F_{2,31}$=3,469, p=0,04 and $F_{2,31}$=5,192, p=0,01 respectively). More detailed analyses displayed slightly significant decreases in the amount of mature spruce forest in the 50 m and 500 m buffer zones (t=-1,85, p=0,07 and t=-1,849, p=0,07 respectively), as well as significant decreases in the 250 m buffer zone (t=-2,103, p=0,04) for “Empty nest 2013”. The same analysis for the other mature forest hasn’t shown any significant relationship (Table 6), but visually a slight decreasing in “Occupied nest” sites was seen (Appendix F).

Table 6. Results of the statistical analyses when comparing the other mature forest values in buffer zones with F-test for new coded occupancy factor

Buffer zones	$F_{2,31}$	p
50m	0,789	0,46
100m	1,474	0,25
250m	0,088	0,92
500m	2,281	0,12

According to figure 17, low-stocking forest increased in “Empty nest 2013”. Furthermore, statistical analysis showed slight significant increase of this landscape type for the 50 m and 100 m buffer zones when it comes to “Empty nest 2013” (t=1,958, p=0,06 and t=1,771, p=0,09). Additionally, a nearly significant increase in the low-stocking forest was found for “Occupied nests” in the 50 m buffer zone (t=1,869, p=0,07).

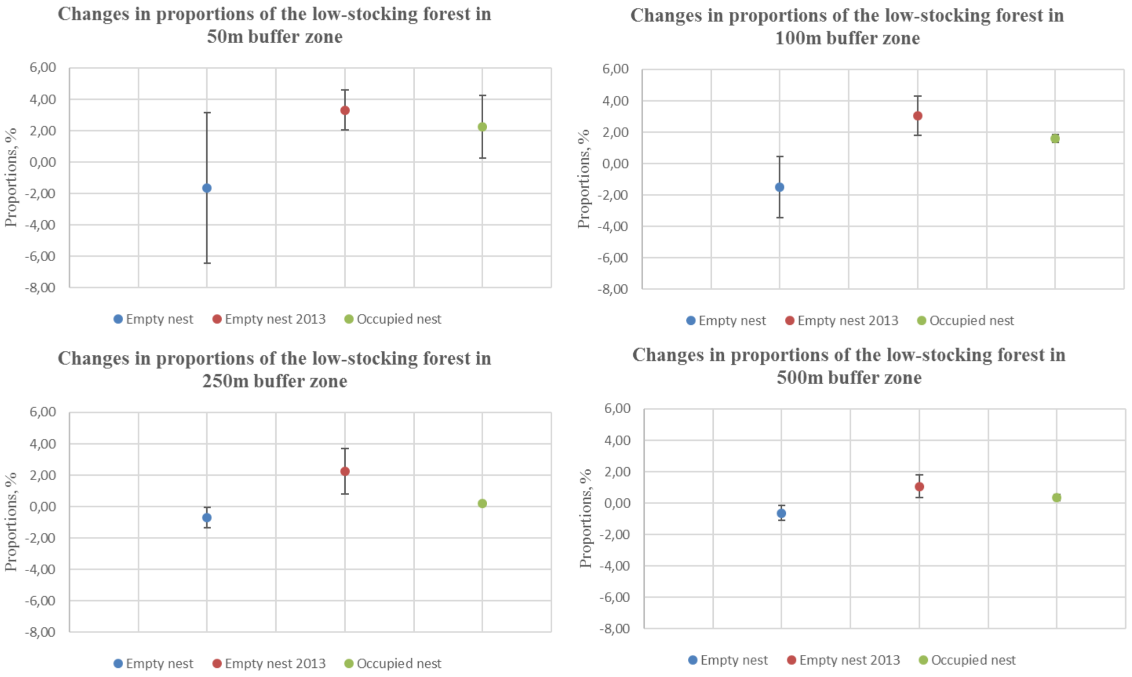


Figure 17. Changes in low-stocking forest (and SD) in relation to northern goshawk occupancy (modified coding)

5. Discussion

The objective of the study was to investigate whether there is any relationship between changes in the mature spruce forest and the species distribution in Suupohja, as well as to find whether there are changes in the protected areas. The results showed that a decreasing amount of mature spruce forest together with an increase in agricultural area could affect northern goshawk breeding and population size. Nevertheless, a strong relationship between changes in the mature spruce forest and Northern goshawk occupancy was found. Decreasing forest usually was accompanied by decreasing species occupancy. However, at the same time the effect of decreasing mature spruce forest on northern goshawk occupancy was not clear in the 250 m buffer zone. This result can be explained by the small amount of samples (n=34) and would require a more in-depth investigation. Also, the results supported the hypothesis that the influence of human activities is reduced to "zero" in protected areas and showed that the data in the maps are reliable. Moreover, a strong decreasing trend when it comes to urban areas in NR was found, which even exceeds my expectations.

In the analysis, a strong relationship was found between variations in the amount of mature spruce forest and the northern goshawk occupancy. This could be the reason for the appearance of the "Stable empty sites" category. At the same time, the amount of other types of mature forest does not show any significant relation to northern goshawk occupancy, so this makes me confident that the mature spruce forest plays the main role. However, I got interesting results analyzing low-stocking forests. The results show that the increasing trend for this type of forest could be an additional reason for the absence of AG and the moves to other nests. The regrouping of the AG occupancy factors showed more generalized results. Nevertheless, I found the same trend in the relationship for the northern goshawk occupancy and the mature spruce forest that supported my hypothesis. Moreover, I found that increasing amounts of low-stocking forest could also be a reason for absent and moving northern goshawk.

The results of this study could be generalized and applied to other boreal zones that preferably will show the same relationship between the mature spruce forest and species occupancy. Moreover, northern goshawk and Ural owl are indicators of high biodiversity in a forest area, so changing in their population can be a trigger of the biodiversity loss (Burgas, Juutinen, & Byholm, 2016). Thus, changes in the landscape composition, preferably in the mature spruce forest, have a direct impact on the biodiversity in boreal zones. During this research a decrease in the mature spruce forest in Genuine sites (50 m and 100 m buffer zones) and in Nest sites (250 buffer zone) was found. It is means that these sites are under threat of declining in biodiversity. Therefore, forestry has a strong impact on the changes in biodiversity and a more careful and sustainable strategy should be applied during forest management. Furthermore, the places for cutting forest should be selected with an understanding of the influence of landscape fragmentation on the species richness. According to the island biogeography theory, “gaps” should be avoided in the landscape configuration, as this lead to the extinction of species.

Nevertheless, the amount of studied sites is quite low and they are concentrated in one region. This is limiting the applicability of the results from this research and requires more in-depth analyses for different regions in Finland. Moreover, for investigating general trends it would be best not to be limited by one country. Due to the behavior of northern goshawks, it would also be interesting to extend buffer zones up to 1000 and 1250 meters. The same applies to Ural owl sites, which require more detailed and special approach due to the behavior of this species. One more limit for my study is the short time period of between gathered data. This is not enough to be confident in the distribution of species and especially not of changes in the landscape configuration in protected areas. Moreover, for the distribution of Ural owls, I recommend doing the pair-years investigation (e.g. from 2009 to 2013 and from 2010 to 2014) for avoiding gaps in data due to the breeding behavior of these birds.

However, I found a strong dependency of the northern goshawk for the mature spruce forest, but there are several factors not taken into account in this research, such as prey species population (as the studied species are predators), breeding behavior, climate factors, etc. This would be required to do more complex research in the future.

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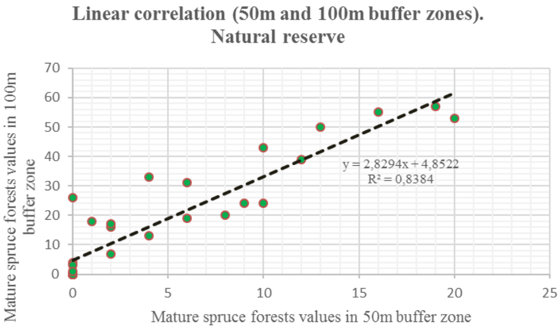
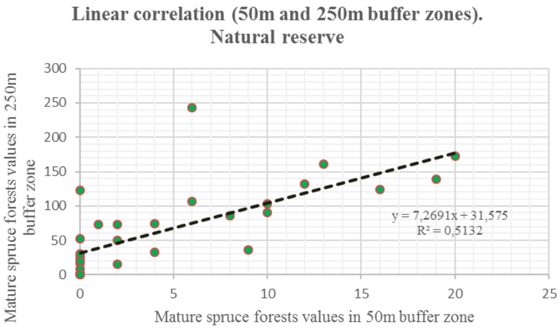
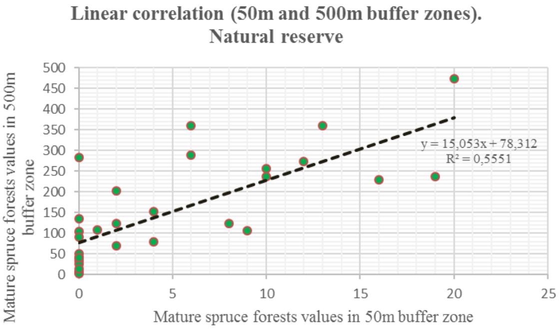
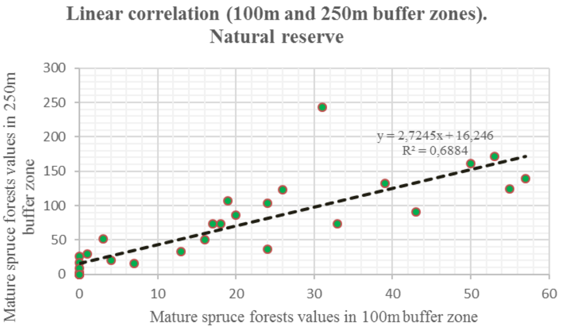
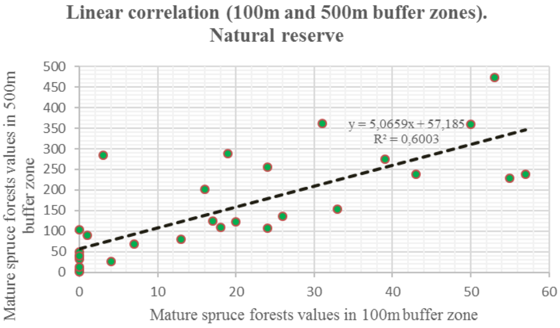
Appendix A. Correlations graphs in 2009 data (Natural reserve sites) between different buffer zones

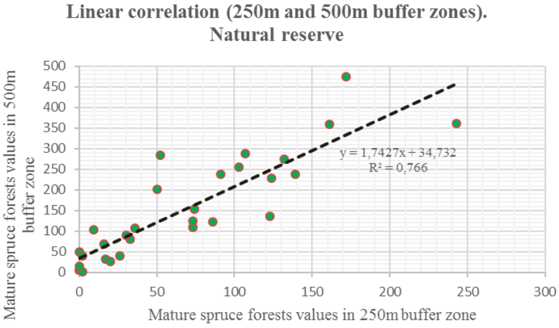












Appendix B. Proportions (SD) of the landscape patches and proportions of the changes in landscape composition (50m, 100m, 250m and 500m)

a) Buffer zone 50m

50m	Northern goshawk			Ural owl			Natural reserve
2009	Nest n=34	Genuine n=34	Random n=34	Nest n=35	Genuine n=35	Random n=35	n=30
Mature spruce forests	43,24 (26,97)	38,67 (23,71)	3,34 (1,29)	19,86 (10,45)	20,64 (10,97)	1,30 (2,65)	25,13 (14,07)
Other mature forests	12,91 (5,52)	16,01 (7,69)	7,14 (1,40)	16,81 (8,30)	22,99 (12,63)	12,39 (5,20)	16,40 (7,90)
Young forests	26,28 (14,97)	37,76 (23,07)	62,92 (40,84)	50,72 (32,28)	40,85 (25,26)	52,31 (33,42)	46,42 (29,12)
Low-stocking forests	16,37 (7,96)	4,68 (0,32)	24,77 (13,68)	9,13 (2,87)	8,78 (2,59)	27,95 (16,20)	5,41 (0,12)
Water bodies	0 (3,61)	0 (3,63)	0 (3,65)	0,14 (3,48)	0 (3,62)	0 (3,57)	0 (3,70)
Agricultural areas	0,30 (3,40)	0 (3,63)	0 (3,65)	0 (3,59)	0 (3,62)	1,01 (2,85)	0,35 (3,46)
Urban areas	0 (3,61)	1,21 (2,78)	1,06 (2,90)	0 (3,59)	1,46 (2,59)	2,59 (1,73)	3,84 (0,99)
Mature pine-dominated forests	0,75 (3,08)	1,66 (2,46)	0,76 (3,12)	3,33 (1,23)	5,27 (0,10)	0,86 (2,95)	2,44 (1,97)
Open bogs, marshes and meadows	0,15 (3,50)	0 (3,63)	0 (3,65)	0 (3,59)	0 (3,62)	1,59 (2,45)	0 (3,70)
50m	Northern goshawk			Ural owl			Natural reserve
2013	Nest n=34	Genuine n=34	Random n=34	Nest n=35	Genuine n=35	Random n=35	n=30
Mature spruce forests	40,99 (25,38)	19,34 (10,04)	2,89 (1,61)	22,90 (19,60)	14,64 (6,73)	3,89 (0,82)	26,70 (15,18)
Other mature forests	15,17 (7,11)	12,54 (5,23)	9,73 (3,22)	14,64 (6,76)	19,33 (10,04)	10,81 (4,08)	18,50 (9,38)
Young forests	20,72 (11,04)	29,61 (17,30)	55,32 (35,46)	42,61 (26,54)	34,55 (20,81)	51,30 (32,71)	39,44 (24,19)
Low-stocking forests	20,27 (10,72)	33,84 (20,29)	29,18 (16,98)	11,16 (4,30)	17,42 (8,70)	22,33 (12,23)	5,06 (0,12)
Water bodies	0 (3,61)	0 (3,63)	0 (3,65)	0,14 (3,48)	0 (3,62)	0 (3,57)	0 (3,70)
Agricultural areas	0,15 (3,50)	0 (3,63)	0 (3,65)	0 (3,59)	0,59 (3,21)	1,15 (2,75)	0,17 (3,58)
Urban areas	0 (3,61)	1,21 (2,78)	1,06 (2,90)	0 (3,59)	1,46 (2,59)	2,59 (1,73)	3,14 (1,48)
Mature pine-dominated forests	2,70 (1,70)	3,47 (1,17)	1,52 (2,58)	8,55 (2,46)	12,01 (4,87)	5,62 (0,41)	6,63 (0,99)
Open bogs, marshes and meadows	0 (3,61)	0 (3,63)	0,30 (3,44)	0 (3,59)	0 (3,62)	2,31 (1,94)	0,35 (3,46)

50m	**Northern goshawk**			**Ural owl**			**Natural reserve**
Changes	Nest n=34	Genuine n=34	Random n=34	Nest n=35	Genuine n=35	Random n=35	n=30
Mature spruce forests	-2,25 (5,20)	-19,34 (17,30)	-0,46 (3,98)	3,04 (1,43)	-6 (7,87)	2,59 (1,73)	1,57 (2,59)
Other mature forests	2,25 (2,02)	-3,47 (6,09)	2,58 (1,83)	-2,17 (5,12)	-3,66 (6,21)	-1,59 (4,69)	2,09 (2,22)
Young forests	-5,56 (7,54)	-8,16 (9,40)	-7,60 (9,03)	-8,12 (9,33)	-6,30 (8,08)	-1,01 (4,28)	-6,98 (8,64)
Low-stocking forests	3,90 (0,85)	29,15 (16,98)	4,41 (0,54)	2,03 (2,15)	8,64 (2,48)	-5,62 (7,54)	-0,35 (3,95)
Water bodies	0 (3,61)	0 (3,63)	0 (3,65)	0 (3,59)	0 (3,62)	0 (3,57)	0 (3,70)
Agricultural areas	-0,15 (3,72)	0 (3,63)	0 (3,65)	0 (3,59)	0,59 (3,21)	0,14 (3,46)	-0,17 (3,83)
Urban areas	0 (3,61)	0 (3,63)	0 (3,65)	0 (3,59)	0 (3,62)	0 (3,57)	-0,70 (4,20)
Mature pine-dominated forests	1,95 (2,23)	1,81 (2,35)	0,76 (3,12)	5,22 (0,10)	6,73 (1,14)	4,76 (0,20)	4,19 (0,74)
Open bogs, marshes and meadows	-0,15 (3,72)	0 (3,63)	0,30 (3,44)	0 (3,59)	0 (3,62)	0,72 (3,06)	0,35 (3,46)

b) buffer zone 100m

100m	Northern goshawk			Ural owl			Natural reserve
2009	Nest n=34	Genuine n=34	Random n=34	Nest n=35	Genuine n=35	Random n=35	n=30
Mature spruce forests	34,85 (23,74)	30,92 (20,96)	5,73 (3,15)	14,40 (9,28)	19,32 (12,76)	2,05 (0,54)	23,45 (15,68)
Other mature forests	13,47 (8,62)	17,32 (11,34)	8,95 (5,43)	16,62 (10,85)	21,26 (14,13)	10,14 (6,27)	16,58 (10,83)
Young forests	31,06 (21,06)	41,75 (28,62)	62,58 (43,35)	50,67 (34,93)	43,64 (29,96)	53,39 (36,84)	46,82 (32,21)
Low-stocking forests	19,20 (12,68)	7,68 (4,53)	20,04 (13,27)	14,33 (9,23)	10,48 (6,51)	28,12 (18,98)	5,98 (3,33)
Water bodies	0 (0,90)	0 (0,90)	0 (0,90)	0,58 (0,49)	0 (0,90)	0 (0,91)	0,04 (0,87)
Agricultural areas	0,86 (0,29)	0 (0,90)	0,11 (0,82)	0,73 (0,39)	0 (0,90)	1,14 (0,10)	1,40 (0,09)
Urban areas	0 (0,90)	1,01 (0,19)	1,24 (0,03)	0,18 (0,77)	0,91 (0,26)	1,87 (0,41)	3,35 (1,47)
Mature pine-dominated forests	0,53 (0,53)	1,31 (0,03)	1,31 (0,03)	2,37 (0,77)	4,16 (2,04)	1,39 (0,08)	2,37 (0,78)
Open bogs, marshes and meadows	0,04 (0,88)	0 (0,90)	0,04 (0,87)	0,11 (0,82)	0,22 (0,75)	1,90 (0,44)	0 (0,90)
100m	**Northern goshawk**			**Ural owl**			**Natural reserve**
2013	Nest n=34	Genuine n=34	Random n=34	Nest n=35	Genuine n=35	Random n=35	n=30
Mature spruce forests	32,93 (22,39)	19,87 (13,15)	5,13 (2,73)	16,88 (11,03)	12,97 (8,26)	2,75 (1,04)	26,04 (17,51)
Other mature forests	14,59 (9,42)	14,09 (9,06)	13 (8,29)	14,66 (9,46)	18,63 (12,27)	10,29 (6,37)	17,51 (11,49)
Young forests	26,93 (18,14)	30,43 (20,62)	52,85 (36,47)	45,68 (31,40)	37,22 (25,41)	53,02 (36,59)	41,98 (28,79)
Low-stocking forests	22,36 (14,91)	31,22 (21,18)	24,53 (16,45)	13,89 (8,92)	20,05 (13,27)	22,01 (14,65)	5,43 (2,94)
Water bodies	0 (0,90)	0 (0,90)	0 (0,90)	0,62 (0,46)	0 (0,90)	0 (0,91)	0 (0,90)
Agricultural areas	0,60 (0,48)	0 (0,90)	0,11 (0,82)	0,77 (0,36)	0,69 (0,41)	1,14 (0,10)	1,15 (0,09)
Urban areas	0 (0,90)	0,94 (0,24)	1,20 (0,05)	0,07 (0,85)	0,88 (0,28)	1,76 (0,34)	2,97 (1,20)
Mature pine-dominated forests	2,59 (0,93)	3,45 (1,54)	3,07 (1,27)	7,11 (4,12)	9,28 (5,66)	6,77 (3,88)	4,83 (2,52)
Open bogs, marshes and meadows	0 (0,90)	0 (0,90)	0,11 (0,82)	0,33 (0,67)	0,29 (0,70)	2,27 (0,70)	0,08 (0,84)

100m	**Northern goshawk**			**Ural owl**			**Natural reserve**
Changes	Nest n=34	Genuine n=34	Random n=34	Nest n=35	Genuine n=35	Random n=35	n=30
Mature spruce forests	-1,91 (2,25)	-11,06 (8,72)	-0,60 (1,32)	2,48 (0,85)	-6,36 (5,40)	0,70 (0,41)	2,59 (0,93)
Other mature forests	1,13 (0,11)	-3,22 (3,18)	4,04 (3,18)	-1,97 (2,29)	-2,63 (2,76)	0,15 (0,80)	0,93 (0,24)
Young forests	-4,13 (3,82)	-11,32 (8,91)	-9,74 (7,79)	-4,99 (4,43)	-6,43 (5,45)	-0,37 (1,17)	-4,83 (4,32)
Low-stocking forests	3,15 (1,33)	23,54 (15,74)	4,49 (2,28)	-0,44 (1,21)	9,57 (5,86)	-6,11 (5,23)	-0,55 (1,29)
Water bodies	0 (0,90)	0 (0,90)	0 (0,90)	0,04 (0,88)	0 (0,90)	0 (0,91)	-0,04 (0,93)
Agricultural areas	-0,26 (1,09)	0 (1,09)	0 (0,90)	0,04 (0,88)	0,69 (0,41)	0 (0,91)	-0,25 (1,08)
Urban areas	0 (0,90)	-0,07 (0,95)	-0,04 (0,93)	-0,11 (0,98)	-0,04 (0,93)	-0,11 (0,98)	-0,38 (1,17)
Mature pine-dominated forests	2,06 (0,56)	2,14 (0,61)	1,76 (0,34)	4,74 (2,45)	5,11 (2,71)	5,38 (2,90)	2,46 (0,84)
Open bogs, marshes and meadows	-0,04 (0,93)	0 (0,90)	0,07 (0,85)	0,22 (0,75)	0,07 (0,85)	0,37 (0,65)	0,08 (0,84)

c) buffer zone 250m

250 m	**Northern goshawk**			**Ural owl**			**Natural reserve**
2009	Nest n=34	Genuine n=34	Random n=34	Nest n=35	Genuine n=35	Random n=35	n=30
Mature spruce forests	20,79 (14,56)	16,79 (11,73)	6,23 (4,26)	8,75 (6,04)	10,42 (7,23)	2,85 (1,87)	13,55 (9,44)
Other mature forests	12,08 (8,40)	14,37 (10,02)	12,21 (8,49)	13,72 (9,56)	15,17 (10,58)	9,94 (6,88)	14,19 (9,89)
Young forests	43,01 (30,27)	45,66 (32,14)	58,66 (41,33)	49,30 (34,72)	48,68 (34,28)	52,79 (37,18)	51,92 (36,57)
Low-stocking forests	20,10 (14,07)	17,32 (12,10)	18,97 (13,27)	19,76 (13,83)	18,68 (13,07)	26,18 (18,37)	10,13 (7,02)
Water bodies	0 (0,14)	0 (0,14)	0 (0,14)	1,28 (0,76)	0 (0,14)	0,62 (0,30)	1,45 (0,88)
Agricultural areas	1,89 (1,19)	2,91 (1,92)	0,49 (0,20)	3,21 (2,12)	1,25 (0,74)	2,54 (1,65)	3,93 (2,63)
Urban areas	0,42 (0,15)	1,53 (0,94)	1,21 (0,71)	0,75 (0,39)	0,94 (0,52)	0,94 (0,52)	2,11 (1,35)
Mature pine-dominated forests	1,26 (0,75)	1,23 (0,73)	1,68 (1,04)	2,68 (1,75)	3,73 (2,49)	2,16 (1,38)	2,32 (1,49)
Open bogs, marshes and meadows	0,44 (0,17)	0,19 (0,01)	0,55 (0,24)	0,55 (0,25)	1,12 (0,65)	1,98 (1,26)	0,41 (0,14)
250 m	**Northern goshawk**			**Ural owl**			**Natural reserve**
2013	Nest n=34	Genuine n=34	Random n=34	Nest n=35	Genuine n=35	Random n=35	n=30
Mature spruce forests	18,05 (12,62)	13,91 (9,69)	5,49 (3,74)	9,39 (6,49)	7,78 (5,36)	3,38 (2,25)	16,36 (11,42)
Other mature forests	13,19 (9,18)	12,47 (8,68)	13,73 (9,57)	11,59 (8,05)	13,17 (9,17)	10,96 (7,61)	14,94 (10,42)
Young forests	40,84 (28,73)	40,94 (28,80)	53,84 (37,93)	48,20 (33,94)	43,09 (30,33)	50,06 (35,25)	46,78 (32,93)
Low-stocking forests	21,83 (15,29)	24,64 (17,28)	20,22 (14,16)	18,77 (13,13)	23,54 (16,50)	22,46 (15,74)	8,79 (6,07)
Water bodies	0 (0,14)	0 (0,14)	0 (0,14)	1,36 (0,81)	0 (0,14)	0,61 (0,29)	1,52 (0,93)
Agricultural areas	1,83 (1,15)	3,08 (2,04)	0,55 (0,25)	3,19 (2,11)	1,82 (1,14)	2,53 (1,64)	3,89 (2,61)
Urban areas	0,42 (0,15)	1,40 (0,85)	1,15 (0,67)	0,62 (0,30)	0,87 (0,47)	0,90 (0,49)	1,90 (1,20)
Mature pine-dominated forests	3,51 (2,34)	3,51 (2,34)	4,32 (2,91)	6,35 (4,34)	8,50 (5,87)	7,15 (4,91)	5,25 (3,57)
Open bogs, marshes and meadows	0,32 (0,08)	0,04 (0,11)	0,69 (0,34)	0,54 (0,24)	1,22 (0,72)	1,94 (1,23)	0,56 (0,25)

250 m	**Northern goshawk**			**Ural owl**			**Natural reserve**
Differences	Nest n=34	Genuine n=34	Random n=34	Nest n=35	Genuine n=35	Random n=35	n=30
Mature spruce forests	-2,74 (2,08)	-2,88 (2,18)	-0,74 (0,67)	0,63 (0,30)	-2,64 (2,01)	0,54 (0,23)	2,81 (1,84)
Other mature forests	1,11 (0,64)	-1,90 (1,48)	1,52 (0,93)	-2,13 (1,65)	-2,00 (1,56)	1,02 (0,58)	0,75 (0,39)
Young forests	-2,17 (1,68)	-4,73 (3,49)	-4,81 (3,55)	-1,10 (0,92)	-5,59 (4,09)	-2,73 (2,07)	-5,14 (3,78)
Low-stocking forests	1,72 (1,08)	7,32 (5,03)	1,25 (0,74)	-0,99 (0,85)	4,86 (3,29)	-3,72 (2,78)	-1,34 (1,09)
Water bodies	0 (0,14)	0 (0,14)	0 (0,14)	0,08 (0,09)	0 (0,14)	-0,01 (0,15)	0,07 (0,09)
Agricultural areas	-0,05 (0,18)	0,17 (0,18)	0,06 (0,10)	-0,02 (0,16)	0,57 (0,26)	-0,01 (0,15)	-0,03 (0,17)
Urban areas	0 (0,14)	-0,13 (0,23)	-0,06 (0,19)	-0,13 (0,23)	-0,07 (0,19)	-0,04 (0,17)	-0,21 (0,29)
Mature pine-dominated forests	2,25 (1,45)	2,28 (1,47)	2,64 (1,72)	3,67 (2,45)	4,77 (3,23)	5,00 (3,39)	2,94 (1,93)
Open bogs, marshes and meadows	-0,12 (0,23)	-0,14 (0,25)	0,14 (0,04)	-0,01 (2,15)	0,10 (0,07)	-0,04 (0,17)	0,15 (0,04)

d) buffer zone 500m

500m	**Northern goshawk**			**Ural owl**			**Natural reserve**
2009	Nest n=34	Genuine n=34	Random n=34	Nest n=35	Genuine n=35	Random n=35	n=30
Mature spruce forests	12,36 (8,70)	11,03 (7,77)	6,26 (4,39)	6,41 (4,50)	6,30 (4,42)	3,23 (2,25)	7,67 (5,39)
Other mature forests	11,65 (8,20)	11,94 (8,41)	12,05 (8,49)	13,02 (9,17)	12,04 (8,48)	10,20 (7,17)	11,18 (7,87)
Young forests	49,94 (35,27)	47,71 (33,70)	57,15 (40,38)	46,87 (33,10)	48,49 (34,25)	49,16 (34,72)	50,80 (35,89)
Low-stocking forests	20,49 (14,45)	21,43 (15,12)	19,19 (13,54)	21,67 (15,29)	22,97 (16,21)	24,01 (16,94)	12,81 (9,02)
Water bodies	0,16 (0,08)	0 (0,04)	0,03 (0,02)	1,11 (0,75)	0,01 (0,03)	1,69 (1,16)	3,64 (2,54)
Agricultural areas	1,81 (1,24)	4,89 (3,42)	0,85 (0,56)	5,03 (3,52)	3,13 (2,18)	4,60 (3,22)	6,31 (4,42)
Urban areas	0,68 (0,45)	1,24 (0,84)	0,99 (0,66)	1,06 (0,71)	1,80 (1,23)	0,85 (0,56)	2,57 (1,78)
Mature pine-dominated forests	1,54 (1,05)	1,20 (0,81)	1,83 (1,26)	2,95 (2,05)	3,31 (2,30)	3,07 (2,14)	2,29 (1,59)
Open bogs, marshes and meadows	1,37 (0,94)	0,56 (0,36)	1,64 (1,13)	1,89 (1,30)	1,95 (1,35)	3,20 (2,23)	2,73 (1,89)
500m	**Northern goshawk**			**Ural owl**			**Natural reserve**
2013	Nest n=34	Genuine n=34	Random n=34	Nest n=35	Genuine n=35	Random n=35	n=30
Mature spruce forests	11,24 (7,91)	10,44 (7,35)	6,72 (4,71)	6,43 (4,51)	4,91 (3,44)	3,26 (2,27)	9,55 (6,72)
Other mature forests	12,89 (9,08)	12,56 (8,84)	13,87 (9,77)	11,17 (7,86)	11,09 (7,80)	10,80 (7,60)	11,73 (8,26)
Young forests	46,37 (32,76)	45,17 (31,90)	53,93 (38,10)	46,71 (32,99)	45,20 (31,92)	47,69 (33,69)	46,76 (33,03)
Low-stocking forests	21,29 (15,02)	21,38 (15,08)	17,26 (12,17)	20,28 (14,31)	23,82 (16,80)	21,27 (15,01)	11,81 (8,31)
Water bodies	0,18 (0,09)	0 (0,04)	0,02 (0,02)	1,13 (0,76)	0,02 (0,02)	1,70 (1,17)	3,66 (2,55)
Agricultural areas	1,82 (1,25)	4,96 (3,47)	0,86 (0,57)	4,92 (3,45)	4,05 (2,83)	4,58 (3,21)	6,23 (4,37)
Urban areas	0,64 (0,41)	1,08 (0,73)	0,90 (0,60)	0,91 (0,61)	1,60 (1,10)	0,73 (0,48)	2,11 (1,45)
Mature pine-dominated forests	4,33 (3,02)	4,00 (2,80)	4,86 (3,40)	6,42 (4,51)	7,22 (5,07)	6,74 (4,73)	5,23 (3,66)
Open bogs, marshes and meadows	1,23 (0,84)	0,41 (0,26)	1,58 (1,08)	2,02 (1,39)	2,09 (1,44)	3,22 (2,24)	2,92 (2,03)

500m	**Northern goshawk**			**Ural owl**			**Natural reserve**
Changes	Nest n=34	Genuine n=34	Random n=34	Nest n=35	Genuine n=35	Random n=35	n=30
Mature spruce forests	-1,12 (0,83)	-0,59 (0,46)	0,46 (0,29)	0,02 (0,02)	-1,39 (1,02)	0,03 (0,02)	1,88 (1,29)
Other mature forests	1,25 (0,85)	0,61 (0,40)	1,81 (1,25)	-1,84 (1,34)	-0,95 (0,71)	0,61 (0,39)	0,55 (0,35)
Young forests	-3,56 (2,56)	-2,54 (1,83)	-3,22 (2,31)	-0,15 (0,15)	-3,29 (2,36)	-1,46 (1,07)	-4,04 (2,90)
Low-stocking forests	0,80 (0,53)	-0,05 (0,07)	-1,94 (1,41)	-1,39 (1,02)	0,85 (0,56)	-2,73 (1,97)	-1,00 (0,74)
Water bodies	0,02 (0,02)	0 (0,04)	-0,01 (0,04)	0,02 (0,02)	0,01 (0,03)	0,02 (0,02)	0,01 (0,03)
Agricultural areas	0,01 (0,03)	0,07 (0,03)	0,01 (0,03)	-0,10 (0,11)	0,92 (0,61)	-0,02 (0,05)	-0,07 (0,09)
Urban areas	-0,04 (0,07)	-0,16 (0,15)	-0,09 (0,10)	-0,15 (0,14)	-0,19 (0,17)	-0,12 (0,12)	-0,46 (0,36)
Mature pine-dominated forests	2,79 (1,93)	2,80 (1,94)	3,02 (2,10)	3,47 (2,42)	3,91 (2,73)	3,67 (2,56)	2,94 (2,04)
Open bogs, marshes and meadows	-0,14 (0,14)	-0,14 (0,14)	-0,06 (0,08)	0,13 (0,06)	0,14 (0,06)	0,02 (0,02)	0,20 (0,10)

Appendix C. Proportions of the changes in landscape composition in relationship with the northern goshawk distribution (50m, 100m, 250m and 500m)

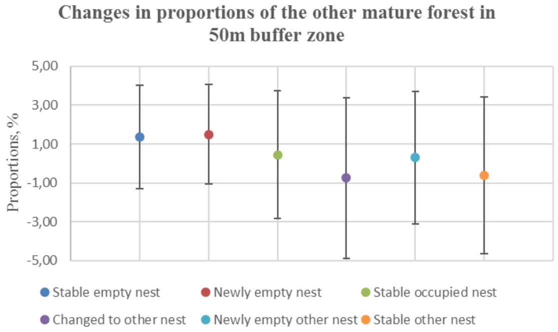
Buffer 50m	Northern goshawk											
	Stable empty nest		Newly empty nest		Stable occupied nest		Changed to other nest		Newly empty other nest		Stable other nest	
	Proportion	SD	Proportion	SD	Proportion	SD	Proportion	SD	Proportion	SD	Proportion	SD
Mature spruce forests	1,20	2,76	-5,11	7,22	0,00	3,61	1,05	2,87	0,15	3,50	0,45	3,29
Other mature forests	1,35	2,65	1,50	2,55	0,45	3,29	-0,75	4,14	0,30	3,40	-0,60	4,03
Young forests	-1,35	4,57	1,80	2,34	-0,75	4,14	-0,45	3,93	-2,85	5,63	-1,95	4,99
Low-stocking forests	-1,65	4,78	1,35	2,65	0,00	3,61	0,15	3,50	1,95	2,23	2,10	2,12
Water bodies	0,00	3,61	0,00	3,61	0,00	3,61	0,00	3,61	0,00	3,61	0,00	3,61
Agricultural areas	0,00	3,61	-0,15	3,72	0,00	3,61	0,00	3,61	0,00	3,61	0,00	3,61
Urban areas	0,00	3,61	0,00	3,61	0,00	3,61	0,00	3,61	0,00	3,61	0,00	3,61
Mature pine-dominated forests	0,45	3,29	0,75	3,08	0,30	3,40	0,00	3,61	0,45	3,29	0,00	3,61
Open bogs, marshes and meadows	0,00	3,61	-0,15	3,72	0,00	3,61	0,00	3,61	0,00	3,61	0,00	3,61

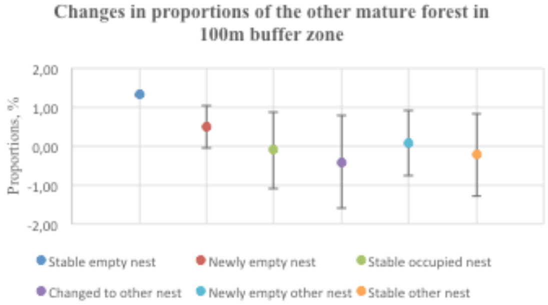
Buffer 100m	Northern goshawk											
	Stable empty nest		Newly empty nest		Stable occupied nest		Changed to other nest		Newly empty other nest		Stable other nest	
	Proportion	SD	Proportion	SD	Proportion	SD	Proportion	SD	Proportion	SD	Proportion	SD
Mature spruce forests	0,19	0,77	-3,04	3,05	0,26	0,72	0,45	0,58	-0,53	1,27	0,75	0,37
Other mature forests	1,31	0,03	0,49	0,56	-0,11	0,98	-0,41	1,19	0,08	0,85	-0,23	1,06
Young forests	-0,56	1,30	-0,23	1,06	-1,01	1,62	0,04	0,88	-0,79	1,46	-1,58	2,02
Low-stocking forests	-1,50	1,96	2,03	0,53	0,53	0,53	-0,04	0,93	1,01	0,19	1,13	0,11
Water bodies	0,00	0,90	0,00	0,90	0,00	0,90	0,00	0,90	0,00	0,90	0,00	0,90
Agricultural areas	0,00	0,90	-0,04	0,93	0,00	0,90	-0,23	1,06	0,00	0,90	0,00	0,90
Urban areas	0,00	0,90	0,00	0,90	0,00	0,90	0,00	0,90	0,00	0,90	0,00	0,90
Mature pine-dominated forests	0,56	0,50	0,83	0,32	0,34	0,66	0,19	0,77	0,23	0,74	-0,08	0,95
Open bogs, marshes and meadows	0,00	0,90	-0,04	0,93	0,00	0,90	0,00	0,90	0,00	0,90	0,00	0,90

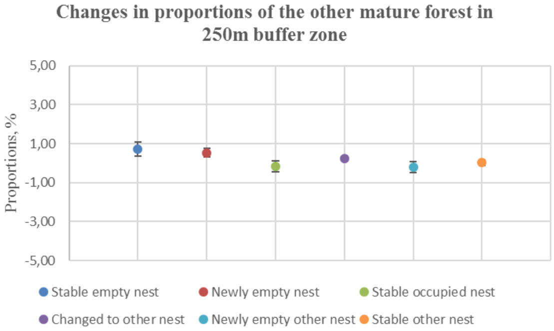
Buffer 250m	Northern goshawk											
	Stable empty nest		Newly empty nest		Stable occupied nest		Changed to other nest		Newly empty other nest		Stable other nest	
	Proportion	SD	Proportion	SD	Proportion	SD	Proportion	SD	Proportion	SD	Proportion	SD
Mature spruce forests	0,02	0,13	-2,24	1,73	0,22	0,01	0,19	0,01	-1,32	1,08	0,39	0,13
Other mature forests	0,72	0,37	0,52	0,22	-0,17	0,26	0,22	0,01	-0,20	0,29	0,02	0,13
Young forests	-0,53	0,52	-0,28	0,34	-0,68	0,63	-0,17	0,27	0,34	0,09	-0,84	0,74
Low-stocking forests	-0,71	0,65	1,46	0,88	0,15	0,04	-0,07	0,19	0,80	0,42	0,11	0,07
Water bodies	0,00	0,14	0,00	0,14	0,00	0,14	0,00	0,14	0,00	0,14	0,00	0,14
Agricultural areas	0,00	0,14	0,02	0,13	0,00	0,14	-0,08	0,20	0,01	0,14	0,00	0,14
Urban areas	0,00	0,14	0,00	0,14	0,00	0,14	0,00	0,14	0,00	0,14	0,00	0,14
Mature pine-dominated forests	0,46	0,18	0,51	0,22	0,48	0,19	0,10	0,08	0,37	0,12	0,34	0,09
Open bogs, marshes and meadows	0,03	0,12	0,02	0,13	0,00	0,14	-0,17	0,27	0,01	0,14	-0,01	0,15

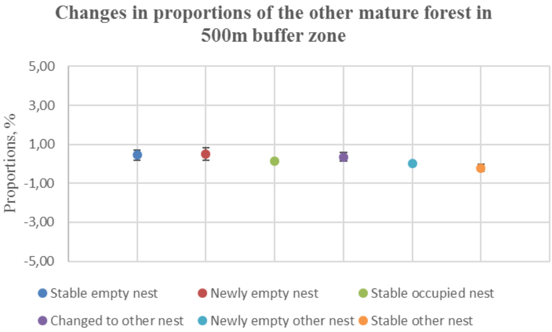
Buffer 500m	Northern goshawk											
	Stable empty nest		Newly empty nest		Stable occupied nest		Changed to other nest		Newly empty other nest		Stable other nest	
	Proportion	SD	Proportion	SD	Proportion	SD	Proportion	SD	Proportion	SD	Proportio n	SD
Mature spruce forests	0,22	0,12	-1,16	0,86	0,09	0,02	0,22	0,12	-0,30	0,25	-0,18	0,16
Other mature forests	0,44	0,28	0,50	0,32	0,13	0,06	0,35	0,21	0,04	0,01	-0,21	0,19
Young forests	-0,83	0,62	-0,68	0,52	-0,46	0,36	-0,39	0,31	-0,51	0,40	-0,70	0,53
Low-stocking forests	-0,62	0,48	0,72	0,47	-0,22	0,19	-0,15	0,14	0,35	0,21	0,72	0,47
Water bodies	0,02	0,02	0,00	0,04	0,00	0,04	0,00	0,04	0,00	0,04	0,00	0,04
Agricultural areas	0,00	0,04	0,00	0,04	-0,04	0,06	0,04	0,01	0,00	0,03	0,01	0,03
Urban areas	-0,01	0,05	-0,02	0,05	0,01	0,03	0,00	0,04	0,00	0,04	-0,02	0,05
Mature pine-dominated forests	0,81	0,54	0,67	0,44	0,52	0,33	0,02	0,02	0,42	0,26	0,34	0,21
Open bogs, marshes and meadows	-0,02	0,05	-0,02	0,05	-0,03	0,05	-0,10	0,11	0,00	0,03	0,03	0,02

Appendix D. Changes in the other mature forest (and SD) in relation to northern goshawk occupancy.









Appendix E. Proportions of the changes in landscape composition in relationship with the northern goshawk distribution in more generalized coding (50m, 100m, 250m and 500m)

Buffer 50m	Northern goshawk					
	Empty nest		Empty nest 2013		Occupied nest	
	Proportion	SD	Proportion	SD	Proportion	SD
Mature spruce forests	1,20	2,76	-4,95	7,11	1,50	2,55
Other mature forests	1,35	2,65	1,80	2,34	-0,90	4,25
Young forests	-1,35	4,57	-1,05	4,35	-3,15	5,84
Low-stocking forests	-1,65	4,78	3,30	1,27	2,25	2,02
Water bodies	0,00	3,61	0,00	3,61	0,00	3,61
Agricultural areas	0,00	3,61	-0,15	3,72	0,00	3,61
Urban areas	0,00	3,61	0,00	3,61	0,00	3,61
Mature pine-dominated forests	0,45	3,29	1,20	2,76	0,30	3,40
Open bogs, marshes and meadows	0,00	3,61	-0,15	3,72	0,00	3,61

Buffer 100m	Northern goshawk					
	Empty nest		Empty nest 2013		Occupied nest	
	Proportion	SD	Proportion	SD	Proportion	SD
Mature spruce forests	0,19	0,77	-3,56	3,42	1,46	0,13
Other mature forests	1,31	0,03	0,56	0,50	-0,75	1,43
Young forests	-0,56	1,30	-1,01	1,62	-2,55	2,71
Low-stocking forests	-1,50	1,96	3,04	1,25	1,61	0,24
Water bodies	0,00	0,90	0,00	0,90	0,00	0,90
Agricultural areas	0,00	0,90	-0,04	0,93	-0,23	1,06
Urban areas	0,00	0,90	0,00	0,90	0,00	0,90
Mature pine-dominated forests	0,56	0,50	1,05	0,16	0,45	0,58
Open bogs, marshes and meadows	0,00	0,90	-0,04	0,93	0,00	0,90

Buffer 250m	Northern goshawk					
	Empty nest		Empty nest 2013		Occupied nest	
	Proportion	SD	Proportion	SD	Proportion	SD
Mature spruce forests	0,02	0,13	-3,56	2,66	0,80	0,42
Other mature forests	0,72	0,37	0,32	0,08	0,07	0,10
Young forests	-0,53	0,52	0,05	0,11	-1,70	1,35
Low-stocking forests	-0,71	0,65	2,25	1,45	0,19	0,01
Water bodies	0,00	0,14	0,00	0,14	0,00	0,14
Agricultural areas	0,00	0,14	0,03	0,12	-0,08	0,20
Urban areas	0,00	0,14	0,00	0,14	0,00	0,14
Mature pine-dominated forests	0,46	0,18	0,88	0,48	0,91	0,50
Open bogs, marshes and meadows	0,03	0,12	0,03	0,12	-0,18	0,27

Buffer 500m	Northern goshawk					
	Empty nest		Empty nest 2013		Occupied nest	
	Proportion	SD	Proportion	SD	Proportion	SD
Mature spruce forests	0,22	0,12	-1,47	1,07	0,13	0,06
Other mature forests	0,44	0,28	0,54	0,34	0,27	0,15
Young forests	-0,83	0,62	-1,19	0,88	-1,54	1,13
Low-stocking forests	-0,62	0,48	1,07	0,72	0,36	0,22
Water bodies	0,02	0,02	0,00	0,04	0,00	0,04
Agricultural areas	0,00	0,04	0,00	0,04	0,01	0,03
Urban areas	-0,01	0,05	-0,02	0,05	0,00	0,04
Mature pine-dominated forests	0,81	0,54	1,10	0,74	0,88	0,59
Open bogs, marshes and meadows	-0,02	0,05	-0,02	0,05	-0,10	0,11

Appendix F. Changes in the other mature forest (and SD) in relation to northern goshawk occupancy (modified coding).