Action A3.1: Illustrating the potential habitat network of the Flying squirrel

Deliverable: Predictive habitat maps on potential Flying squirrel habitat network in Finland and Estonia ready and available

Flying squirrel LIFE (LIFE17 NAT/FI/000469)

Beneficiary responsible for implementation: LUKE

April 17th 2023

As part of the European Union -funded Flying Squirrel LIFE project, suitable habitats for the flying squirrel were modeled throughout the species' range in Finland. The results of the modeling are published as maps that predict the quality of the habitat suitable for the flying squirrel. The maps do not predict the presence of the flying squirrel. Forecast maps have no legal or regulatory effect. The use of the maps requires acceptance of the map description and license.

Background

As part of the European Union -funded Liito-orava-LIFE project (https://www.metsa.fi/projekti/liito-orava-life/), suitable habitats for the flying squirrel were modeled throughout the species' range in Finland. The purpose of the modeling was to produce a high-resolution forecast map, which, based on statistical modeling, shows habitats likely to be suitable for flying squirrels in the species' distribution area. The forecast maps do not describe the occurrence or probability of occurrence of the flying squirrel, but the habitats that are suitable for it. The forecast map material can be downloaded and used in accordance with the approval and license of the information below.

About the flying squirrel

The flying squirrel (Pteromys volans L.) occurs in Finland mainly south of the Kalajoki-Posio-Kuusamo line. Out of EU countries, Flying squirrels are only found in Finland and Estonia. In Finland, the flying squirrel is classified as endangered (VU) and is protected based on the EU habitat directive and the Nature Conservation Act (1096/1996). It is forbidden to weaken

and destroy flying squirrel breeding or resting places. All felling methods according to the Forest Act are possible around the breeding and resting places of the species, as long as the instructions on taking the flying squirrel into account when cutting forests are followed. More information can be found at https://tapio.fi/oppaat-ja-tyovalineet/liito-oravan-huomioon-otettane-metsankayton-yttssa-neuvontamaterialiari/.
The flying squirrel prefers mature spruce-hardwood mixed forests, which often also have other diversity values. For food, it uses leaves and catkins of deciduous trees. The flying squirrel leaves outside nest mostly at dusk and at night, which is why it is rarely seen. The flying squirrel can use trees over 10 meters high to move around. The forest areas most used by individuals can be identified most easily based on faeces or urine marks in spring. More information can be found in e.g. https://julkaisut.metsa.fi/assets/pdf/lp/Esittete/liito-orava-life-esite.pdf and https://www.sll.fi/app/uploads/2020/06/Liitis-kartoitusopas- A5-WEB-openings.pdf.

Why was habitat modeling done?

There are numerous observations of the flying squirrel throughout its range, and the observations have been stored in the registers of various authorities. Flying squirrel observations are now collected in the laji.fi database maintained by the National Natural History Museum (Luomus), where there are about 63,000 of them. However, flying squirrels have not been systematically mapped everywhere, but the information in different databases is based on the work of individual enthusiasts, nature organizations, authorities and research projects' observations. It is likely that there are numerous sites where flying squirrels occur, but which have not been mapped.

Since the flying squirrel is short-lived, living on average perhaps only one to two years, the presence of the species even in suitable forests and habitats varies considerably. A suitable forest spot may be temporarily empty after the death of a local inhabitant, before a new individual finds it again.

With modeling based on habitat requirements, potentially suitable habitats for the species can be comprehensively predicted throughout its range of occurrence, regardless of the presence of individuals of the species at the time of the prediction. The predictive maps show the probability of the forest areas suitable for flying squirrel habitats.

Habitat prediction maps can be used for several purposes, but they are most suitable for examining large areas and, for example, as a support for regional planning. Forecast maps can be a good help, for example, when it is necessary to target flying squirrels over a wide area more precisely. The description of the forecast maps of potentially suitable habitats can also be used as partial information when assessing and setting the forest owner's goals in forest planning. However, the presence of the flying squirrel in an area should always be confirmed by means of careful field inventories. It should be noted that the areas shown probable for flying squirrel on the maps do not limit forests or other land use or cause legal effects as such.

It should be noted that forecast maps cannot be used to estimate the size of the flying squirrel population. The occurrence of the species even in good environments varies a lot due to natural reasons, and not all sites that seem suitable are ever inhabited. On the other hand, forecasts always also include the so-called false positive targets, i.e. computationally suitable targets that are not actually suitable for flying squirrels. Flying squirrels can also occur in areas that do not appear on maps as likely habitats (false negative).

With the help of forecast maps, the development of the flying squirrel's habitats can be monitored over time, so that the modeling is repeated and forecasts from different points in time are compared to each other.

Model description

This modeling work started at the beginning of 2019. The more reliable the modeling work and the predictive maps made based on it are needed, the more careful the quality assurance of the material in use must be.

Flying squirrel observations from the database of the Finnish Environmental Center (Syke) were used as flying squirrel data. Initially, there were approx. 48,500 observations in the material, which have been accumulated since 1980. The material as a whole is heterogenous and contains, for example, old and uncertain observations. As a result, part of data had to be removed under certain conditions to ensure the reliability of the modeling work. For modeling purposes, the observations made before 2009 were removed, as well as those located in water bodies, forests cut down after the observation was made, settlements, fields and other non-forested areas. There were often numerous observations in a single stand, so only one observation from the observations that were 170 meters closer to each other was picked up by random sampling. The home range of female flying squirrels is approx. 8 ha, and by removing observations that were too close to each other, the aim was to ensure that the observations would represent information on the home range level rather than variation within the forest. As a result 5,613 observations were used in the final modelling.

In the modelling, the multi-source national forest inventory data (MS-NFI data) from the year 2017 was used as the data describing the forests. The description of the MS-NFI data can be found, for example, here: https://www.luke.fi/tietoa-luonnonvaroista/metsa/metsavarat-ja-metsasuunnittu/metsavarakartat- and municipal statistics/.

The size of the image element (pixel) of the MS-NFI data corresponds to an area of 16 m × 16 m on the earth's surface. The multi-source material was classified according to tree species and volume into older spruce-leaf mixed forests suitable for the flying squirrel, other older forests suitable for the movement of the flying squirrel, and open areas. Older forests were defined based on the volume of the forests, and the volume criteria were adjusted regionally based on the age-volume data published by NFI and partly based on observations of flying squirrels. In addition, fields, settlements, roads, other non-forest areas and water bodies obtained from the land survey database of the Land Survey were added to the landscape data.

The structural features of the flying squirrel's habitat were calculated from the following landscape categories: forests suitable for flying squirrels, forests suitable for movement (>10 m), young forests and clear-cuts, agricultural fields, settlements and water bodies. The structural features of the landscape were used as explanatory variables in the model.

In the next step, a regular network of points was placed every 500 meters in the area where the flying squirrel occurs, and the same landscape indice were calculated for the points as for the flying squirrel and control points. For each point, the probability given by the model between 0-100% of the suitability of the habitat for the flying squirrel was further calculated. Finally, the probabilities were interpolated into the 100 m grid cells by using so-called natural neighbor method. The smallest distinct unit of the predictive maps corresponds to a 100 m × 100 m area in the terrain. The maps show the probability between 0-100% by 1 % intervals.

Accuracy and service life of predictive maps

Predictive maps are based on statistical modeling, which is characterized by the fact that models are always simplifications of reality. They do not predict the response variable, i.e. in this case the probability of a suitable habitat for the flying squirrel with 100% accuracy.

In principle, the accuracy of predictive maps can be measured in several ways, but the most frequently used measures are sensitivity and specificity. Sensitivity means the model's ability to correctly predict the phenomenon being modelled, i.e. in this case it tells how large a proportion of flying squirrel observations (habitats) can be predicted correctly by the model (true positive rate). The specificity, on the other hand, means how large a proportion of the control cases, i.e. in this case random points, are predicted correctly (true negative rate). In the models that were the basis of the prediction maps, the sensitivity varied between 60.5 and 75 and the specificity between 67.5 and 90.3. The so-called models overall accuracy (Receiver Operating Characteristic, ROC) ranged from 0.78 to 0.92.

In summary, this means that, based on modeling, suitable habitat areas for flying squirrels can be predicted better than pure guesswork, i.e. correctly in about 60-75 percent of cases. The most likely stands suitable for the flying squirrel within the areas predicted to be suitable are mature spruce forests with mixed hardwoods, or mature and old hardwood stands.

Outside of the areas predicted to be good flying squirrel habitats, there are still some sites that are suitable for flying squirrels and vice versa. Objects unsuitable for flying squirrels can be distinguished a little better than objects predicted to be suitable for flying squirrels. Due to the prediction generalization technique, the areas marked as probable in the predictive maps also contain places that are not necessarily suitable for flying squirrels.

The accuracy of the maps is also affected by the time that has passed between the moment the maps are made and the moment they are used. The model has been made with multi-source data from the 2017 national forest inventory, and as a principle it can be considered that the longer time passes between the ML-VMI data and the moment of use, the more the landscape changes, e.g. as a result of logging and other land use. Therefore, the predictability of the models decreases over time.

This modeling work is connected to the Liito-orava-LIFE project, which will end in 2025, and it may not be possible to repeat or renew it after a certain time for the sake of comparison. Forest areas can change a lot in a short time due to logging. On the other hand, connections between suitable habitats can substantially improve in a certain region over the course of a few years, when the trees in some forest exceed ten meters in height and the flying squirrels get to use a new route to move from one place to another.

Examples of the use of predictive maps

The predictive maps contain only the probability of the suitable habitat for flying squirrel in 100 m × 100 m resolution and 1 % interval between 1-100 % probabilities. Maps cover the whole occurrence area of the flying squirrel except the easternmost Finland, where the accuracy of the predictive models was low (Fig. 1). Therefore, the area was left out of the maps.

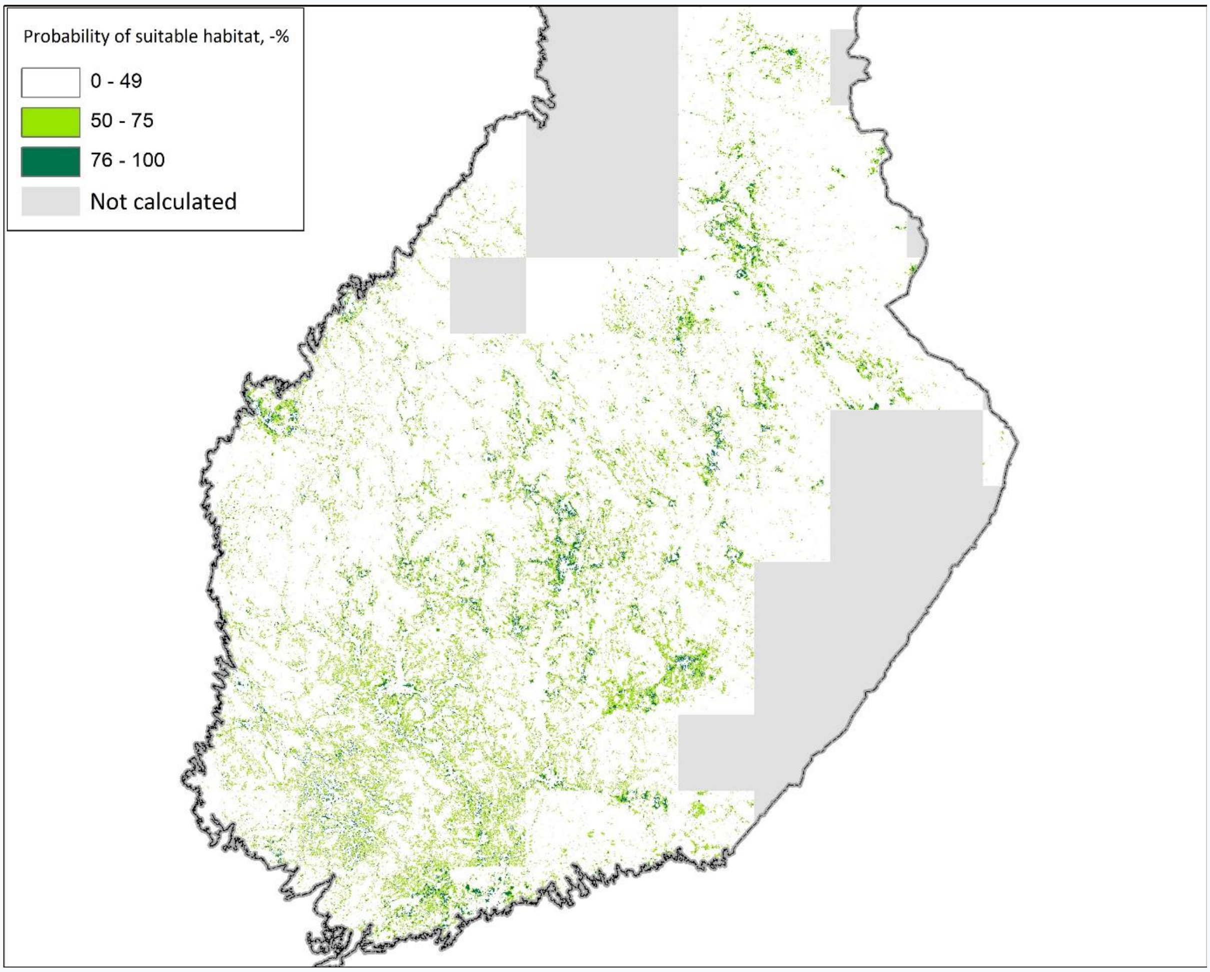

Figure 1. The probability of flying squirrel suitable habitat in Finland. In the easternmost Finland the accuracy of the predictive models was low and the predictions were not calculated there.

For forest planning and e.g. field inventories it is necessary to overlay predictive maps forest data showing different types of forests. Because the smallest element in predictive maps is 100 m × 100 m in the ground, it can partly contain also habitats not suitable for flying squirrel. Figure 2 shows an example where predictive map has been overlaid with classified MS-NFI data. MS-NFI data was classified to suitable forests for flying squirrel, other mature forests and other habitats. Inhabited areas, agricultural fields and waters were also overlaid to map. The map shows that there are suitable forests also outside the area that was predicted as ≥50% suitable. The reason for this is probably that they are not well connected to other suitable habitats or there are some other landscape features that make these forests as non-probable flying squirrel forests.

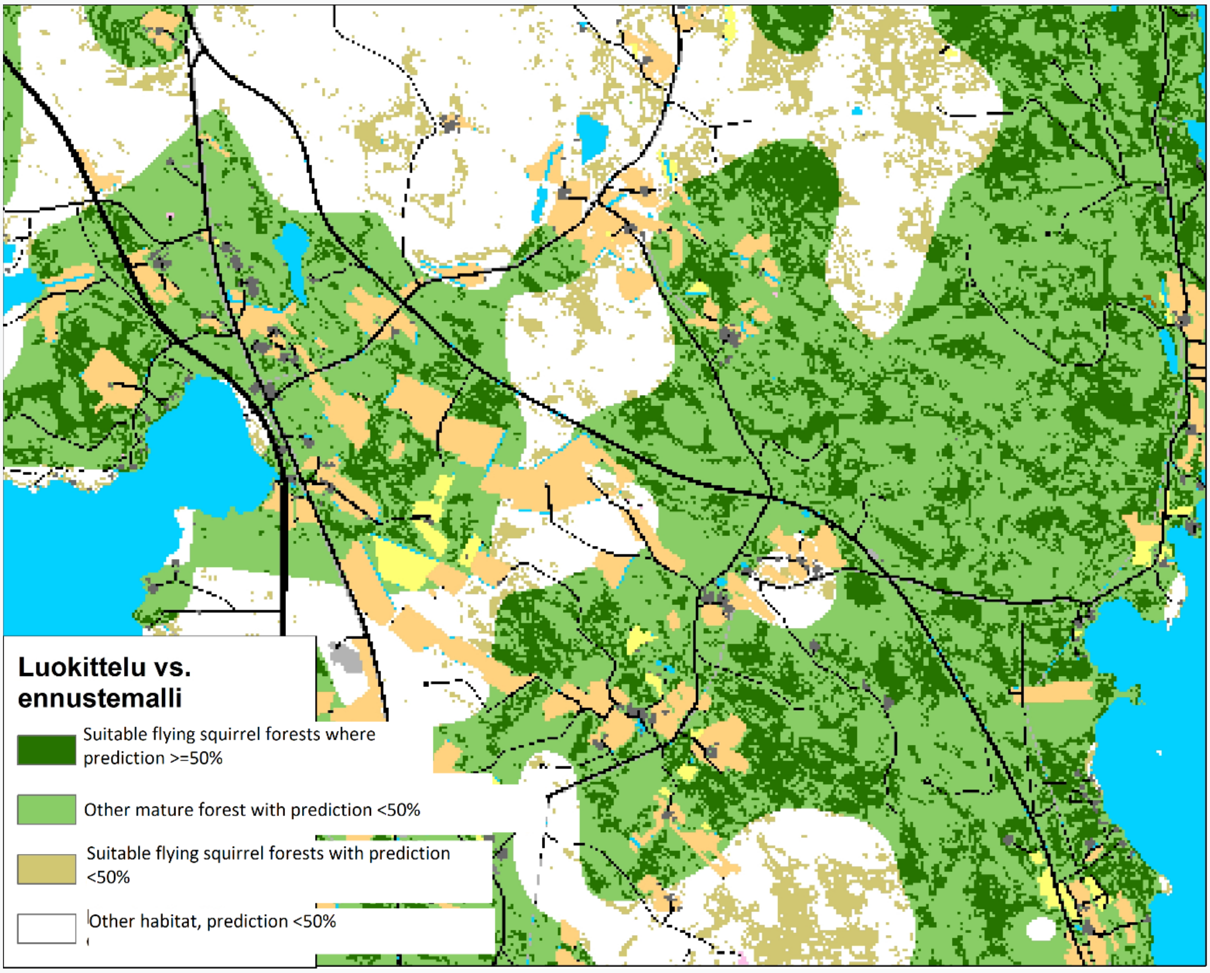

Figure 2. An overlay of the predictive map with classified MS-NFI data.

Another example of the joint use of predictive maps and forest planning data is shown in Figure 3. Only the boundaries of distinct forest patches are shown here but it is possible to classify forest planning data according to e.g. tree species composition, age, cutting preferences and compare resulting maps with predictions.

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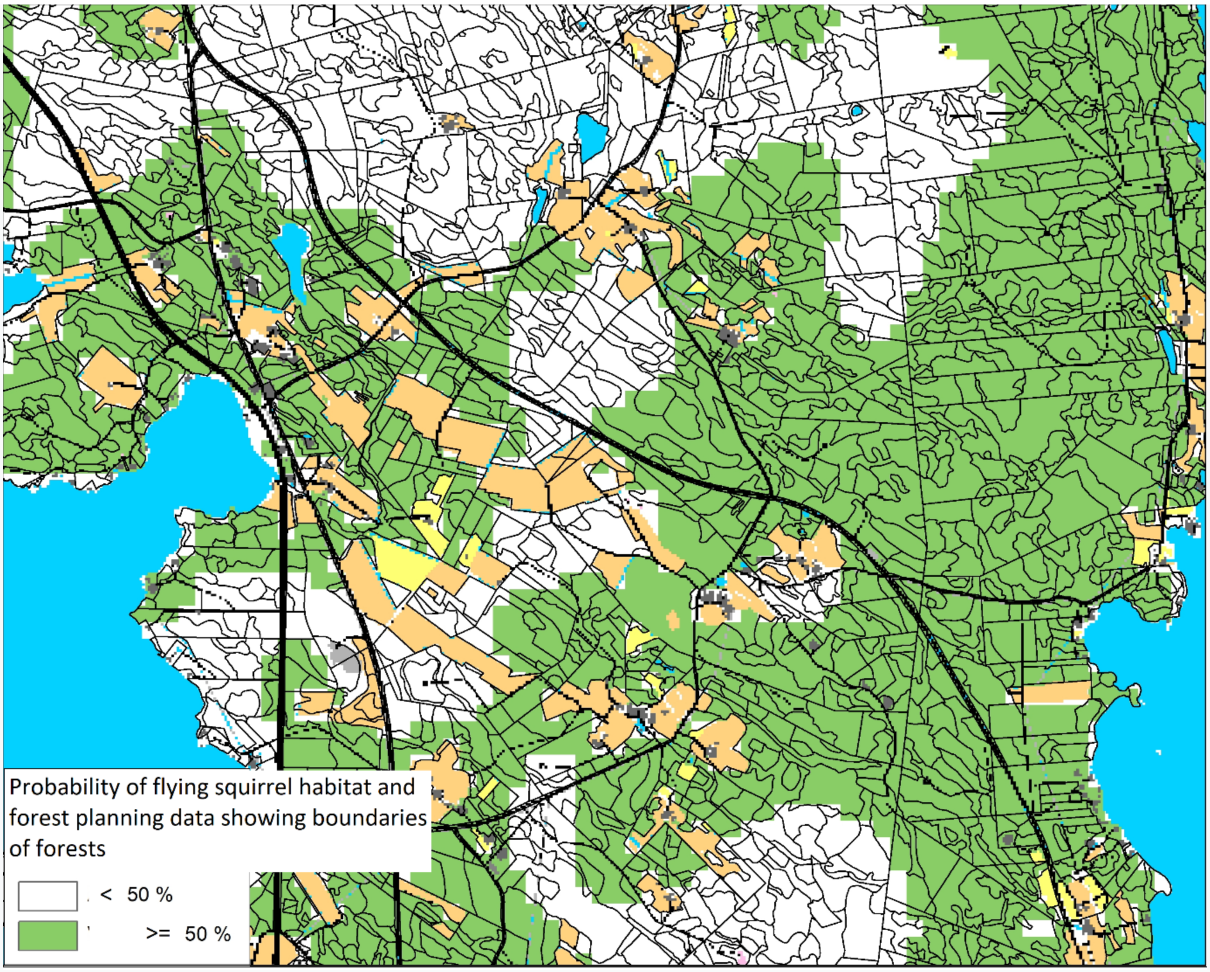

Figure 3. Predicted suitable habitats for flying squirrel and boundaries of forests in forest planning data. By classifying forest planning data to various forests it is possible to examine the effects of forest operations to flying squirrel habitats.

Figures 4 and 5 show the connectivity of flying squirrel habitats according to predicted habitat suitability around two big cities in Finland, Jyväskylä and Kuopio. Also previous studies of the occurrence of suitable habitats of flying have shown that there are often a lot of good habitats around big cities or other inhabited areas (Jokinen et al. 2010). This is probably due to more fertile soils around inhabited areas or the less intensive forest management in forests around cities.

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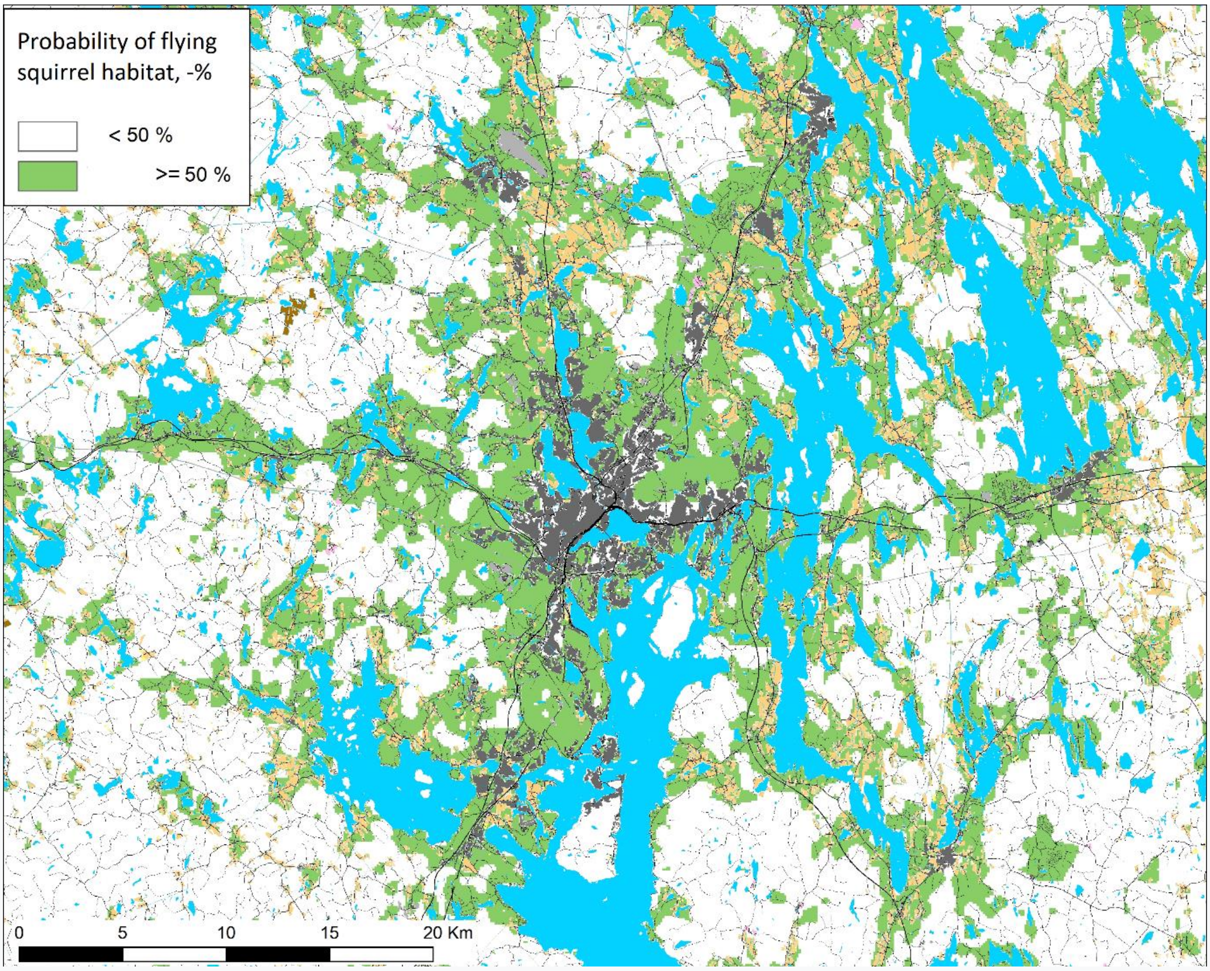


Figure 4. A mesoscale predictive map around Jyväskylä city showing the connectivity of flying squirrel habitats with predictions of ≥50% probability.

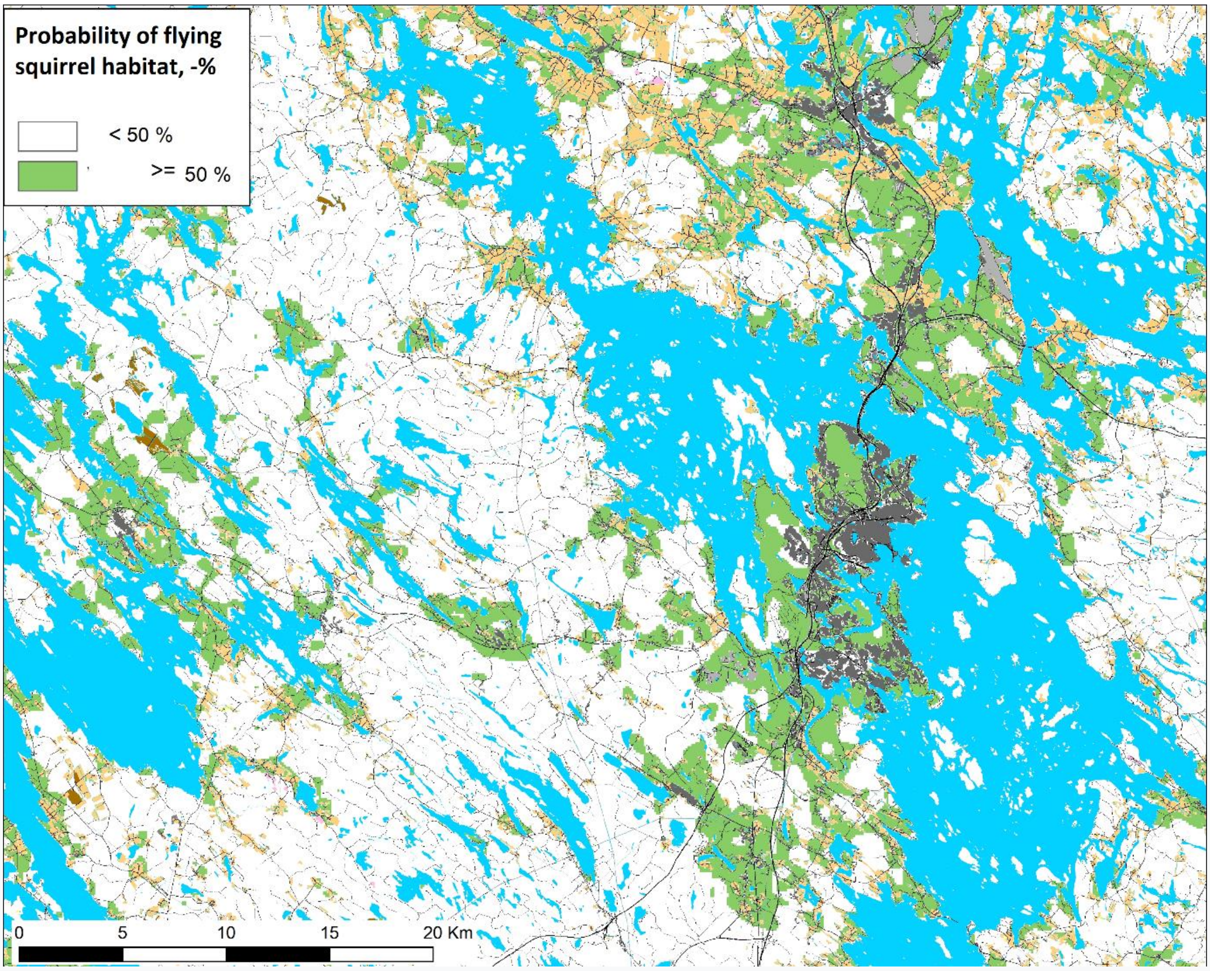


Figure 5. A mesoscale predictive map around Kuopio city showing the connectivity of flying squirrel habitats with predictions of ≥50% probability.

Publicity of predictive maps

The predictive maps have been produced as part of the Liito-orava-LIFE project included in the Life program of the European Union and have been produced with public funding. That's why the public nature of the materials is the starting point, and there are no grounds for secrecy (Act on the Publicity of Official Activities 621/1999).

Predictive maps have been published in December 8th 2021 and can be found at the data service of The Finnish Museum of Natural History Luomus: https://laji.fi/about/5922

Use of forecast maps and privacy protection

The predictive maps do not contain information related to persons or land ownership. If predictive maps are combined with personal data, it is the responsibility of the combiner to ensure that the combination is done in accordance with the legislation on the protection of personal data (Data Protection Act 1050/2018).

Technical description of predictive maps

• The format is a georeferenced image in tiff format
• The map is in the ETRS-TM35FIN level coordinate system (EUREF-FIN datum)
• The forest resource data of the models that form the basis of the forecast map (multi-source VMI) is from year 2017
• The resolution of the map is 100 m × 100 m
• The prediction value is calculated for each square and rounded to a whole number between 0-100
• Large water bodies and other non-forest areas (less than 50% forest in the square) are assigned a value of 0

Disclaimers

The project has received funding from the LIFE Programme of the European Union. The material reflects the views by the authors, and the European Commission or the CINEA is not responsible for any use that may be made of the information it contains.

References

Jokinen, A., Nikula, A., Nygren, N., Tersa, P. & Haila, Y. **2010**. Liito-oravan elinympäristöjen mallitus ja ennakointi Tampereen kaupunkiseudulla. *Suomen Ympäristö – Finnish environment - Miljön i Finland* 11/2010. 71p.

Predictive habitat map on potential Flying squirrel habitat network in Estonia

Flying Squirrel LIFE (LIFE17 NAT/FI/000469)

Action A3, deliverable „Predictive habitat maps on potential Flying squirrel habitat network in Finland and Estonia ready and available“

Environmental Board (EEB; Keskkonnaamet) Tallinn, 2023

We have acquired a significant amount of knowledge about the habitat requirements of the flying squirrel, primarily based on the available data. However, to fully understand the extent of flying squirrel habitats, we need to correlate the existing data with the specific habitat characteristics that influence the flying squirrel's habitat selection. By doing so, we can extrapolate the knowledge we have gained to encompass a broader territory. Nevertheless, in order to achieve a comprehensive understanding of the flying squirrel's habitats across the desired area, we require a dataset that encompasses the diverse range of habitats found within it.

A valuable dataset for assessing potential flying squirrel habitats is the Estonian National Forest Register. This register contains information about various forest characteristics, including age, reserve, dominant tree species, and more. Initially, preliminary assessments of potential flying squirrel habitats were made by utilizing simple queries based on the forest register data. However, not all forests are taxed, i.e. they are not registered in the forest register. As a result, there are significant gaps or "holes" in the map, where our dataset does not provide sufficient information to evaluate habitat suitability.

By utilizing satellite images that capture multiple spectral ranges, including near-infrared, red, green, and blue light wavelengths, we can effectively differentiate between various types of forests. This enables us to distinguish between deciduous forests, coniferous forests, as well as differentiate between young and old forests.

Aerial laser scanning, conducted by Estonian Land Board's aircraft for base map update, provides valuable information on the height, connectivity, and canopy density of the forest.

The next step involves establishing a correlation between the presence of flying squirrel habitats and remote sensing data that characterizes the surrounding areas. This is where statistics and machine learning methods, play a crucial role by describing the statistical relationship between observed habitat data and environmental attributes.

The outcome of this analysis is the map of flying squirrel habitat model, which enables us to predict the probability of habitat occurrence across the entire surveyed area. The resulting map can be visualized using GIS programs, employing distinct color scales to represent varying levels of suitability. For instance, more favorable habitats can be depicted in shades of red, while less suitable habitats may appear as green areas.

The habitat model has proven to be a very useful tool when searching for new flying squirrel sites. In addition, the habitat model makes it possible to assess the protection effectivness of flying squirrel habitats, the connectivity between habitats, and to answer many other questions regarding flying squirrel protection and landscape use.

Workflow

A total of 60 variables were used to assess the environment, comprising 42 variables derived from remote sensing data. Among these, 6 variables were collected from the Sentinel-2 satellite platform, while 36 variables were obtained from an aerial laser scanner mounted on an aircraft.

For the analysis, three channels of the Sentinel-2 satellite images captured on April 15, 2019, and June 18, 2021, were utilized. These channels correspond to the green, red, and near-infrared light wavelengths (Copernicus Sentinel data, 2019, 2021).

The aerial laser scanning height points from the early spring basic mapping flight conducted in 2022 were used as the source data for variables derived from aerial laser scanning data (Land Board, 2022). The data were processed using the lidR extension in R (Roussel and Auty, 2022), enabling the calculation of various metrics based on aerial laser scanning point clouds.

The training data consisted of two components: the occurrence selection and the background selection. The occurrence sample aimed to describe the locations where the flying squirrel is found, while the background sample aimed to describe the overall environment, including the variability of environmental variables.

To describe the occurrence, data from flying squirrel nest trees (N=2091) from previous years until 2022 were utilized. These nest trees served as representative data for the presence of flying squirrels in the study area.

For the background sample, random points (N=10000) were selected from across the entire study area. These points were used to provide a comprehensive representation of the environmental conditions and variability within the study area.

The relationship between the training data and environmental variables was assessed using various machine learning methods. Among the selection of methods, the algorithms Maxent (Phillips, Dudík, and Schapire, s.a.), GBM (Generalized Boosting Models) (Hickey et al., 2016), and CatBoost (Prokhorenkova et al., 2017) were used.

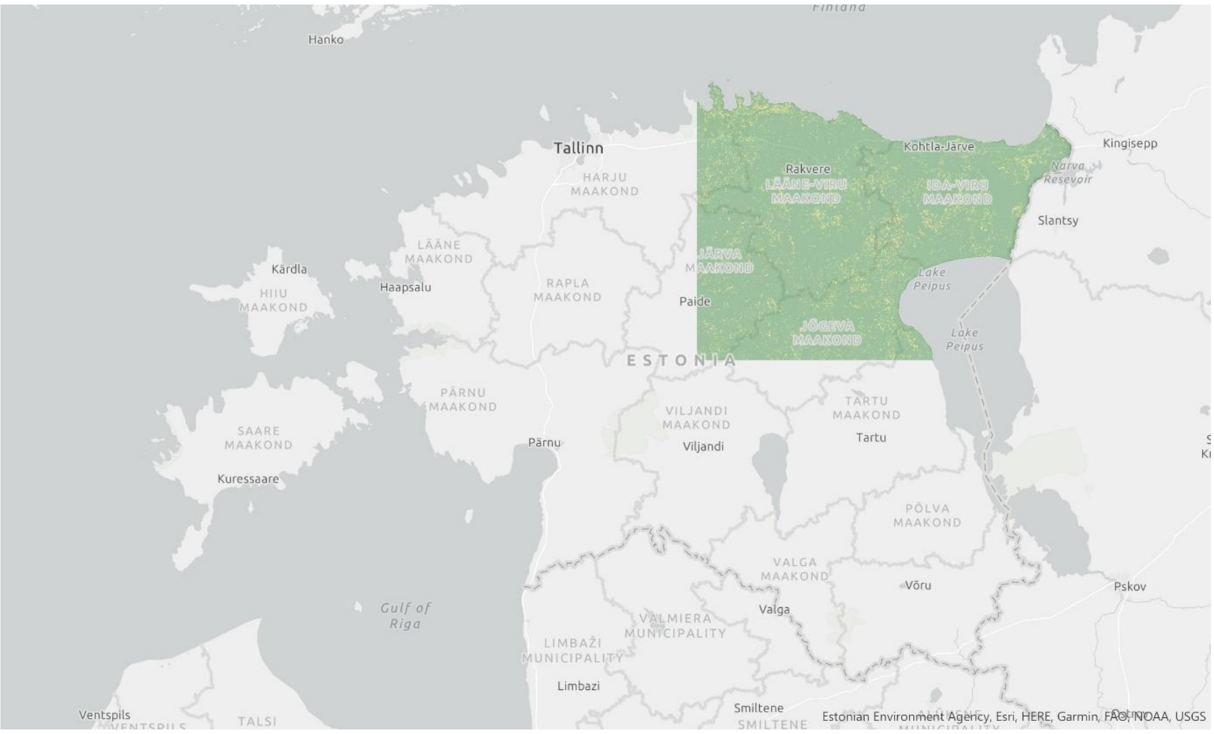
Maxent, or the maximum entropy model, aims to predict a distribution that closely resembles a uniform distribution across the entire study area by determining the probability of occurrence.

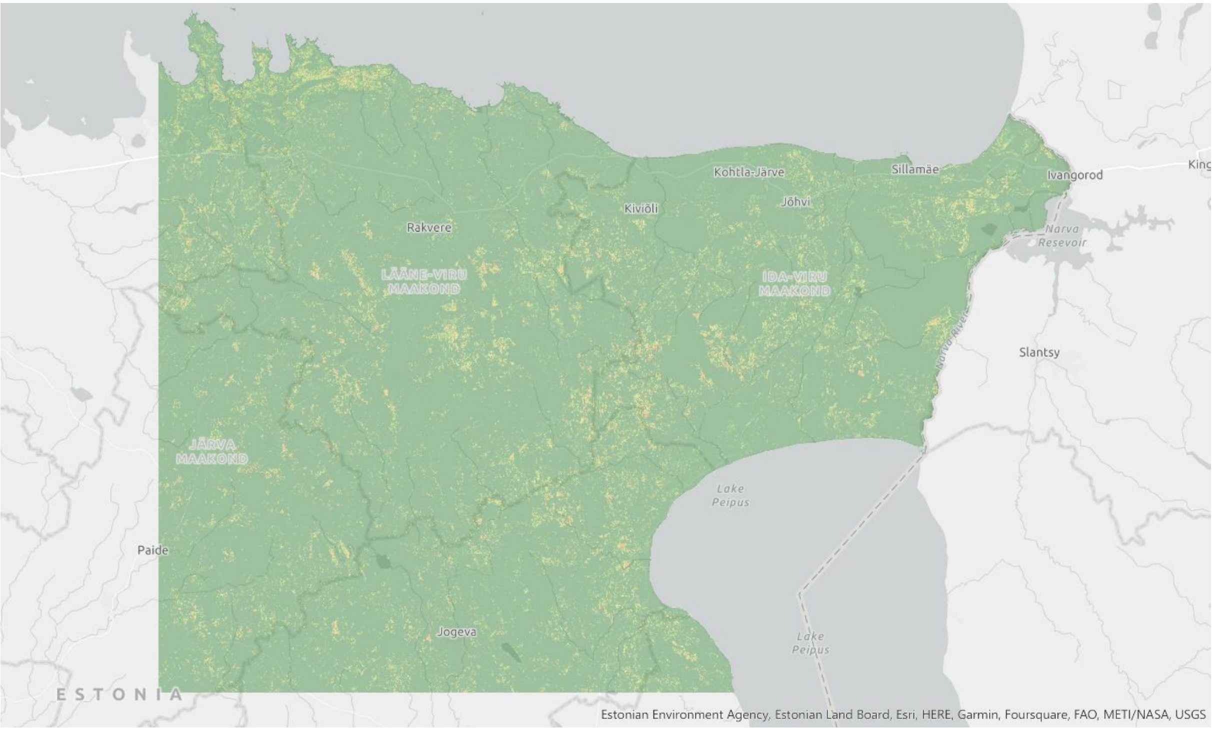
GBM, or generalized boosted models, combines two machine learning techniques: decision trees and boosting.

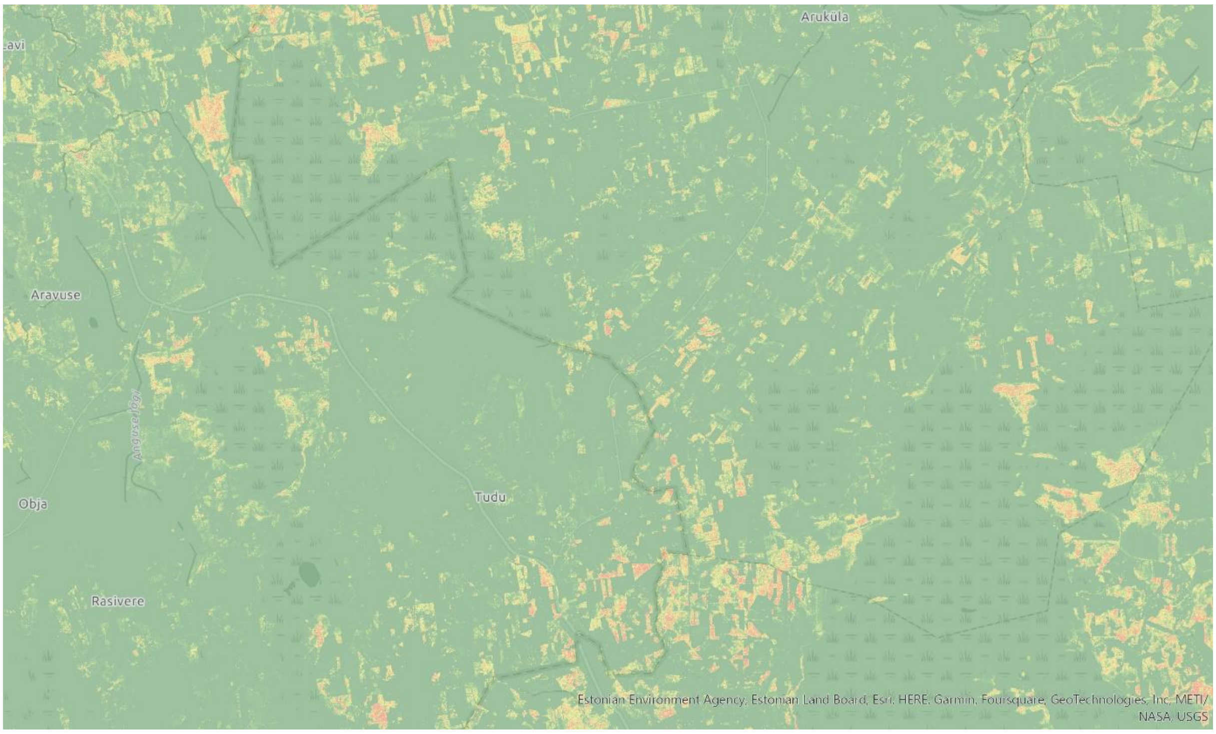
The CatBoost algorithm is based on gradient-boosted decision trees. During the training process, a series of decision trees are constructed sequentially, with each subsequent tree minimizing the loss compared to the previous trees.

In spring 2021, the suitability of the habitat (0 - not suitable, 1 - suitable) was assessed in the N=988 forest compartments visited during the flying squirrel monitoring fieldwork. From these 988 pixels within the forest compartments, a test sample was generated.

The following map images are examples of the flying squirrel habitat modelling results:



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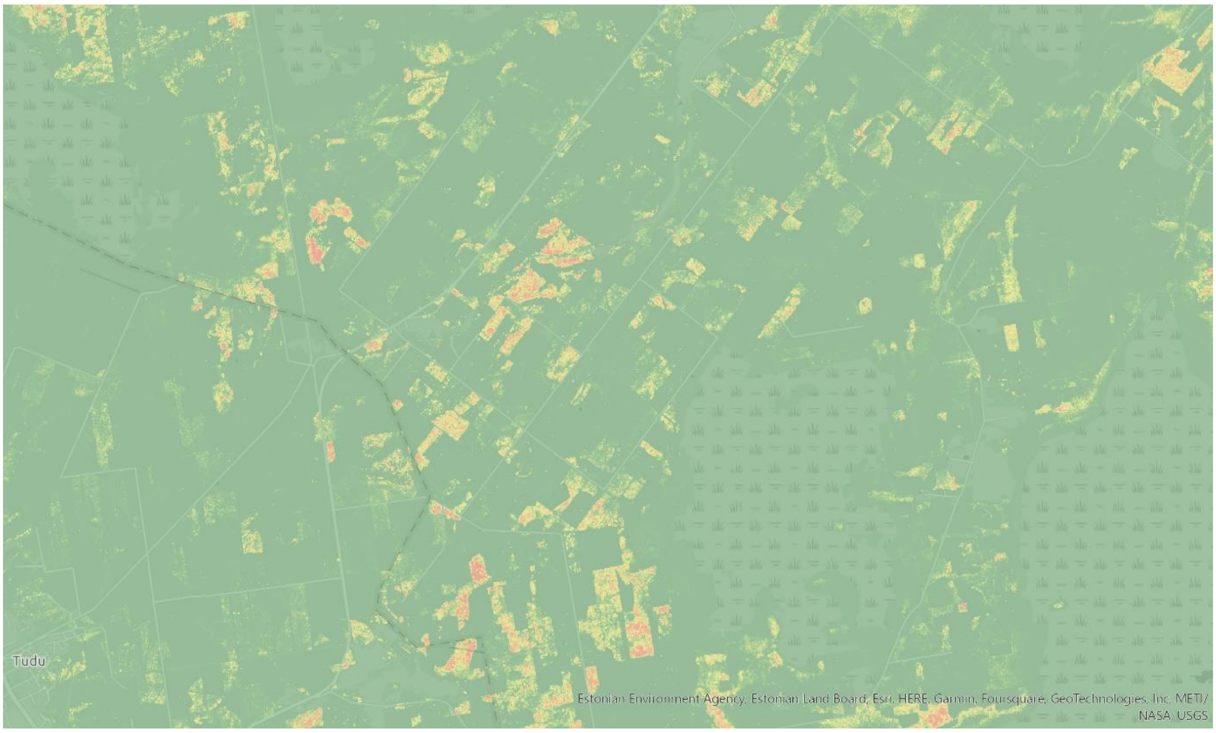
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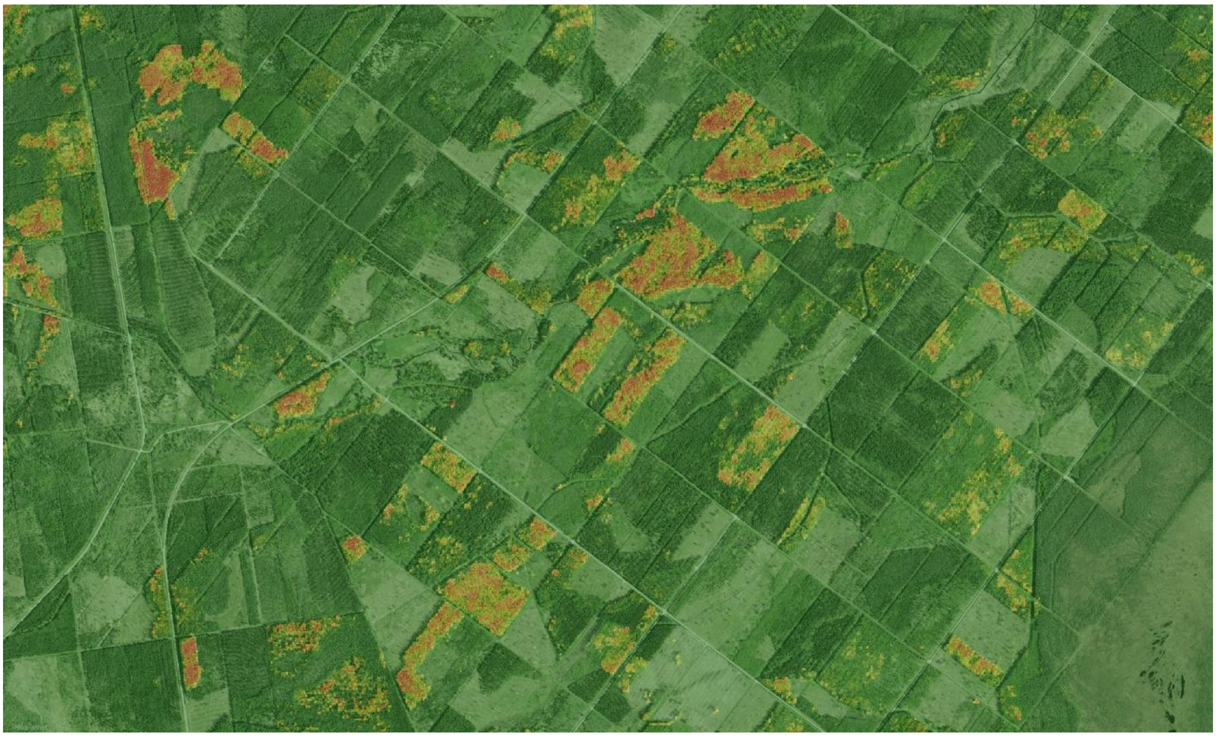

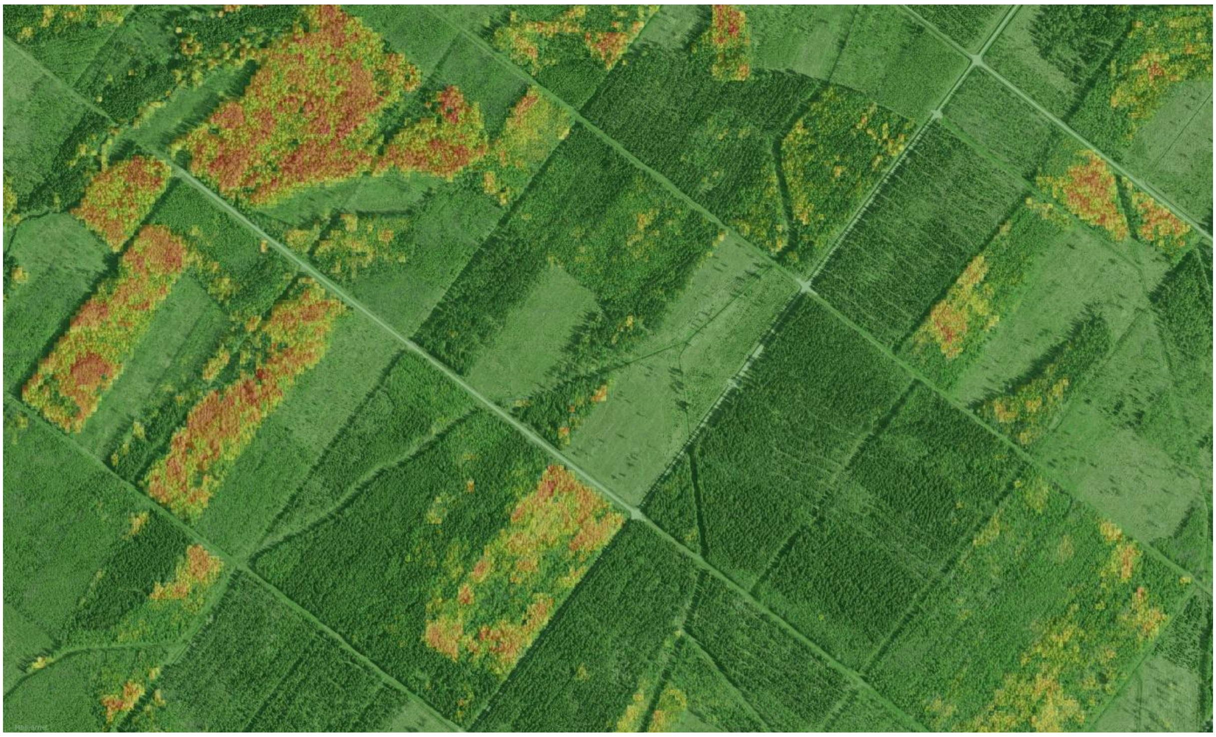

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