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Assessment of changes in forest coverage based on historical maps

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Abstract. Forest has always been an important natural resource. Issues related to forest reserve, coverage area, distribution pattern and status have been important to the forest, nature protection, as well as to environment management specialists. The present studies have proved that it is not easy to find a clear and simple answer to the above-mentioned essential issues. The indicators of the importance of the forest coverage or the coverage area at a certain period of time depend on the applied assessment methodology, primary source used, etc. The main objectives of this study were to analyze the possibilities of using historical maps for studying the formation and changes of the forest coverage in the longer timely retrospect. The continuity of the forests and the possibilities of defining the variation of the areas covered with forest and open landscape were studied at the test area using the map material covering 150-year period (reference years were 1850, 1949 and 2002). The results of the analyses show that it is possible to reconstruct partially the formation of the forest in some areas and it is possible to define the areas, which have been covered with forests for tens or hundreds of years. It is possible to analyze from which land use classes the present forest community has been formed of and define the age of it. At the same time, several methodological questions arise in connection with the interpretation of the map information of the materials of the 19th century and definition of the term "forest". For example, one problematic issue is the vague definition of the class "*Buschland*" which in present terms could have at the time of mapping been either agricultural land or already a young forest. The comparison carried out at the test area showed that the coverage rate of the present forest areas with the areas covered with forests or such vague areas in 1850 is 75%.

Key words: forest, forest coverage, historical maps.

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Introduction

For a long time, historical maps on paper were the sources of information mainly for the historians (Peil, 2005). However, with the application of the GIS software and development of the digitization technology, historical maps can be used also at studying the development history of the landscapes (Antrop, 2000; Cousins, 2001; Domaas *et al.*, 2001). This approach has been applied in different studies of Estonia (Palang & Mander, 2000; Hellström, 2002; Raet *et al.*, 2004; Koppel, 2005; Veski *et al.*, 2005; Tomson, 2007). Geographers have used cartographic maps mainly in studying changes in the landscape during a longer period in Estonia as a whole (Palang,

1998) or concentrating on a specific area, *e.g*. some island (Ratas & Puurman, 1995; Kokovkin & Loodla, 1998; Peil, 1999; Hellström, 2002).

On the assumption of the objectives of the nature conservation the formation of the settlement in Otepää (Kalda & Arik, 2006), changes in the landscape at Karula National Park (Tomson, 2007), changes in the forest at Naissaar Island (Kiimann *et al.*, 2007) and changes in the land use at Pakri peninsula (Peil, 2005) have been studied on the basis of the historical maps. Nature conservation specialists and ecologists are interested in the age and continuity of different ecosystems. The knowledge of the historical background enables to specify and define primeval and natural forests. The objective of this work was to study the possibilities of defining the continuity of the areas covered with forest in the last centuries.

Forest is an integral part of the landscape, forming the proportions of the open landscape. Forest can be treated as a phenomenon diversifying and structuring the landscapes as well as a phenomenon blocking and restricting the landscapes. After the end of Soviet occupation, there has been an opinion that the structure of present land use is a heritage of the Soviet period and it has little connection with the traditional land use and landscapes in Estonia. Should we strive to the restoration of the former landscape view? At the same time, a justified question often arises– what is an ideal landscape in landscape transformation towards which we should strive? Land use and landscape transformation did not start at the time of Estonia's pre-occupation. Before going deep into this philosophical topic, we should first find out the length of the period about which we can find information concerning the landscape and areas covered with forests.

Regarding forests, it is possible to use official and unofficial information about the forest coverage of the bigger administrative divisions in order to get a better idea. The first statistical figures, although doubtful, can be found in the middle of the 19th century at the more or less trustworthy province maps. Older statistical information has often been used at deriving statistical figures, but this may not always give precise results. For example, according to the statistical information, the forest coverage on Saaremaa Island was 5% in the 19th century, but according to the topographers of the Russian general staff, it was 42% (Etverk, 2000).

The figures of the forest coverage include smaller and bigger risks. When using the first figures without studying this information in detail, it may appear that practically different information has accidentally been compared. One and the most common stumbling-block has been the administrative borders. The most common example is the comparison of the figures of the pre-occupation Estonia and Soviet Estonia, as it is often forgotten that the territory of Soviet Estonia did not include Petserimaa (South East Estonia, formerly Estonian territory, nowadays territory of the Russian Federation) and the area around Jaanilinn/Ivangorod (North East Estonia, formerly Estonian territory, nowadays territory of the Russian Federation). In case of smaller administrative units, the situation is even more confused as the administrative borders have changed during different governmental regimes (counties and provinces, rural municipalities and village councils).

The second ring of problems may arise when using the source data for calculating the forest coverage. Forest coverage is the ratio of the area covered with forest to the area of some territory reflected in percentage. An expression that may seem simple could have been calculated based on very different source data. For example, the area of the forest can be only the forested area covered with forest or the total area registered as forested area. The area of the territory with which the territory covered with forest is divided can be the total area of the administrative unit or only the ter-

restrial area of it. Tens of figures differing from each other could be received of the same administrative unit depending on which specific information is used in the calculations (Etverk, 1988).

The third ring of problems may arise from the definition of the forest at different periods and areas. For example, the definition of forest was different at the assessment of land in the provinces of Estonia and Livonia at the beginning of the 20th century. The definition was stricter in Livonia where the natural conditions were better, i.e. not all areas registered in Estonia as forested areas might have been classified as forests in Livonia (Etverk, 2000). It has often been a land use planning decision depending on the will of the landowner and not the actual look of the area whether it has been classified as a forest or not a forest. This is precisely the reason why the forest coverage on Saaremaa Island was 5% in the 19th century. At that time, the land use planning regulations said that a farm should have a certain amount of grassland and pasture land to each unit of arable area, thus, in order to meet the requirements the areas covered with some forest were also registered as grassland and pasture land (Etverk, 2000).

In case of using historical sources at describing the phenomenon defined as forest, local and general background and potential moments of comparison should likewise be taken into consideration. For example, in Tõikvere manor in Tartu County, the expression "there was no forest in the manor" used in 1839 meant, according to the audit report, that 19% of the land of this manor was covered with forest (Lippus, 1983). In the areas where there was enough land covered with forest, the term "forest" was used to mark the forest with good quality. In the less forested areas, even brushwood was defined as firewood. The meaning of the term "forest" can change in one specific area in the course of time in connection with decreasing availability of forests and wood.

When talking of the forest coverage of Estonia before Soviet occupation, information can be found in literature where it is stated, based on the cadastral data, that in 1939, the forest coverage in Estonia was 21%. However, the agricultural census of 1939 also includes the grassland and pasture land forest with tree crown integrability of 30% and more. Including the mentioned forests, the forest coverage in Estonia was in 1939 ca 33% (Meikar, 2003). The impact of the will of the landowner also persisted in the reflection of the actual situation in the Soviet Estonia. In addition to the state forests managed by the forest enterprises, there were agricultural forests (former agricultural land) belonging to state farms and collective farms in Soviet Estonia. It is very difficult or even impossible to get correct information about the area of the agricultural forests. The area of the agricultural forests shown officially was smaller than the actual area, as it was shown under the area of agricultural land parcels (grassland, pasture land). It enabled to perform cutting without restrictions and obligations (Etverk, 2003).

Apparently, statistical figures can be used as the source of information about the forest coverage, but there may be problems in comparing these data. Besides statistical information, cartographic map material that should be more trustworthy can be used for defining the forest. The aim in describing the formation of the land use in some area is to use as detailed information as possible. This information can be found at the local level at the large-scale cartographic materials.

The objective of this study was to find out for how long period it is possible to establish database of the dynamics of the forest and forested areas in Estonia using historical cartographic material and test it at one test area bringing out potential problems.

Material and Methods

Historical maps

The first detailed large-scale cartographic materials about the areas in Estonia can be found from the 17th century when Estonia was part of the Swedish Kingdom. The mapping of the land of the manors was started in Estonia in the 1680s with the objective to establish fixed basis for taxing the land of the manors as the present term "ploughland" did not give adequate information about the land and income of the manors (Peil, 2005). The scale of the maps was usually 1:10400.

One may think that it would be possible to define the dynamics of the forests already from the second half of the 17th century if a map from that period could be found from the archives. However, it is not like that in reality. In the 17th century, the settlement was not so dense and broad and forest was not a limited resource. The value of the manors depended more on how much arable land there was. The maps made for taxing the land concentrated more on the agricultural land and the areas covered with forests located far from the centre of the manor were often mapped only on ocular estimation. Sometimes the forests, pasture land and swamp areas located far from the centre of the manor have not been defined at all. Therefore, the maps from the 17th century are a valuable source material to the scientists studying the formation of settlements and agricultural land but not to the forest specialists.

In the 18th century, there was no bigger mapping performed in Estonia. The next large-scale maps about the land use in manors date back to the middle and second half of the 19th century when the mapping of the land divided into lots was started. These maps are mainly in the scales 1:4200 or 1:5600 and are quite precise and detailed (Koppel, 2005; Koppa, 2006). At the same time, there were no uniform requirements to mapping at the 19th century and the symbol system used for land use classes in various regions can be very different. In case there are no maps of the manors, one could try to find maps of the farms covering smaller territory. However, it is quite time-consuming to put together a mosaic picture from the farm maps if one has to cover a larger area. Use of farm maps is complicated also because not all of them have preserved and the names of the farms and borders of the detached plots of land have changed in the course of time.

The land use at the end of the 19th and beginning of the 20th century is reflected best at the so-called Russian one verst map in the scale 1:42000. The land use in the pre-occupation Estonia is reflected at the topographic map in the scale 1:50000. These two maps can be used in case someone wants to get an idea of the land use at some bigger area. However, these maps do not meet the needs of those who are looking for detailed information. The scale is too general and some objects, e.g. bigger roads are reflected not in the correct scale. One verst Russian map is sometimes not readable and it is difficult to understand whether the line on the map is a line object/border of the land parcel or an elevation isoline as this map is black-and-white. At the same time, it is the easiest way to get hold of the mentioned two maps as these maps have been digitized by AS Regio (an Estonian mapping and GIS company) as raster charts covering the whole territory of Estonia. These maps are related already to the geographic coordinates, so there is no need for georeferencing in the process of the analysis, which can be very time-consuming.

Large-scale cartographic materials from the Soviet period are the land use plans of the state and collective farms, orthographic photos and topographic maps of the General Staff of the Armed Forces of the USSR. The best material for reflecting the present situation is the Estonian Basic Map and orthographic photos in scale 1:10000.

The Estonian Basic Map is in digital version. Cartographic materials from the earlier period are mainly on paper and need at first digitization after which georeferencing and vectorizing can be done.

It is possible to restore a picture of the landscape from the middle of the 19th century and use it for comparing with the situation at present. For bringing out the dynamics, the land use at least one certain period during the middle of the 19th century and present-day situation should be fixed. The best period for comparing the information would be the period just before Soviet occupation and during the first years of Soviet Estonia, i.e. from the period when the agricultural land use was the most intensive and large-scale amelioration works had not started yet.

There are several studies of the changes in the land use in Estonia based on the cartographic material but in most of them bases differing more or less from the standpoints of this work have been used. The differences are mainly in the methodology used (Koppel, 2005; Koppa, 2006; Kiimann *et al.*, 2007), bigger generalization of the used map material (Mander & Palang, 1994; Palang *et al.,* 1998; Tomson, 2007) or the large–scale map material has been used but the author has concentrated on other periods of time (Hellström, 2002; Koppel, 2005; Kaasik *et al.,* 2008).

Among the other conceptual issues, the scale of investigation and classification schemes is most essential. One has to use the information from the maps with certain reservation. The same terms (units of classification, classes) have been used for classifying a bit different items in the course of time.

One of such samples is the definition of the class "forest" which seems at first quite simple. The borders between the classes are vague more in Western Estonia where wooded pasture was mapped as grassland but based on the terms of the present Forest Act it could be classified as "forest". Besides, there is a class "*Buschland*" on the maps from the middle of the 19th century, which is difficult to be divided between the present land use classes. It has been translated into Estonian in several ways: "võsamaa" *(*brush-wood*),* "võsapõld" (brush-field), "metsmaa" (forestland) and "alevõsa" (slash and burn agriculture). It was virgin land taken into use that was kept untouched for a while and then taken into use again. Brush-wood can be related to spreading of the cultivation of the virgin lands. If this land was not used for a while, it could have looked like a young forest. At the same time, the land could be out of use only for a few years being field when it was used and grassland/fallow when it was not used. It might be that some specific area was primeval field already for some time but the word *brush-wood* was still used in the name of this plot (Ligi, 1963; Koppel, 2005). It might have also been so that after the woodland areas were not any more cleared and burnt-over for cultivation in the 19th century, part of the brush-wood was left out of use as agricultural land and these areas began to look like forest although the term brush-wood was used (Meikar, 1997).

Test area

Map analysis were decided to perform at 5×5 km the test area (which is also the size of one quadrate of the Estonian Basic Map) to define the methodological aspects of the analysis of the changes in the forest coverage. Most of similar studies in Estonia have been performed in Western and North Estonia. Therefore, it was decided to find a test area somewhere in South Estonia, where the landscape is more mosaic and more hilly. Another reason was that in present sense vague class "*Buschland*" was represented well on the South Estonia maps from the middle of the 19th century but not on North and West Estonia maps.

One critical factor of the map analysis covering long period of time is the pres-



Figure 1. Location of the test area.
Joonis 1. Testala asukoht.

ervation of the map material. Therefore, it is important in defining the location of a test area to move from the past to present time, *i.e.* the map possibilities of the 19th century should be taken into consideration at locating the test area. After studying the preserved maps at the Estonian Historical Archives in Tartu, it was decided to select the territory of the former Vastse-Kasaritsa manor. Partially the land use information of the Vana-Kasaritsa manor locating next to the test area was used. The test area is located in the south-eastern part of the present Võru rural municipality in Võru County (Figure 1).

Methods

Vastse-Kasaritsa manor map (item code in the Estonian Historical Archives: EAA. 2072-3-57b) from the year 1850 and Vana-Kasaritsa manor map from the year 1849 (EAA. 2072-3-56c) were used for studying the forest coverage at the test area in the 19th century. The scale of both maps was 1:5200.

Photographing was used for the digitization of the maps. More ideal solution would have been scanning but this process would have caused the deformation of the maps that is inadmissible in case of the only copies of the archives.

Photographical pictures of the maps were georeferenced using GIS software MapInfo. As it is easier to find fixed points for marking coordinates at the map material from the later period, the manor maps of Vastse-Kasaritsa and Vana-Kasaritsa with the borders of the farms from the year 1876 (EAA. 3724-4-1861, EAA. 3724-4-1865) were used at defining coordinates of the maps from 1849/1850 moving step-by-step into the past (at first georeferencing was made at the maps of 1876 and after that at the maps of 1849/1850). Estonian Basic Map and the borders of the present

land units were used for georeferencing. Surprisingly, many corner points and outlines coincided with the farm plots from the year 1876. Only the forested areas and the so-called areas that looked like forests ("grey zone" – brush-wood, wasteland and pasture land with bushes) were vectorized at the coordinated maps from the middle of the 19th century. Other areas were not digitized. As maps from 1876 were missing some information and did not cover the whole study area, these were not used for mapping forest areas.

Based on literary sources the forest coverage was minimum just before Soviet occupation and during the first years of Soviet Estonia (Kasepalu, 1991; Meikar, 1997; Etverk, 2000). Therefore, it was tried to find map material reflecting that period. The only map material of the mentioned period of the test area was the map of the General Staff of the Armed Forces of the USSR in scale 1:25000 (map sheets O-35-79-A-в and O-35-79-B-б). There are maps of the test area of the General Staff of the Armed Forces of the USSR in scale 1:10000 but these maps date back to 1960ies. The topographic map in scale 1:50000 from the 1930/40ies is too general. The selected map sheets in the scale 1:25000 were scanned and related to geographic coordinates after which the classes "forest" and "young forest" were vectorized at the test area and integrated into one forest class.

The data of the vectorized historic maps on paper was compared for showing the dynamics with the Estonian Basic Map (squares 54083, 54084, 54181, 54182). Basic Map information for this area was reflecting situation from year 2002. The classes "forest" and "young forest" were filtered out from the quadrates of the Estonian Basic Map vector version at the test area and integrated after that into one class. Comparative analysis of the "forest layer" classes of different years was performed in GIS software MapInfo.

Results

The analysis of the forest layers at the test area (1850, 1949, 2002) and the additional layer (Figures 2, 3 and 4) of the potentially forested areas at the 19th century enabled to give a review of the distribution and formation of the forest at the test area since 1850.

In 1850, an area of 205 ha was fixed at the test area as an area looking like forest from which 106 ha was classified as forest also in 1949 (Figure 4). The area of the so-called "grey zone" was 1 417 ha in 1850. The area of the forest at the test area was 701 ha based on the map of 1949 the coverage of which with the forest of 1850 and the "grey zone" was 79% (556 ha). The area of the forest at the test area was 1 397 ha based on the map of 2002. From the forest area in 1949 (701 ha) 93% (654 ha) had preserved as forest by the year 2002. Coverage ratio of the forested areas of 2002 with the forest of 1850 was 11% and 63% with the "grey zone" of 1850. If we treat the forest of 1850 and the "grey zone" as an entirety, the coverage ratio with the forested areas in 2002 is 75%. Thus, it is possible to say in principle that the forest has "come back" after the low period of 1949 to the areas where there used to be forest or brushwood in 1850. As not all land use classes were vectorized in the frames of this work, it is not possible to show the matrix of the changes of the land use classes but it is possible to show the overall transformation matrix of the forest (Figure 4). It is possible to say based on visual inspection that the rest 25% of the present forest was mostly under the grassland in 1850.

It must be recognized that it is not possible to give a simple and concrete assessment to the range of the forest meeting the present-day definition several centuries

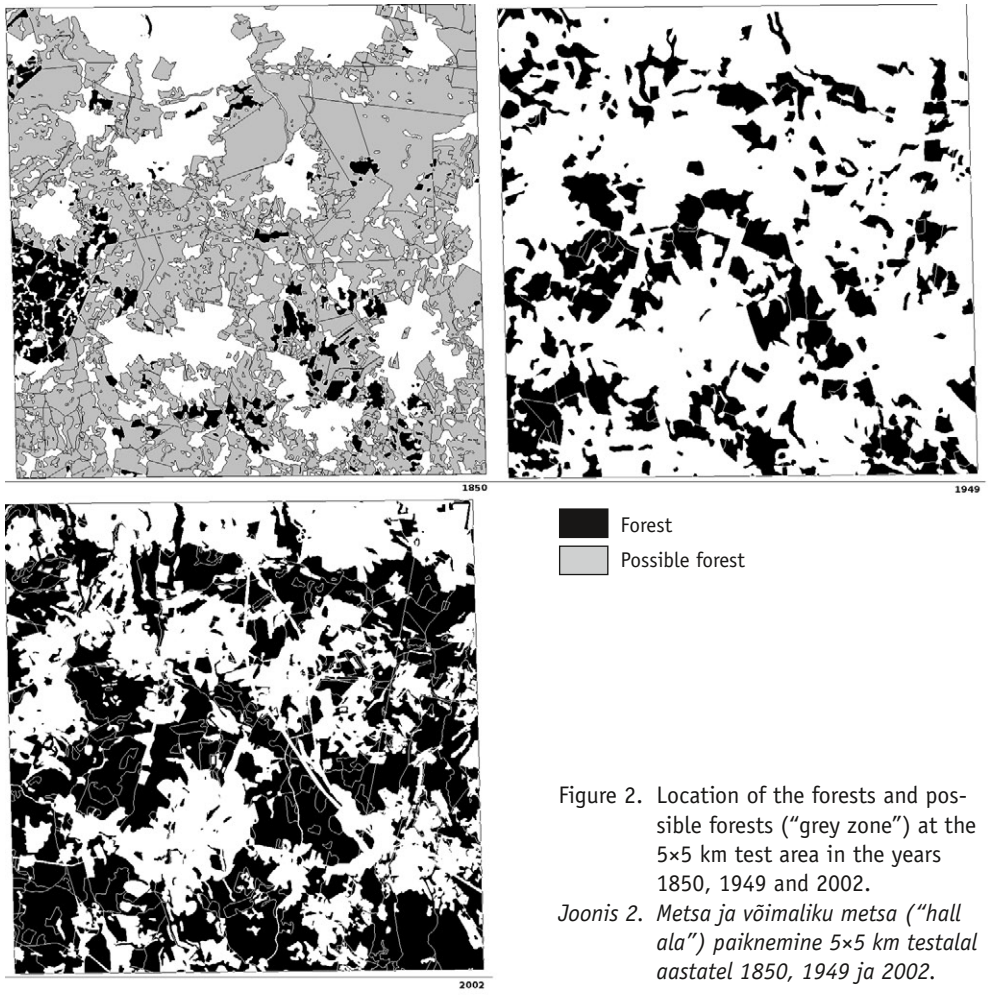


Figure 2. Location of the forests and possible forests ("grey zone") at the 5×5 km test area in the years 1850, 1949 and 2002.

Joonis 2. Metsa ja võimaliku metsa ("hall ala") paiknemine 5×5 km testalal aastatel 1850, 1949 ja 2002.

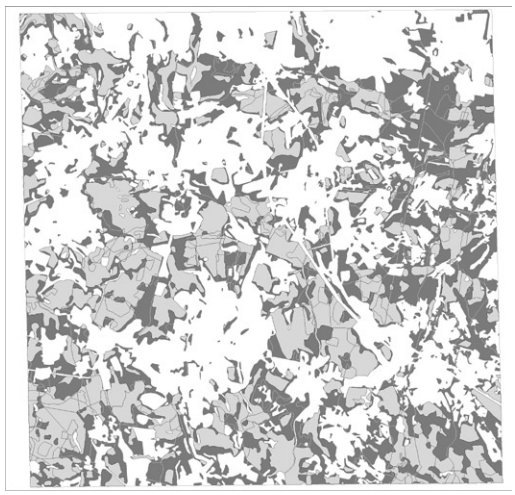


Figure 3. Overlapping forest areas at the 5×5 km test area in 1949 and 2002.

Joonis 3. 2002 ja 1949 metsaalade kattumine 5×2 km testalal.

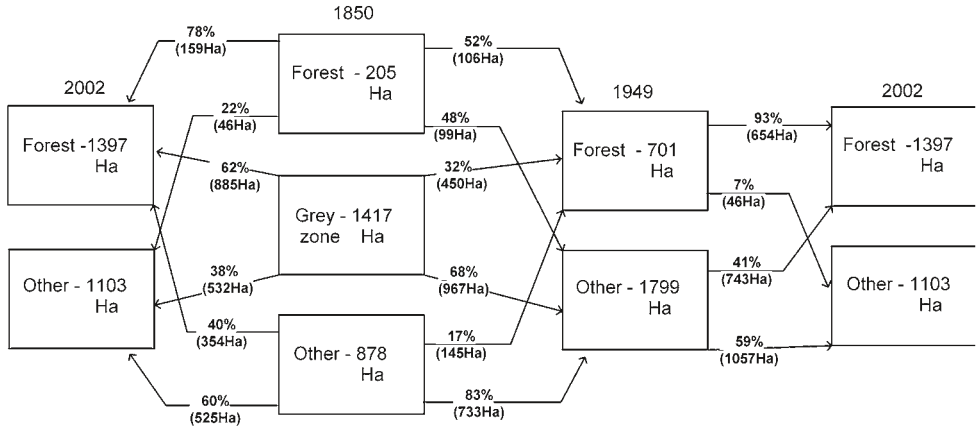


Figure 4. Transformation matrix of the forests at the test area.
Joonis 4. Testala metsade üleminekumaatriks.

ago based on the historical maps on paper. However, it is possible to get an idea of the range and distribution of the forest and areas related to forest ("grey zone"). This would include forest and potential areas looking like forest (brush-wood, wasteland, wooded meadow and wooded pasture). It is possible to describe the changes in the distribution and metrics of the open landscape using the described methods.

One can specify the nature of the areas covered with forest in case it is possible to use the old books of map description. Certain proof that at least part of the land covered with brushwood was under some kind of forest stand could be found at studying the test area. As the map material of two neighbouring manors was used in analyzing the test area, the situation where the contours of the land parcels were seen across the border between the manors and the land use class changed being forest stand on one side of the border and land covered with brushwood, could be noticed.

Discussion and Conclusions

It must be recognized that it is quite complicated to get a review of the changes in the historical distribution of the forest based on cartographic maps. The analysis in the changes of the area of some large territory covered with forest and metrics is quite easily performable based on the maps from the middle of the 20th century and later period. However, the application of older large-scale maps at analyzing the changes in the forest can cause methodological and practical problems. The first problem is that it is difficult to find the necessary map material. The second methodological problem is the interpretation of the information at the maps.

As every country is having its own historical background they are also having different land use mapping histories and traditions. There has been several studies based on historical land use maps covering even up to 300 years (i.e. Cousins, 2001; Skanes & Bunce, 1997). In that case these studies quite often involve cartographic materials from 17th, 18th and 20th century but not from 19th century. Only few have used cartographic materials from 19th century (Hamre *et al.*, 2007; Petit & Lambin, 2002).

Large-scale cartographic material of different areas in Estonia can be found already about the 17th century but the value of these maps at defining the term "forest" can be questionable. Mapping was concentrated more on the agricultural land and the areas covered with forests were often mapped only on visual estimation or were not defined at the map at all. Oldest useable detailed large-scale land use maps in Estonia can be found from the middle or from the second half of the 19th century.

It can be quite time-consuming to use historic maps for analyzing changes in the distribution of the forest coverage or changes in the land use. Maps are not only difficult to read and interpret, but it takes time to find the maps. Not always the land use maps of the manors covering the whole study area have preserved and the mosaic picture must be put together by separate farms.

Estonian Historical Archives has a user-friendly register of old maps but it may not include information about all preserved maps. Some maps can be stored in different funds of archives. For example, P. Tomson found several preserved maps of the farms when looking for the map material of Karula National Park not in the map funds but in the fund "Land credit society of Livonia" in the Estonian Historical Archive (Tomson, 2007). In the old times, the farmers had to prove the value of their land to the credit society when they wanted to borrow money presenting corresponding maps.

The most confusing at studying the historic distribution of the forest is the vague definition of the class "*Buschland*" (brush-wood) which might have been at the period of mapping in the 19th century either arable land or brushwood.

The experience received in the frames of this study shows that full territory covering digitization should be used when old map material is digitized. At first the classification of the land use of different periods of time should be synchronized and then digitized. The advantage of full territory digitization is to develop in case of time-series transformation matrixes of different classes and analyze them. The class of the so-called half-open areas could be applied for describing better the dynamics of the forest coverage.

Finally, it should be stated that it is not possible to analyze the changes in the forest coverage of large areas, e.g. the whole municipality or county during the last few centuries as the maps from the 19th century and older period do not cover such large areas. In the best case, it would be possible to perform the analysis based on the test areas the area of which might be big as it was in this study or there can be a bigger number of smaller test areas. In selecting the area and number of test areas it must be taken into consideration how representative the test areas are. The historical analysis of the forest coverage in some area presumes the use of both statistical information and cartographic materials and presentation of this.

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Metsasuse hindamine ajalooliste maakasutuskaartide abil

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Kokkuvõte

Mets on ajast aega olnud tähtsaks loodusressursiks. Küsimused metsa tagavarast, pindalast, levikumustrist ja seisundist on tähtsad olnud nii metsameestele, loodushoidjatele kui ka keskkonnakorraldajatele. Senised uuringud on näidanud, et eelpoolnimetatud olulistele küsimustele ei ole alati lihtne anda ühest ja selget vastust. Metsasuse osatähtsuse või metsa pindala näitaja mingil ajahetkel sõltub otseselt rakendatud määramismetoodikast, kasutatud algallikast jne. Selle töö eesmärgiks oli uurida ajalooliste kaartide kasutamise võimalusi metsasuse kujunemise ja metsasuse muutuste uurimisel pikemas ajalises tagasivaates. Kasutades 150 aastatalist perioodi hõlmavat kaardimaterjali (kaardiinfo aastatest 1850, 1949 ja 2002), analüüsiti ühe testalal metsaalade järjepidevuse ning metsa ja avatud maastiku vaheldumise määramise võimalusi. Analüüsi tulemused näitavad, et ajaloolise kartograafilise materjali abil saab osaliselt rekonstrueerida mingi piirkonna metsa kujunemist ja on võimalik piiritleda alad, mida aastakümneid või -sadu on pidevalt katnud mets. Võimalik on analüüsida milliste maakatte tüüpidest on kujunenud tänased metsakooslused ja määratleda nende vanust. Samas tekivad 19. sajandi materjalide puhul mitmed metoodilised küsimused seose kaardiandmete interpreteerimisega ja metsa piiritlemisega. Problemaatiliseks nähtuseks on hägune klass "*Buschland*", mis tänapäeva defineeringute kohaselt võis kaardistushetkel olla nii põllumajanduslik maa kui ka juba noore metsa ilmeline. Testalal läbi viidud võrdlus näitas tänapäeva metsade kattuvust 1850.a. metsa ja taoliste metsaga seotud häguste aladega 75% osas.

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