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Investigation of Forest Area Change in the 19th–21st Century Using Military Topographic Maps

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Abstract. Long-term changes of the Earth's cover are imperceptible. Several generations change, people do not see what had been there before they were born, they do not see what happens after they are gone, meanwhile, maps preserve the image of the surroundings that was prevailing hundreds of years ago and the analysis of which allows highlighting certain occurring tendencies. The present study aims at the analysing the change in the forest coverage on the territory of Lithuania employing statistical data and analysing the change in the forest land area from the 19th c. until the 21st c. in the Elektrenai municipality using military topographic maps. During the study, digitalised archival maps and devectorised forest areas were used, and the obtained results were compared. The information provided in the maps reveals a decrease in the forest land area during 19th–20th c. and an increase during the 20th–21st c., however, the current increase has not compensated the earlier decrease.

Keywords: cartography, military-topographical maps, forest area, landscape.

Introduction

Escalating global, regional processes of anthropogenic origin harmful to the nature and ecosystems, which affect the stability of the biosphere, has a direct impact on Lithuania as well. Moreover, an intensive use of the land for agricultural purposes and an excessively intensive reclamation of large land areas during an intensive land amelioration impoverished the biodiversity and increased the amount of land affected by the soil erosion. The landscape has become bleak to the eye, easily damaged due to agricultural activities and extreme natural factors (Pauliukevičius & Kenstavičius, 1995).

The rational use and protection of natural resources as well as energy sources is one of the top-priority fields when aiming at the development of directions of the sustainable anthropogenic activity. The landscape management plays a significant role in solving this complex issue. The landscape, apart from being a historical body, is also a system with spatial relations, chain reactions, a memory, an internal self-regulation mechanism which protects from sudden system changes caused by an external influence. The most important landscape zone is the soil, groundwater and plant zone, where the most intensive transformation of matter and energy is taking place, and the information is stored (Pauliukevičius & Kenstavičius, 1995; Kavaliauskas et al., 2013a, 2013b).

The Law on Protected Areas of the Republic of Lithuania explains the landscape in the following manner: a territorial compound of the land surface natural components (surface rocks, ground level air, surface and ground waters, soil, living organisms) and/or anthropogenic (archaeological remnants, construction works, engineering installations, land and information field) components related by material, energy and information links.

A natural and cultural landscapes are distinguished.

A cultural landscape means a landscape created as a result of human activities and reflecting his co-existence with the environment. A natural landscape is a landscape which has preserved a natural character. Before the expansion of humans, the territory of the Republic of Lithuania was dominated by a natural landscape, but, as people were changing their surroundings, simultaneously, the landscape was changing as well. The territory of Lithuania was dominated by woodlands which, due to the development of human agricultural activities, have been decreasing over time. The change in the forest-covered area may be analysed on the basis of literary sources, preserved archival statistical data and by employing military topographic maps. The latter allow compiling the image of the change that

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the Earth's cover, as well as woodlands, have undergone. Due to a generalization inherent to maps as well as cartographic methods of the location, the forest land lines are generalised, therefore, a generalised change of the forest land may be analysed without expecting each line turn of a conventional sign to exactly match the outline of the forest land.

The present work aims at conducting a study of the forest-covered area of the territory of the Republic of Lithuania and an analysis of the change in the forest land area in the Elektrenai municipality that has taken place during 19th–21st c.

Tasks: To analyse the change in the forest land of the territory of the Republic of Lithuania in accordance with statistical data. To conduct an analysis of the forest land in the Elektrenai municipality using archival military topographic maps and the 2019 forest cadastral data.

1. Change in the coverage by forests in Lithuania

Before the human migration to the continent of Europe, the forest land area was regulated by naturally occurring processes, and it covered much larger territories than nowadays. The contemporary landscape as we know it is the result of the human impact on the ecosystem that has been lasting for thousands of years. It was being altered in order to develop agricultural activities more and more by carrying out agricultural reforms and later – by improving technologies and the urbanizing the area.

The change in forest-covered area on the territory of Lithuania was constant during the life of the human population. However, up until the mid-18th c., there are no detailed written sources on the area covered by forests. In 1599, G. Valavičius compiled a description of the forests of the Grand Duchy of Lithuania "Reistr spisan'ja i vyviedan'ja pušč i perechodov zverinnych u panstvie ego korolevskoe milosti, Velikom Kniazstvie Litovskom, kotoroe sja stalo, za roskazan'em jego korolevskoe milosti, našego milostigovo pana, čerez mene Grigor'ja Bogdanoviča Volovič, starostu Mstibogovskogo", but the data provided therein is extremely vague. Forests are thought to constitute approximately 60% of the GDL area during that time (Žemaitis, 1964).

A more reliable data on the area of almost all forests appeared in the second half of the 18th c. after the general land demarcation was initiated in 1766, and cartographic materials appeared in the second half of the 18th c. (Pauliukevičius & Kenstavičius, 1995). The first inventory and management works in Lithuanian forests, in the literal sense of the words, were started in the Klaipėda region in 1801, afterwards, the management of the forests of Užnemunė was started as well. The inventory of the GDL part which was included into the composition of the Tsarist Russia was only initiated in 1843−1847.

Figure 1 depicts the forest-covered area of the territory of Lithuania by the percentage of the forest land and the total area of the country provided by different authors (authors: Cvetkovas, 1957; Matulionis, 1930; Brukas, 1987; Pauliukevičius & Kenstavičius, 1995; Lietuvos katalikų mokslų akademija, 1968; Valstybinė miškų tarnyba, n.d., http://www.amvmt.lt/).

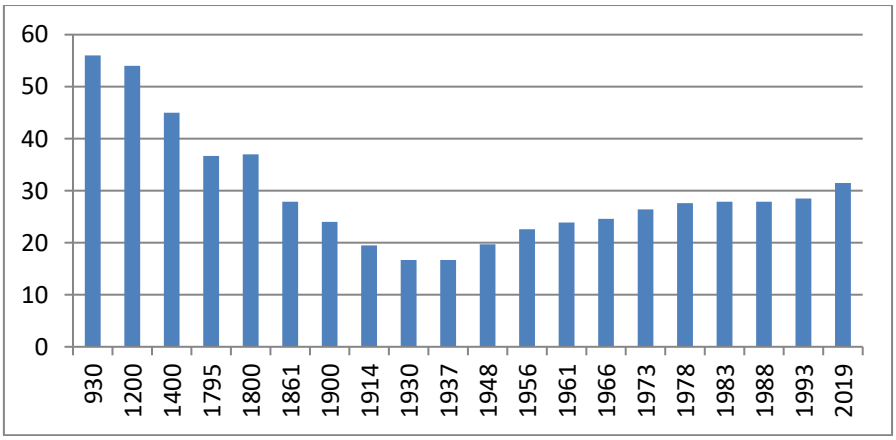

Figure 1. The forest land of Lithuania (by percentage) by the area covered by forests, from different sources (created by the authors)

Figure 1 reveals that the coverage of Lithuania by forests was changing over time. Forest land areas started to decrease significantly after the technological development started. The changes in the field of agriculture that allowed absorbing larger and larger areas of cultivated land as well as the industrial development predetermined the beginning of the era of the massive deforestation. A particularly intensive deforestation took place in the 19th c. Between World War II and 1993, the forest-covered area covered increased by 11 percent. In accordance with the data provided by the State Forest Service, the area covered by forests in Lithuania amounted to 31.5 percent in 2019.

When conducting a study, it is important to take into account the methodology employed for the estimation of the forest-covered areas, because the employment of different methodologies provides different results. In the countries of the Central Europe of the former USSR territory, the forest land was determined in accordance with the forest-covered area. According to SNO FAO recommendations, the determination of the forest land should be carried out on the basis of the total area of the forest land and perennial volunteer and artificial greenery and shrubs. Forest land estimation methodologies employed on the territory of Lithuania have changed over time.

The Forestry Law of the Republic of Lithuania approved on 22 November 1994 has defined the forest in the following manner: "Forest is defined as a tract of land not less than 0.1 ha, covered by trees or other forest vegetation or temporary lost of it (cleared or burned areas). Clusters of trees situated in fields, by roadsides, water bodies, within towns or rural settlements as well as cemeteries, narrow – up to 10 metres – tree lines, hedges, single trees and shrubs as well as parks planted by man, which are situated within towns and rural settlements, are not considered as forest. The procedure for care, protection and utilization of green plantation shall be established by the Government of the Republic of Lithuania" (Lietuvos Respublikos Seimas, 1994a).

The Amendment of the Forestry Law of the Republic of Lithuania that came into force on 2001-07-01 revises the definition of a "Forest". A "Forest" in the Forestry Law now is defined as follows: "Forest – a land area not less than 0.1 hectare in size covered with trees, the density of which is not less than 0.3 m and the height in a natural habitat in the maturity age is not less than 5 meters, other forest vegetation, as well as a land area not less than 0.1 hectare in size, in which a stand is thinned or temporary without tress due to human activities or natural factors (clearings to be planted with, cutting areas, dead stands). Clusters of trees situated in fields, by roadsides, water bodies, within residential areas and cemeteries, greenery planted along road lanes, trees and shrubs growing in non-forest land plots managed on the basis of the right of trust by a manager of the public railway infrastructure, narrow – up to 10 metres – tree lines, hedges, single trees and shrubs as well as the greenery planted on the non-forest land in towns and villages are not considered a forest") (Lietuvos Respublikos Seimas, 1994b, 2001). A new concept is introduced – an urban forest. From the date of this regulation, only an area covered with trees or other forest vegetation is not considered a "Forest".

2. Comparison of maps

The changes of the forest land area may be analysed on the basis of old military topographic maps. In this case, a land area covered with trees will be considered a "forest". Topographic maps were compiled by performing measurements, the forest land was marked on the basis of the actual situation of the territory. Furthermore, up to 2011, the understanding of a "Forest" included an area covered with trees, therefore, the current situation must be taken into account during the analysis of the change of the forest land according to the old topographic material.

When the territory of Lithuania was started to be mapped, an opportunity to analyse the changes in landscape over centuries emerged. In the 19th c., when the triangulation network was being developed and the need for military topographic maps with sufficient accuracy arose in the military field, large-scale maps which were significantly more accurate and detailed compared to the previous times were started to be compiled.

First topographic maps with sufficient accuracy on the territory of Lithuania were compiled by military topographers of the Tsarist Russia in the 19th c.

The following was used for the study (Figure 2):

- Topographic maps compiled by the Military Topography Department of the Tsarist Russia.
- 1:25,000M maps published by the Military Topography Department of Lithuania during the interwar period.
- Soviet 1:50,000M topographic maps.
- Forest cadastral data, the State Forest Service, 2019.

Topographic maps of the European part of the empire compiled in the second half of the 19th c. in the Tsarist Russia were published in 1860−1890. The scale is 1 English inch to 3 miles, what corresponds to M1:126.000. The map page is rectangular, 58×42 cm, it corresponds to 73×53 km at the location. The measurement accuracy of important objects is 50−200 m, of unimportant – 100−300 m. In some instances, the tolerance reaches 500 m and more.

The works of compiling topographic 1:25.000M maps during the interwar period in Lithuania were started in 1924. The published materials map the territory of the country of that time, the map page size is 47×45 cm. The publishing activities were performed by the Military Topography Department of the Military Headquarters, years of publication: 1930−1939.

Soviet 1:50.000M maps were compiled after the 1956−1957 renewal of the cartographic data and published in 1988. For the renewal, aerial photos and location studies were used. The map was compiled in accordance with the coordinate system of 1942.

a) b)

c)

Figure 2. Map fragments: a) a topographic map compiled by the Military Topographic Department (1866); b) a map compiled during the interwar period in Lithuania (1932); c) a map compiled in the Soviet Lithuania (1985)

3. Change in the forest land area in the Elektrenai municipality in 19th–21st c.

The territory of the Elektrenai municipality was selected for the study of the change in the forest land area in accordance with archival military topographic maps. At present the forest cover in this municipality corresponds to the average of Lithuanian forest cover. For the study, 1860−1890, 1930−1939, 1988 maps presented in Figure 2 and the cadastral data of forests provided by the State Forest Service were used (http://www.amvmt.lt/), the date of the data: 2019. After an administrative unit was selected, an orientation of maps by selected points unchanged over time was performed at the location. A layer of cadastral data on forests was added, and the vectorization of forests depicted on the maps was carried out.

The 19th c. map stood out from the selected group of maps. It is black and white, conventional signs differ from the conventional signs of maps published in 20th c. (Figure 3).

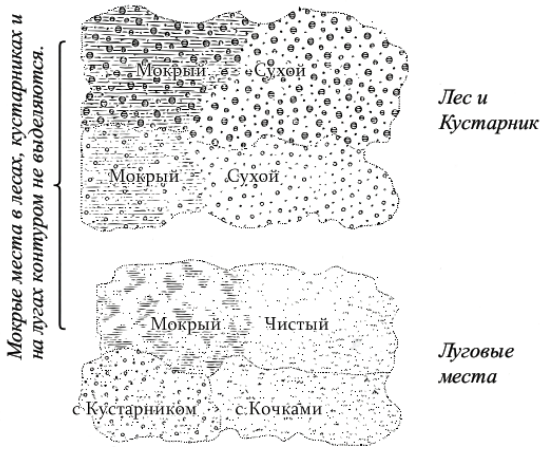

Figure 3. A legend fragment of the map published by the Military Topography Department

The data from the Forest Cadastre covers small forest areas as well (Figure 4). Due to the scale and generalization, such areas are not depicted on military topographic maps. An assumption can be made that such small forest land areas were also present during the studied period, but, due to the lack of data, the inclusion of them into the study is impossible. However, the presence/absence of small areas of this kind does not significantly affect the final result.

Figure 4. Small forest land areas (Regia, n.d., https://www.regia.lt/map/elektrenu?lang=0)

The image obtained after the devectorization of forest stands mapped during different periods (Figure 5):

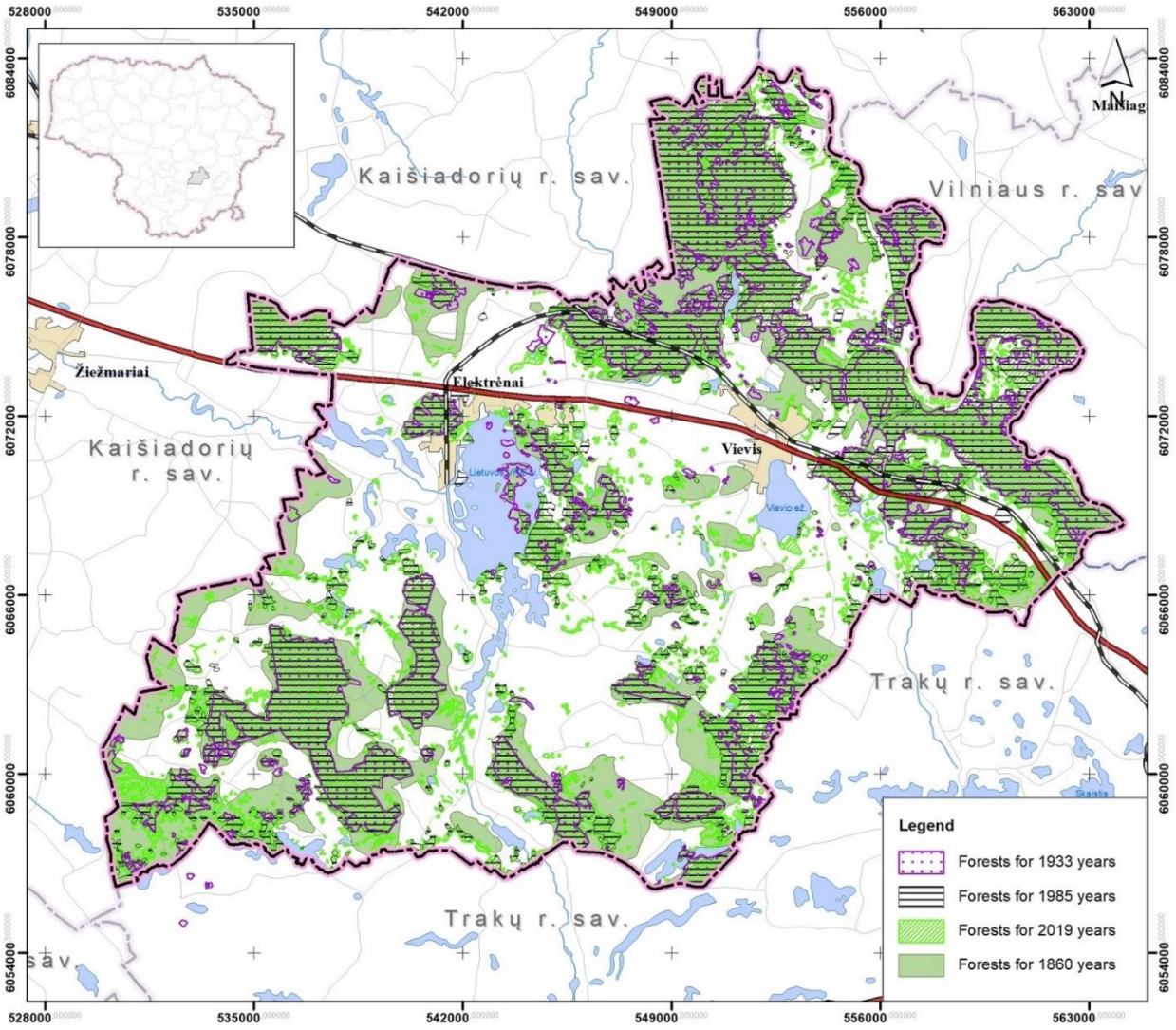

Figure 5. Forest stands during different periods in the Elektrenai municipality (created by the authors)

Figure 5 reveals that the locations of forest stands remained unchanged in the 21st c. when compared to the 19th c., but, when analysing the graphic material, it is evident that there were much larger forest land areas in the 19th c. than now. At some locations, forest land areas have completely disappeared (Figure 6).

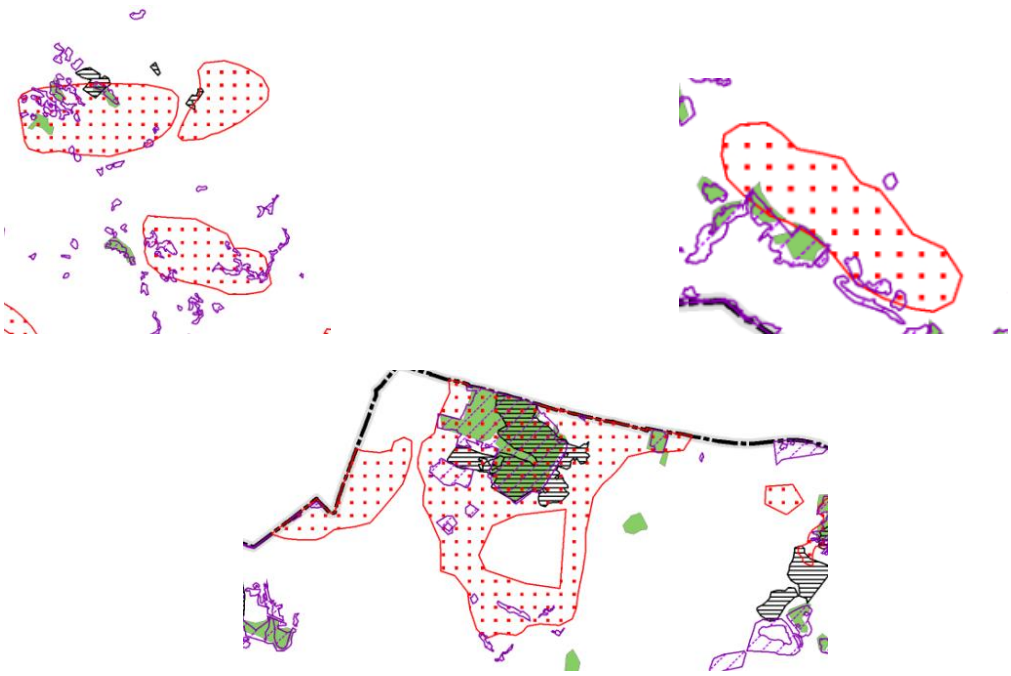

Figure 6. The change in the forest land areas

During the study, forest land areas estimated for different periods are provided in Table 1.

Table 1. The study results of the cartographic material

Period	Forest land area, ha	District coverage by forests, %	Change in the forest land area, ha
2nd half of 19th c.	21350.20	41.9	–
1st half of 20th c.	10475.56	20.6	−10874.64
2nd half of 20th c.	15448.86	30.3	4973.30
21st c.	16581.64	32.6	1132.78

The change in the percentage of the forest-coverage of the territory of the Elektrenai municipality is provided in Figure 7.

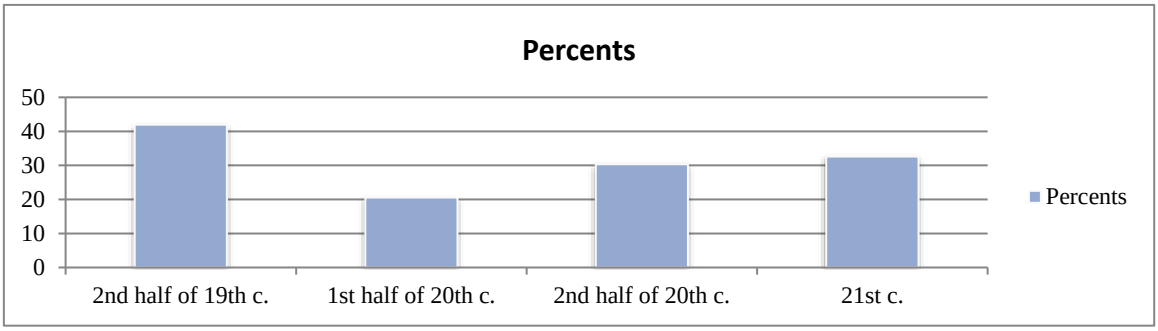

Figure 7. The change in the percentage of the forest-coverage of the territory (created by the authors)

The most rapid decrease in the forest land area occurred between the 19th c. and the first half of the 20th c., almost 11.000 ha of the forest was lost during that period, the coverage of the territory of the municipality decreased by 21.3%. Later, the increase of the forest-covered areas is observed, which constituted almost 5.000 ha in the second half of the 20th c. (9.7%), and a subsequent increase by 1.000 ha in the 21st c. (2.3%). The total decrease of the former forest land area has not been compensated by the subsequently observed increase. The area covered by forests in the 19th c. in the Elektrenai municipality is 9.3% higher than nowadays. As is evident form the tendencies of the change, the increase

in the forest-covered area is relatively unnoticeable and, in the near future, there is no reason to claim that the forest-coverage of the 19th c. will be achieved.

It is evident that the landscape has changed significantly, it is more agrarian affected by the human activity when compared to the 19th c. The most rapid change of the landscape took place in the 19th-first half of the 20th c., when almost 11.000 ha of forests were lost in the territory of 50.900 ha over a 60-year period. The deforestation speed was 183 ha per year. Undoubtedly, the deforestation was not so uniform, but such a relatively significant change in the vegetation had had to affect the landscape considerably. Even the subsequent gradual increase of the forest land has not provided for the return to the landscape of the second half of the 19th c. in respect to the forest land.

Conclusions

The coverage of the Lithuanian territory by forests has decreased by 24.5 percent during the period from the 1st millennium until today. The least forest area was recorded in the 1930s (16.7 percent). Between the 1st millennium and the first half of the 20th c., forest land areas decreased from 56 to 16.7 percent. Lithuania lost 39.3 percent of the forest-covered area. Afterwards, the forest-coverage has been gradually increasing and has reached 31.5 percent, but it is 24 percent less than in the 1st millennium.

Archival military topographic maps may be used for the analysis of the change in both the landscape and the forest-coverage. It is probably the only measure allowing compiling a landscape model of that time and carrying out the monitoring of the impact of the anthropogenic activity in landscape models. A landscape being formed due to the anthropogenic influence is observed to replace the landscape of wooded areas in certain locations.

The coverage of Lithuanian territory by forests started a rapid decrease in the 19th c. While, according to the available data, the forest-coverage decreased by 8 percent between the 15th and the 19th c., it decreased by as much as 13 percent between the 19th and the 20th c. A further decrease of 7.3 percent in the forest land area is observed during the subsequent 4 decades. In the post-war period, the forest land area starts to increase, and it reaches 31.5 percent in 2019, i.e. it increases by 14.8 percent. During the entire period, the forest land area in the territory of the Republic of Lithuania decreased by 24.5 percent.

In Elektrenai municipality, the forest cover decreased over time. From 41.9 percent in the second half of the 19th century to 20.6 percent in the first half of the 20th century. It then gradually increased to the present 32.6 percents. The former of the area forest cover in the 19th century has not been reached until now, with a difference of 9.3 percent (4769 ha). This is in line with the general trend of deforestation.

References

Brukas, A. (1987). Tiesos ir melo santykis statistikoje [The relationship between truth and falsehood in statistics]. *Girios, 11*, 4−6 (in Lithuanian).

Cvetkovas, M. A. (1957). *Miškingumo kaita europinėje Rusijos dalyje nuo XVII a. pabaigos iki 1914 m.* [Changes in forest cover in the European part of Russia since the 17th century. end of 1914]. SSSR Mokslų akademijos leidykla (in Lithuanian).

Kavaliauskas, P., Jankauskaitė, M., Veteikis, D., & Šimanauskienė, R. (2013a). *Lietuvos Respublikos kraštovaizdžio erdvinės struktūros įvairovės ir jos tipų identifikavimo studija* [Study of the diversity of spatial structure of the landscape of the Republic of Lithuania and identification of its types] (I dalis: kraštovaizdžio supratimo ir jo erdvinės struktūros pažinimo nuostatos). Lietuvos Respublikos aplinkos ministerija (in Lituanian).

Kavaliauskas, P., Jankauskaitė, M., Veteikis, D., Šimanauskienė, R., & Dumbliauskienė, M. (2013b.) *Lietuvos Respublikos kraštovaizdžio erdvinės struktūros įvairovės ir jos tipų identifikavimo studija* [Study of the diversity of spatial structure of the landscape of the Republic of Lithuania and identification of its types] (II dalis: Lietuvos kraštovaizdžio erdvinės raiškos identifikavimo ir lokalizavimo analizė). Lietuvos Respublikos aplinkos ministerija (in Lithuanian).

Lietuvos katalikų mokslų akademija. (1968). *Lietuvos katalikų mokslo akademijos metraštis IV*. Piazza della Pilotta, Roma (in Lithuanian).

Lietuvos Respublikos Seimas. (1994a). *Lietuvos Respublikos miškų įstatymas* [Forest law of the Republic of Lithuania] (Nr. I-671). https://www.e-tar.lt/portal/lt/legalAct/TAR.5D6D055CC00C

Lietuvos Respublikos Seimas. (1994b). *Lietuvos Respublikos miškų įstatymas* [Forest law of the Republic of Lithuania] (Nr. I-671). https://www.e-tar.lt/portal/lt/legalAct/TAR.5D6D055CC00C/asr

Lietuvos Respublikos Seimas. (2001). *Lietuvos Respublikos miškų įstatymo pakeitimo įstatymas* [Law on amendments to the law on forests of the Republic of Lithuania] (Nr. IX-240). https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.130604

Matulionis, P. (1930). *Lietuvos žemė ir jos gyventojų gausumas istorijos būvyje* [Lithuanian land and its population in the course of history]. *Kultūra, 5*, 241−245 (in Lithuanian).

Pauliukevičius, G., & Kenstavičius, J. (1995). *Ekologiniai miškų teritorinio išdėstymo pagrindai* [Ecological basis of spatial layout of forests]. AB „Krašto projektai“ (in Lithuanian).

Regia. (n.d.). https://www.regia.lt/map/elektrenu?lang=0

Valstybinė miškų tarnyba. (n.d.). http://www.amvmt.lt/

Žemaitis, V. (1964). *Pietinė Lietuva Grigaliaus Valavičiaus 1599 metų Lietuvos girių aprašyme* [Southern Lithuania in the description of Gregorian Valavičius' 1599 Lithuanian woods]. Čikaga (in Lithuanian).