CHANGES OF FOREST LAND COVER IN LITHUANIA DURING THE Period 1950-2017: A COMPARATIVE ANALYSIS

***Daiva Tiškutė-Memgaudienė**
Vytautas Magnus University, Lithuania
*Corresponding author's email: daiva.tiskute-memgaudiene@vdu.lt

Abstract
Due to human activities Lithuanian historical land use and land cover (LULC) changed. Forest land cover was also changing. 200 years ago, forests occupied almost 40% of the entire Lithuania territory, in 1914 – only 20%, and in 1939 – only 17%. The historical changes in forest land cover were mainly related to deforestation. Today, the forest cover is increasing in Lithuania, but changes within different municipalities boundaries differ. The aim of this study was to compare geodata of forest land cover, within different municipalities of Lithuania boundaries, in the 1950s and 2017 for a better understanding of spatial patterns of occurred forest land cover changes. To evaluate forest land cover changes in Lithuania, two geodatabases, representing the forest cover in the 1950s and 2017, were used. Methods of descriptive statistical analysis, spatial autocorrelation, cluster and outlier analysis using ArcGIS and MS EXCEL software were used to process, evaluate and represent the data of this study.
The results of this study revealed that forest land cover increased by 7.1% during the investigated period resulting in the forest land area proportion of 33.6% in 2017. Despite positive changes of Lithuania forest land cover, two municipalities met afforestation. Forest land covers most intensively, i. e. 17.1–31.1%, increased in the south-eastern part of Lithuania and west-central part of Lithuania. The most passive afforestation was detected in northern, central, and south-western parts of Lithuania, where forest land cover increased only from 1.2% to 4.9%.
Key words: forest land cover, forest land changes, spatial pattern.

Introduction

Human activity is a major force, which influences biodiversity as well as the climate of Earth through land use and land cover (Chaware *et al*., 2021; Manzoor *et al*., 2021). The primary mission of Earth was orientated on sustainable development of all life forms, but anthropogenic activities induced uncontrolled changes of steady processes and natural development. In 2012, the World Wildlife Fund (WWF) reported a study (Living, 2012) where it was stated that for the first time around 1980, the general needs of humanity exceeded the restorative power of the Earth. In 2008, humanity's global needs exceeded the Earth's restorative power by 30%. This means that humanity meets its needs today by consuming the capital of the planet, thus moving toward disaster when the capital is exhausted (Palaima & Mierauskas, 2013). Humanity needs more and more land to carry out its activities. Thus, forest lands were shifted to urban and agricultural surfaces (Ruseckas & Tiškutė-Memgaudienė, 2013; Tiškutė-Memgaudienė & Ruseckas, 2014). Deforestation and forest degradation, in turn, brought climate change (Agrawal *et al*., 2011; Koh *et al*., 2021). The most striking changes due to deforestation were monitored in South America and South-Eastern Asia during the last decades of the 20th century. On a small scale (in small countries), this process was also observed (DeFries *et al*., 2007). It is good that the consciousness of humanity has increased and afforestation is a more common process in most countries, especially developed ones. Although forest land area increases, forest land spatial structure remains not optimal (Juknelienė *et al*., 2017; Tiškutė-Memgaudienė, 2018). Thus, more studies investigating changes in land covers both small and large scale and possible decisions for future generations are required.

As Lithuania is located in Central Europe in the transitional zone between the boreal coniferous and the nemoral broadleaved forests, Lithuania forests are categorized as the European hemi-boreal mixed broadleaved-coniferous forest type (Mozgeris *et al*., 2019). It means that forests have been the most common land cover in the Lithuania landscape since ancient times. Many forests were cleared down during World War II to meet military needs. Therefore, in the post-war years, the expansion of forest cover and the increase of the growing stock productivity came into a focus. Moreover, due to global climate changes and after the ratification of the Kyoto Protocol, which deals with human efforts to mitigate environmental disturbance, afforestation became a more important field, and the particular decision was implemented in the Lithuanian legislation. In total, the afforestation in Lithuania is positive, but this process differs in particular territories (Tiškutė-Memgaudienė, 2018).

The aim of this study was to evaluate the spatial pattern of forest land cover, within municipalities of Lithuania boundaries in the 1950s and 2017, employing GIS overlay techniques. This study will contribute to a better understanding of forest land cover changes in Lithuania. Also, it will provide a reference value for future researches on the alteration of the forest land cover since World War II.

Materials and Methods

This study covers all forested area of Lithuania territory. Two geodatabases were used in order to execute a comparative analysis of forest land cover

changes in Lithuania during the period 1950–2017. First, the geodatabase representing the forest cover status in the 1950s was used as the starting point. This geodatabase was conducted using historical orthophoto maps based on aerial photography within the period just after World War II, georeferenced to the coordinate system of Lithuania (LKS94), and stored in vector-data (Mozgeris, 2012). Second, the geodatabase representing the forest cover status on Jan 1, 2017, available from the State Forest Service was used to estimate changes of forest land area over a half-century. This State Forest Cadastre geodatabase is the latest geodata version of Lithuania forest land cover available in open access. The aforementioned two geodatabases were compared using GIS overlay techniques.

The forest land area, as well as forest land changes within different municipalities of Lithuania boundaries, were estimated and plotted on choropleth maps. To better understand the spatial pattern of forest land cover peculiarities, cluster and outlier analysis was performed: Anselin Local Moran's I based on the "Inverse-distance" contiguity was applied to identify statistically significant hot spots, cold spots and spatial outliers in the mapped forest land values. Global Moran's I was enabled to assess the global spatial autocorrelation of forest land cover within municipalities of Lithuania boundaries.

Results and Discussions

The initial data of this study has shown that forest land covered 1709.0 thous. ha of Lithuania territory in the 1950s. This means that forests covered less than a third, i. e. 26.5% of the whole Lithuania territory. However, by 2017 the area of forest land expanded to 33.6% to reach 2178.9 thous. ha (Figure 1). The total increase in forest land area during the investigated period was 7.1%.

The histogram showing the frequency of occurrence of forest land cover, within municipalities of Lithuania boundaries, in the 1950s, as well as in 2017, Figure 2. Most frequent values were discovered to vary from 13.3% to 33.3% (with an average 26.2% and median 24.5%) in 1950s. However, in 2017 most frequent values of forest land cover, within municipalities of Lithuania boundaries were larger and varied from 15.8% to 43.8% (with an average of 34.2% and a median of 33.3%).

Although forest land cover within different municipalities boundaries is distributed randomly, the presence of statistically significant spatial clusters of forest land cover was observed in the 1950s (Global Moran's Index –0.074, z-score -0.283, p-value 0.777) as well as in 2017 (Global Moran's Index -0.015, z-score -0.009, p-value 0.993) (Figure 3).

Three types of spatial autocorrelation were observed using the Moran's I Local Indicators of Spatial Autocorrelation statistics (High-High, Low-Low, and High-Low). Positive spatial autocorrelation, represented by High-High spatial pattern clusters, was found in the southern part of Lithuania (Druskininkai municipality and Varėna municipality) in both 1950s and 2017. Positive spatial autocorrelation, represented by Low-Low spatial pattern clusters,

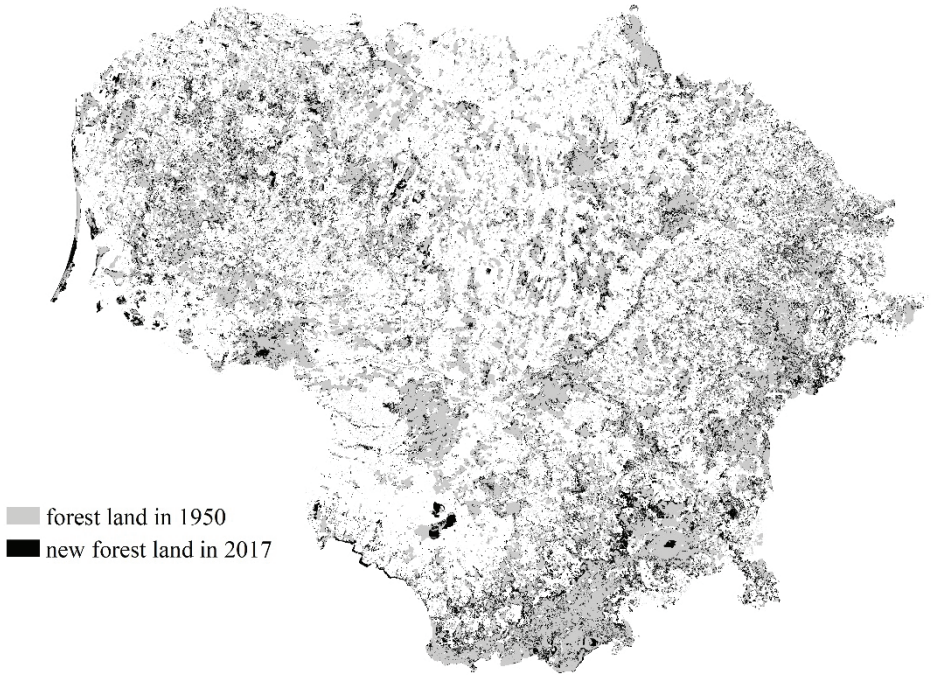

Figure 1. Lithuanian forest land cover in 1950s and 2017.

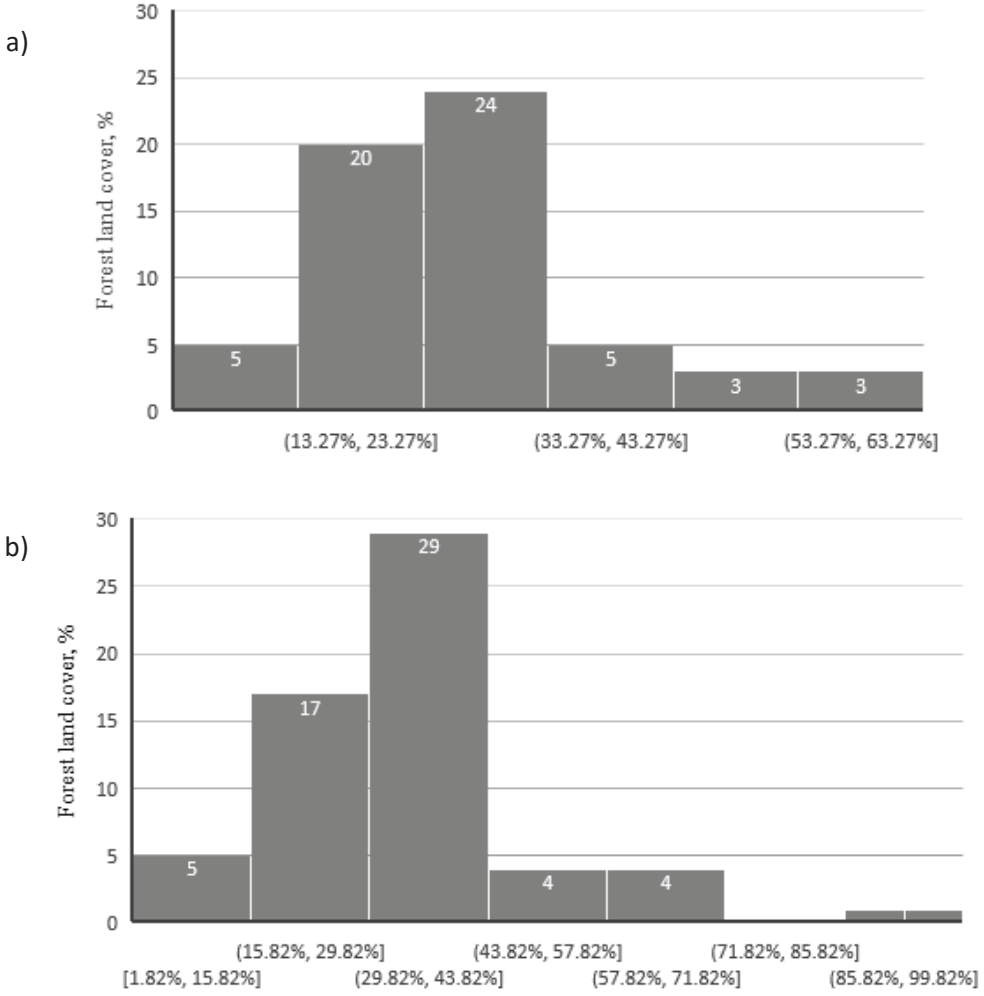

Figure 2. Histogram of forest land cover within municipalities of Lithuania boundaries in Lithuania: a) in 1950s; b) in 2017.

was mapped in the south-eastern part of Lithuania (Kalvarija municipality) in the 1950s, while in 2017, Low-Low spatial pattern clusters were observed not only in the south-eastern part of Lithuania (Kalvarija municipality) but also the northern part of Lithuania (Pakruojis municipality and Pasvalys municipality). This could be explained due to the inconsistent afforestation strategy of the Lithuanian government. Negative spatial autocorrelation represented by High-Low spatial pattern outliers was observed in the western part of Lithuania (Neringa municipality) and south-western part of Lithuania (Kazlų Rūda municipality) in both 1950s and 2017.

The modest value of forest land area in the 1950s was 3.3% (in Panevėžys city municipality), while in 2017, forest land area in this municipality was even lower; 1.8%, and Panevėžys city municipality was recognized as a municipality with modest forest land cover in whole Lithuania territory in 2017. This shows that even though forest land cover in Lithuania territory from the 1950s increased, some municipalities exprienced afforestation. Also, such changes could be explained by urbanization and changed habits of the Lithuanian population which led to an increase in population density in the biggest cities of Lithuania. Larger, but relatively small forest land cover in the 1950s was found in seven more municipalities: Šiauliai city municipality (4.9%), Kalvarija municipality (5.6%), Vilkaviškis municipality (7.3%), Pagėgiai municipality (13.2%), Marijampolė municipality (13.4%), Skuodas municipality (14.0%), and Pasvalys municipality (15.6%). As the results of this study have shown, the number of municipalities with low forest land cover in 2017 increased to 12 municipalities. The lowest forest land cover was found in same municipalities, monitored in the 1950s (Panevėžys city municipality (1.8%), Šiauliai city municipality (6.1%), Kalvarija municipality (14.9%), Vilkaviškis municipality (11.4%), Pagėgiai municipality (17.8%), Marijampolė municipality (16.6%), Skuodas municipality (20.7%), and Pasvalys municipality (17.3%)), also in four new municipalities: Kaunas city municipality (15.4%) and

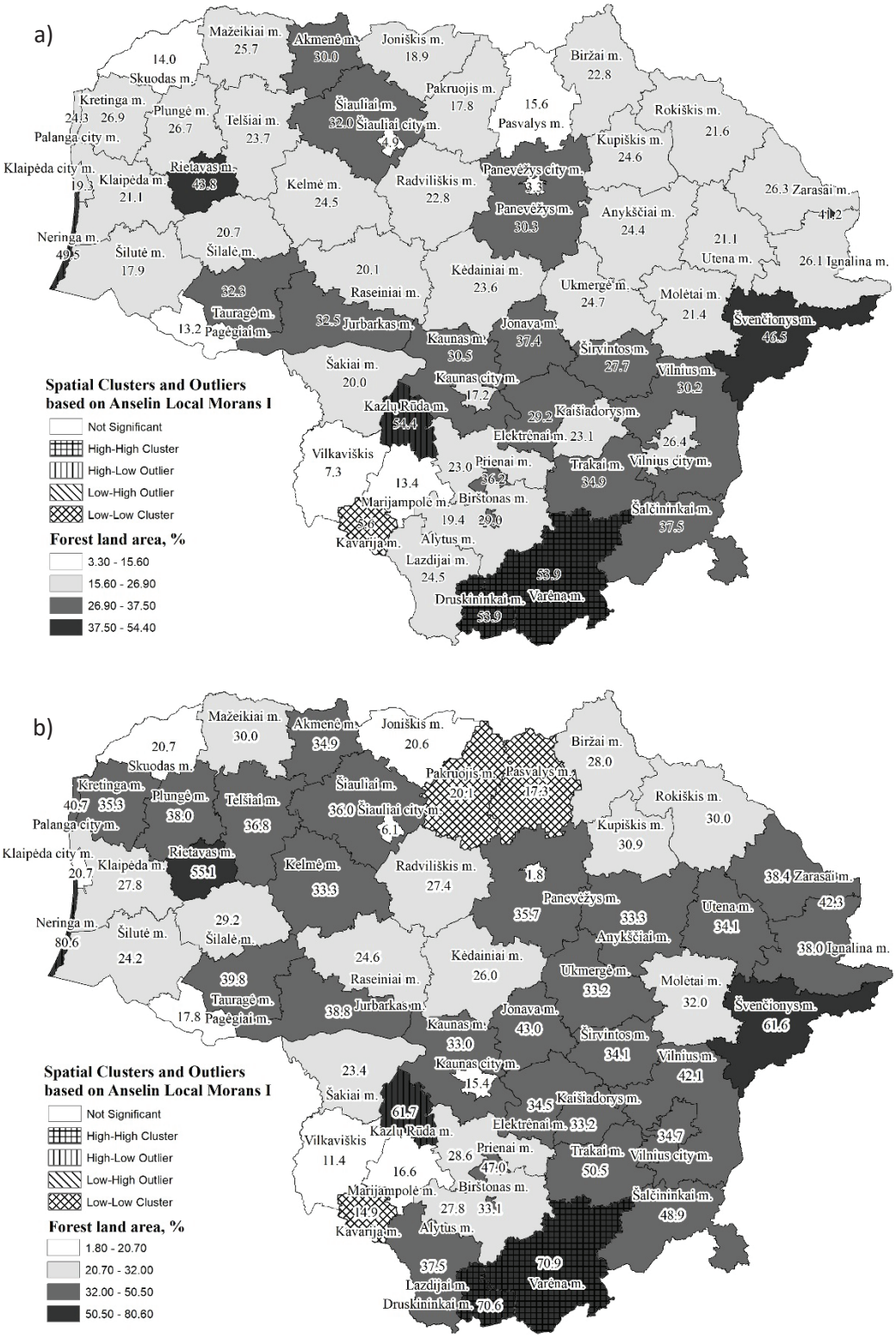

Figure 3. Spatial pattern of forest land within municipalities of Lithuania boundaries: a) in 1950s; b) in 2017.

Klaipėda city municipality (20.7%), also Pakruojis city municipality (20.1%) and Joniškis city municipality (20.6%). Excluding the largest Lithuania cities (Kaunas, Šiauliai, Panevėžys, Klaipėda), rural municipalities with the lowest forest land cover geographically are located on the border of Lithuania territory.

The largest forest land cover in the 1950s was found in Kazlų Rūda municipality – 54.5%. The

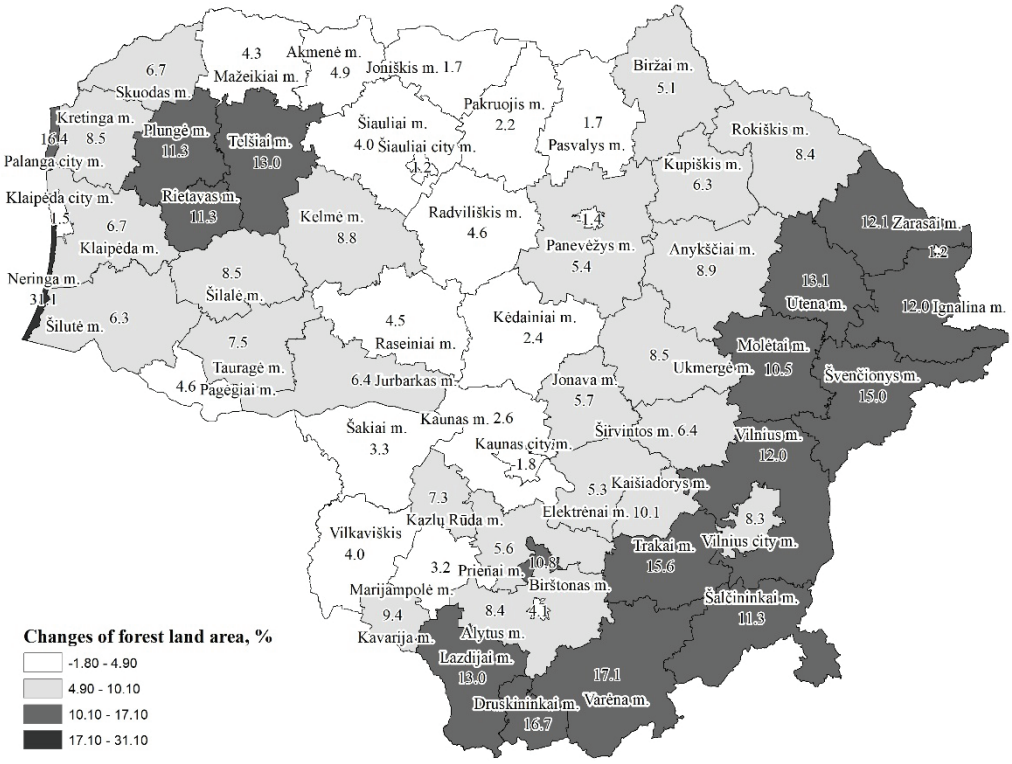

Figure 4. Spatial pattern of changes of forest land area within municipalities of Lithuania boundaries.

largest area, covered by forests in 2017, was found in Neringa municipality – 80.6%. It must be noted that in the area of this municipality, Curonian Spit, one of the most valuable places in Lithuania, which is also included on the Unesco world heritage list, is located. Thus, there must be concluded that environmental restrictions definitely influence the landscape of particular territories. The largest areas of forest land in the 1950s were found in eight municipalities, where forest land area varied from 37.5% in Šalčininkai municipality to 54.5% in Kazlų Rūda municipality. In 2017, largest forest land areas were estimated in seven municipalities, where forest land covered more than half the municipality area (50.5–80.6%).

Total changes of forest land area within municipalities of Lithuania boundaries are mapped in Figure 4.

Despite positive changes in Lithuania forest cover, two municipalities experienced afforestation – changes of forest land area were negative in Kaunas city municipality (-1.8%) and Panevėžys city municipality (-1.4%). During the investigated period, forest land cover was most intensively increased (17.1–31.1%) in the south-eastern part of Lithuania, where forest land cover was already rather large in the 1950s, also in the west-central part of Lithuania around Rietavas municipality with a rather high forest cover proportion which differed from neighbouring municipalities with low forest land cover. The most passive afforestation was found in northern, central, and south-western parts of Lithuania, where forest land area increased only from 1.2% to 4.9%.

Conclusions and Proposals

1. Total increase in forest land cover in Lithuania was 7.1% during the period 1950–2017. The forest land covered 26.5% of the whole Lithuania territory in the 1950s. The area of forest land expanded to 33.6% in 2017.
2. Most frequent values of forest land cover within municipalities of Lithuania boundaries were discovered to vary from 13.3% to 33.3% in the 1950s. However, in 2017 most frequent values of forest land cover within municipalities of Lithuania boundaries were larger and varied from 15.8% to 43.8%.
3. Municipalities with the largest forest land proportions were located in the southern part of Lithuania: positive spatial autocorrelation, represented by High-High spatial pattern clusters, was identified in both 1950s and 2017. Municipalities with the lowest forest land cover were located in the south-eastern part of Lithuania in the 1950s: positive spatial autocorrelation, represented by Low-Low spatial pattern clusters, was found during the study. However, the pattern of the Low-Low spatial cluster in 2017 has changed, and municipalities with the lowest forest

land cover were found not only in the south-eastern part of Lithuania but also in the northern part of Lithuania.

4. Two municipalities experienced afforestation during the investigated period. Changes in forest land cover were negative in Kaunas city municipality (-1.8%) and Panevėžys city municipality (-1.4%). Forest land covers most intensively, i. e. 17.1–31.1%, increased in the south-eastern part of Lithuania and west-central part of Lithuania. The most passive afforestation was found in northern, central, and south-western parts of Lithuania, where forest land cover increased only from 1.2% to 4.9%.

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