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Determination of Land Cover and Land Use Changes on the Island of Lošinj Based on Digital Orthophoto Analysis

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ABSTRACT

In this research, land cover changes in the southern part of the island of Lošinj in the period from 1968 to 2024 were analysed using remote sensing methods and geographic information systems (GIS). The aim of the research was to determine patterns of vegetation cover changes, identify the causes of these changes, and predict possible future trends in landscape development. The analysis was conducted on publicly available digital orthophoto maps (DOP5) from 1968 and 2024, downloaded from the Geoportal of the State Geodetic Administration (DGU) (Geoportal DGU 2025). The images were georeferenced in the official HTRS96/TM coordinate system and were visually interpreted and vectorised in the ArcGIS program. Cartographic representations were created for both years, and spatial and attribute data were compared to quantify the changes. The results showed a significant increase in the area of Aleppo pine (*Pinus halepensis* Mill.) forest, which increased from about 200 ha in 1968 to almost 800 ha in 2024. At the same time, the area under indigenous vegetation that consists of *Quercus ilex* and associated species doubled while agricultural areas almost disappeared. Anthropogenic impact is evident in the expansion of settlements and transport infrastructure to an area twice the size in 2024, but also in the neglect of former agricultural areas that are now overgrown with vegetation. The obtained data confirm the trend of reforestation and natural vegetation succession, which can be linked to historical processes of afforestation, depopulation and reduction of land use intensity. GIS tools have proven to be crucial in the analysis of spatial changes and provide a reliable basis for future planning and sustainable management of the island.

Keywords: land cover; geoinformation; reforestation; remote sensing

INTRODUCTION

Changes in land cover and land use are one of the most visible indicators of the relationship between humans and nature and reflect ecological, social and economic processes that have an impact on shaping the landscape (Lambin et al. 2006). Research on changes in land use in Croatia dates back to the mid-20th century (Crkvenčić 1951, 1957, 1958, Rogić 1958, Malić 1983) when they were based on cadastral maps and table data (Cvitanović 2014). Analyses are still being conducted with an emphasis on economic and social impacts on the dynamics of agricultural lands (Grgić et al. 2017, Jogun et al. 2017, Šetka et al. 2021). Land cover changes primarily include changes in the natural attributes of the earth's surface that can be influenced by human activity. With the development of remote sensing, changes in forest cover have become intensely monitored (Vukelić et al. 2005, Valožić and Cvitanović 2011, Durbešić and Fürst-Bjeliš 2016, Fürst-Bjeliš 2018, Blaće 2019, Karaula 2023). In the Mediterranean area, and especially on the Croatian islands, these changes are often the result of long-term effects of natural processes and human activities. On the island of Lošinj, the transformation of the landscape was largely driven by a shift in the economic activities of the local population. With the end of the maritime period, at the end of the 19th century, part of the population emigrated (Hamzić 2022), and olive groves and cultivated areas were abandoned. On the other hand, tourism opportunities were discovered, leading to afforestation with Aleppo pine, which restored the soil and improved the microclimate

(Ugarković et al. 2019), thus enabling the development of health tourism. These processes indicate the presence of both types of reforestation according to Fürst-Bjeliš (2018) in one isolated and small research area. In general, in Croatia, reforestation, which manifests itself through the spread of woody vegetation to areas of former pastures and croplands, has been recorded primarily in the inner mainland and on the islands as a result of depopulation and abandonment of traditional activities. In contrast, reforestation as a result of afforestation with Aleppo pine and its natural spread has been occurring in coastal areas since the 19th century (Vukelić et al. 2011).

The aim of this research was to record changes in the land cover of the southern part of the island of Lošinj in the period from 1968 to 2024 by analysing aerial photographs in order to explain the causes, determine the direction and intensity of changes, and assess the processes that will shape the landscape in the future. In this case, the use of remote sensing methods and GIS enabled precise monitoring of the spatial dynamics of vegetation in terms of quantification, comparison, and presentation of the obtained results.

MATERIALS AND METHODS

Study Area

The study was conducted on an area of 21 km² in the southern part of the island of Lošinj with a total area of approximately 75 km² (Figure 1).

Located in the southwestern part of the Kvarner Bay, it is characterised by a moderately warm rainy climate with a dry summer period (Csa) (Rauš 1992, Seletković et al. 2011) with an average annual temperature of 15.3°C, a mean annual precipitation of 902 mm (Ugarković et al. 2022) and more than 2500 hours of sunshine per year. The natural vegetation consists of an association of holm oak and black ash (*Fraxino orni-Quercetum ilicis*) (Vukelić et al. 2008), while a large area of the island is covered with Aleppo pine (*Pinus halepensis* Mill.).

Data Sources

The analysis was conducted using free online digital orthophoto maps (DOP5) for 1968 and 2024, downloaded from the Geoportal of the State Geodetic Administration. The data were processed in the ArcGIS 10.x program in the HTRS96/TM coordinate system. The field research served as a check in case of doubts and as a source of supplement in the form of a visual representation of the situation.

Data Processing and Analysis

The images were placed in the ArcGIS program 10.x in the HTRS96/TM coordinate system via the WMS server. The images represented a raster base, based on whose visual photointerpretation a vector layer of delineated polygons was created. A key for classification containing 15 categories of ground cover (Table 1, Figure 3) was created according to the specifications of the area and research objectives.

The codes according to which the polygons were delineated were assigned to them through a new column

Figure 1. Study area (Geoportal DGU).

CODE in the attribute table, and in the column AREA, the area of each delineated polygon was calculated using the Calculate Geometry option. Area data in the form of dbf. files were transferred to Microsoft Excel, where they were systematised and processed, which enabled easier interpretation of the obtained results.

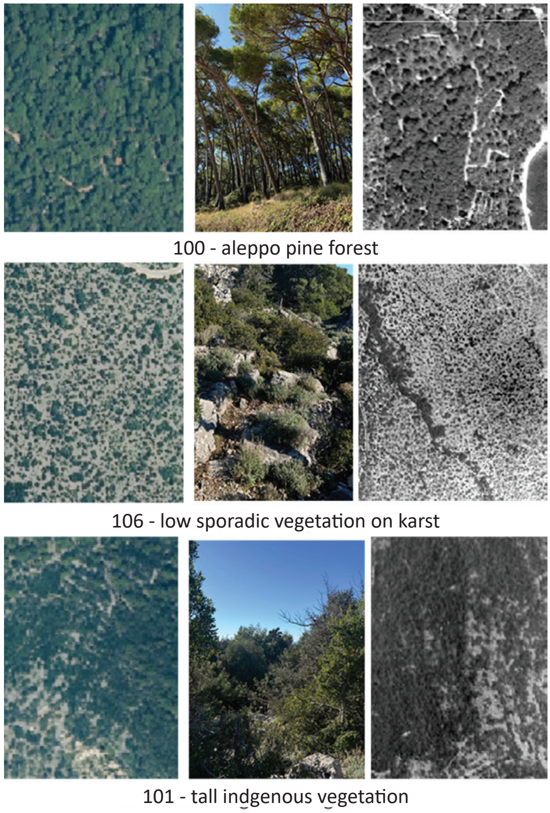

Figure 2. Examples of criteria for category delineation.

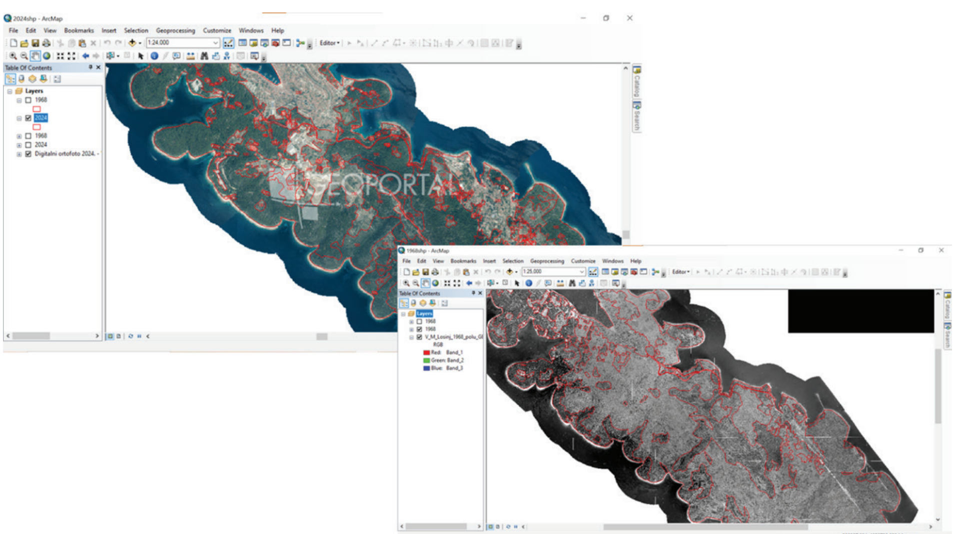

Figure 3. Polygon delineation on DOP5 - 1968 and 2024 (DGU - WMS server).

Table 1. Overview and description of classification codes.

Code	Category
100	Aleppo pine forest
101	tall indigenous vegetation
102	low dense indigenous vegetation
104	drystone walls with maintained vegetation
105	greenery within urban areas
106	low sporadic vegetation on karst
107	bare stone
110	mowed areas in residential areas
120	grassland/mowed areas
130	mosaic of low with individual tall vegetation
140	agricultural areas
200	tourist facility - camp
210	recreational areas
220	residential area
222	educational institutions
230	road/parking
240	tourist facilities
250	industrial areas

RESULTS

The main results of this research are cartographic representations of land cover results recorded for 1968 and 2024, as a product of visual interpretation on DOP5 (Supplementary File 1, Supplementary File 2).

The results show significant changes in the structure of land cover during the observed period. In 1968, agricultural and drystone areas were dominant (more than 50%, 11,435,412 m^2) while Aleppo pine forests occupied about 9.5%, i.e. an area of more than 200 ha, primarily in the northwest, expanding southward along the coast to an isolated area along the coast of Krivica Bay indigenous vegetation 19%, i.e. an area of more than 400 ha. At that time, residential areas covered an area of 800,000 m^2 and karst areas with sporadic vegetation covered 750,000 m^2 on the southern coast (Table 2).

By 2024, the area under Aleppo pine forests had increased to 37%. The pine has spread to almost 800 ha of the observed area, and indigenous vegetation now covers more than 500 ha of the total area, excluding the area of 261 ha occupied by degradation stages, mainly macchia. Agricultural areas and drystone areas have almost completely disappeared, and residential areas have expanded to twice the area (from 790,177 m^2 to 1,638,839 m^2). The areas of transport and tourism infrastructure have

Table 2. Class surfaces shown according to codes (1968).

Category	Area (m^2)	Area (%)
Aleppo pine forest	2 012 632	9.55
tall indigenous vegetation	4 020 393	19.08
drystone walls with maintained vegetation	11 435 412	54.26
low sporadic vegetation on karst	751 876	3.57
bare stone	26 513	0.13
grassland/mowed areas	10 868	0.05
mosaic of low with individual tall vegetation	1 959 366	9.30
agricultural areas	22 196	0.11
residential area	790 177	3.75
road/parking	36 478	0.17
industrial areas	8 886	0.04

Table 3. Class surfaces shown according to codes (2024).

Category	Area (m^2)	Area (%)
Aleppo pine forest	7 863 881	37.11
tall indigenous vegetation	5 040 322	23.79
low dense indigenous vegetation	2 618 077	12.36
drystone walls with maintained vegetation	39 628	0.19
greenery within urban areas	45 315	0.21
low sporadic vegetation on karst	1 186 739	5.60
mowed areas in residential areas	29 795	0.14
grassland/mowed areas	7 856	0.04
mosaic of low with individual tall vegetation	1 906 998	9.00
agricultural areas	1 094	0.01
tourist facility - camp	60 742	0.29
recreational areas	48 864	0.23
residential area	1 638 839	7.73
educational institutions	8 147	0.04
road/parking	289 939	1.37
tourist facilities	93 736	0.44
industrial areas	309 297	1.46

also increased, now occupying more than 1% of the total observed area. Karst areas with sporadic vegetation have remained at slightly more than 1 km^2 at higher altitudes, and in the very south of the island (Table 3).

A spatial comparison of data from 1968 and 2024 confirms the tendency of natural succession of indigenous vegetation in the process of occupation of abandoned cultivated areas and the expansion of areas under Aleppo pine in the northwest-southeast direction, following the morphology of the terrain. Present today in most of the southern half of the researched area, dense areas, predominantly macchia, correspond spatially to the locations of the former natural distribution of indigenous vegetation, which indicates a long-term succession process, but also the occupation of larger areas due to the abandonment of land use. Karst areas with sporadic vegetation show a high degree of spatial stability compared to 1968, remaining in almost identical locations on the southern coast (Table 4, Supplementary File 1, Supplementary File 2). However, one segment at a higher altitude shows signs of degradation and causes an increase in the Karst areas with sporadic vegetation surface, although it is more likely that it is caused by anthropogenic degradation, rather than negative vegetation succession.

Comparison of the results for these two periods allowed for a more detailed understanding of the spatial dynamics, recognition of the causes that shaped the current appearance of landscape and identification of trends of changes.

Table 4. Comparison of the results for two periods (1968 and 2024).

Category	Area 1968 (m^2)	Area 2024 (m^2)
Aleppo pine forest	2 012 632	7 863 881
tall indigenous vegetation	4 020 393	5 040 322
drystone walls with maintained vegetation	11 435 412	39 628
low sporadic vegetation on karst	751 876	1 186 739
grassland/mowed areas	10 868	7 856
mosaic of low with individual tall vegetation	1 959 366	1 906 998
agricultural areas	22 196	1 094
residential area	790 177	1 638 839
road/parking	36 478	289 939
industrial areas	8 886	309 297

DISCUSSION

According to available and documented data, Aleppo pine expanded from 39 hectares of forest area at the end of the 19th century (Kosmos 2016) to 200 hectares by 1968, and by 2024 occupied nearly 800 hectares, indicating an exponential expansion trend (Španjol et al. 2006). Afforestation played a key role in creating today's forest cover, while favourable climate and soil conditions enabled its expansion. Depopulation of the island, economic changes and the development of tourism led to a decrease in agricultural areas and the gradual covering of open terrain with indigenous vegetation, which increased the covered area from 400 ha to more than 750 ha. Areas that were once covered with tall indigenous vegetation are now dense and impassable, which indicates a negative direction of succession, but can be explained by unfavourable terrain conditions in the form of slope, shade and skeletal soil that is characteristic of this area (Pernar 2017). Given that 140 years have passed since the first planting of the Aleppo pine, the first planted trees are approaching the end of their lifespan, as confirmed by the increasingly frequent uprooting and collapse of old trees, especially after strong wind conditions. In some areas of the Aleppo pine forest, young holm oak trees appear in the understory, which is in line with the natural development of the Mediterranean vegetation in which the Aleppo pine forest should be replaced by holm oak, but many authors point out that without intense forest management interventions, afforestation with Aleppo pine does not enable progressive succession of indigenous vegetation, and the replacement of Aleppo pine by a complete stand of holm oak has not yet been recorded (Tekić et al. 2014). According to Španjol et al. (2006), Aleppo pine culture during one rotation age has not enabled the conversion of the form of forest stands. Edaphic conditions and ecological factors, along with negative anthropogenic influence, do not contribute to the improvement of habitat conditions.

By analysing land cover changes in the southern part of the island of Lošinj over the period from 1968 to 2024 and using available literature to connect events from the earlier past, dynamic processes of development and movement of vegetation have been observed.

The results confirm a long-term process of vegetation succession caused by the reduction of anthropogenic pressure in the form of land use and the process of intense reforestation in the form of the spread of Aleppo pine from areas forested at the end of the 19th century.

The obtained data confirm the effectiveness of GIS and remote methods in monitoring land cover changes, and the created maps can serve as a basis for spatial planning, environmental protection and valorisation of natural resources.

CONCLUSIONS

This paper analyses free on line digital orthophoto maps (DOP5) for 1968 and 2024 downloaded from the Geoportal of the State Geodetic Administration with the aim of showing and understanding the processes that have taken place in this area as well as better interpreting upcoming changes with an emphasis on the dynamics of Aleppo pine forests and indigenous vegetation due to the historical events that led to the current state as well as their significance for the development and progress of the island itself.

Graphical representations that reflect the past and present state of vegetation provide insight into the direction and intensity of changes that have occurred over more than half a century and predict the direction and intensity with which they will continue.

Remote sensing enables monitoring of the state of vegetation, which makes it possible to predict potential damage due to the demolition of the oldest pine trees, and spatial data from the past makes it easy to determine which areas are at risk.

By observing spatial and attribute data, a change in the spatial structure of vegetation cover between 1968 and 2024 is clearly visible. The most pronounced process is the expansion of Aleppo pine forest stands in the northwest-southeast direction, following the morphology of the terrain.

The collected data are measurable and located in time and space, which allows their repeatability and analytical applicability.

Understanding these changes is key to assessing the state of the environment, planning sustainable spatial management and preserving the traditional cultural landscape that represents an important part of the island's identity and its natural heritage.

Author Contributions

AS and MA provided expertise in the GIS software analysis, PP collected field data and conducted analysis, JK contributed to the interpretation of results.

Conflicts of Interest

The authors declare no conflict of interest.

Supplementary Materials

Supplementary File 1 - Land cover classification 1968.
Supplementary File 2 - Land cover classification 2024.

REFERENCES

Blaće A, 2019. Promjene šumskoga pokrova na području Ravnih kotara u drugoj polovici 19. stoljeća. *Hrvatski geografski glasnik* 81(2): 69-88. https://doi.org/10.21861/HGG.2019.81.02.03.

Crkvenčić I, 1951. O agrarnoj strukturi gornjeg porječja Bednje. *Geografski glasnik* 13(1): 101-114.

Crkvenčić I, 1957. Prigorje planinskog niza Ivančice. *Geografski glasnik* 19(1): 9-56.

Crkvenčić I, 1958. Prigorje planinskog niza Ivančice. *Geografski glasnik* 20(1): 1-48.

Cvitanović M, 2014. Promjene zemljišnog pokrova i načina korištenja zemljišta u Krapinsko-zagorskoj županiji od 1991. do 2011. *Hrvatski geografski glasnik* 76(1): 41-59. https://doi.org/10.21861/HGG.2014.76.01.03.

Durbešić A, Fürst-Bjeliš B, 2016. Tipovi i trendovi promjene pejzaža planina Svilaje-Ogorje. Ekonomska i ekohistorija: *Časopis za gospodarsku povijest i povijest okoliša* 12(1): 208-221.

Fürst-Bjeliš B, 2018. Deforestacija i reforestacija u hrvatskome dinarskom kršu: Odnosi i implikacije. Ekonomska i ekohistorija: *Časopis za gospodarsku povijest i povijest okoliša* 14(1): 136-144.

Grgić M, Šiško J, Bašić T, 2017. Analiza promjene pokrova i uporabe zemljišta na području Republike Hrvatske te njihova evidencija u službenim registrima. In: Proceedings of the 10. simpozij ovlaštenih inženjera geodezije "Prostorni registri za budućnost". *Grafo-Mark*, 32-37.

Hamzić M, 2022. Spatial Analysis of Changes in the Demographic Characteristics of the Cres-Lošinj Area Using the GIS Model. *Kartografija i geoinformacije* 21(38): 4-24. https://doi.org/10.32909/kg.21.38.1.

Jogun T, Pavlek K, Belić T, Buhin S, Malešić N, 2017. Promjene zemljišnog pokrova u sjevernoj Hrvatskoj od 1981. do 2011. godine. *Hrvatski geografski glasnik* 79(1): 33-59. https://doi.org/10.21861/HGG.2017.79.01.02.

Karaula M, 2023. Analiza promjene šumskog pokrova Spačvanskog bazena od 1975. do 2022. godine pomoću satelitskih snimaka. MSc Thesis, Sveučilište u Zagrebu, Prirodoslovno-matematički fakultet, Zagreb, Croatia. https://urn.nsk.hr/urn:nbn:hr:217:377147.

Kosmos L, 2016. Haračićevi profesorski i znanstveni vidici. Srednja škola Ambroza Haračića, Mali Lošinj, Croatia, 95-105.

Lambin EF, Geist HJ, 2006. Land-Use and Land-Cover Change: Local Processes and Global Impacts. Springer, Berlin/Heidelberg, Germany, 222 pp.

Malić A, 1983. Regionalne razlike i promjene površina kategorija iskorištavanja poljoprivrednog zemljišta SR Hrvatske. *Hrvatski geografski glasnik* 45(1): 55-72. https://hrcak.srce.hr/37356.

Pernar N, 2017. Tlo: nastanak, značajke, gospodarenje. Šumarski fakultet Sveučilišta u Zagrebu, Zagreb, Croatia, 589 pp.

Rauš Đ, 1992. Šume u Hrvatskoj. Šumarski fakultet Sveučilišta u Zagrebu, Hrvatske šume, Zagreb, Croatia, 13-16.

Seletković Z, Tikvić I, Vučetić M, Ugarković D, 2011. Klimatska obilježja i vegetacija sredozemne Hrvatske. In: Šume hrvatskoga sredozemlja (Forests of the Croatian Mediterranean). Akademija šumarskih znanosti, Zagreb, Croatia, 142-161.

Šetka J, Radeljak Kaufmann P, Valožić L, 2021. Promjene zemljišnog pokrova i načina korištenja zemljišta u Donjoneretvanskom kraju od 1990. do 2020. godine. *Hrvatski geografski glasnik* 83(2): 7-31. https://doi.org/10.21861/HGG.2021.83.02.01.

Španjol Ž, Barčić D, Rosavec R, Ugarković D, 2006. The ameliorative role of Aleppo pine (*Pinus halepensis* Mill.) in the regeneration of climatozonal vegetation. *Period Biol* 108(6): 655-662.

Tekić I, Fürst-Bjeliš B, Durbešić A, 2014. Rasprostranjenost alepskog bora (*Pinus halepensis* Mill.) i njegov utjecaj na vegetaciju i strukturu pejzaža šireg šibenskog područja. *Šumarski list* 138(11-12): 593-600. https://hrcak.srce.hr/135183.

Ugarković D, Španjol Ž, Tikvić I, Kapučija D, Plišo Vusić I, 2019. Microclimate differences in the degradation stages of holm oak (*Quercus ilex* L.) forests. *Šumarski list* 143(9-10): 391-402. https://doi.org/10.31298/sl.143.9-10.1.

Ugarković D, Paulić V, Šapić I, Poljak I, Ančić M, Tikvić I, Stankić I, 2022. Climatic relationship of vegetation in forest stands in the Mediterranean vegetation belt of the Eastern Adriatic. *Atmosphere-Basel* 13: 1709. https://doi.org/10.3390/atmos13101709.

Valožić L, Cvitanović M, 2011. Kartiranje promjene šumskog pokrova: analiza prostorne promjene šumskog pokrova u Parku prirode Medvednica pomoću Landsatovih snimaka. *Hrvatski geografski glasnik* 73(1): 245-246. https://doi.org/10.21861/hgg.2011.73.01.16.

Vukelić J, Pernar N, Vratarić P, 2005. Dinamične promjene staništa i šumskoga pokrova u poplavnom području Podunavlja. In: Poplavne šume u Hrvatskoj. Akademija šumarskih znanosti, Zagreb, Croatia, 40-49.

Vukelić J, Mikac S, Baričević D, Bakšić D, Rosavec R, 2008. Šumska staništa i šumske zajednice u Hrvatskoj: Nacionalna ekološka mreža. Državni zavod za zaštitu prirode, Zagreb, Croatia, 187 pp.

Vukelić J, Trinajstić I, Baričević D, 2011. Šumska vegetacija hrvatskoga sredozemlja. In: Šume hrvatskoga sredozemlja (Forests of the Croatian Mediterranean). Akademija šumarskih znanosti, Zagreb, Croatia, 193-214.

Rogić V, 1958. Velebitska primorska padina. Acta *Geographica Croatica* 2(1): 8-119. https://hrcak.srce.hr/146403.

Geoportal DGU. Available online: https://geoportal.dgu.hr/ (Accessed 21 November 2025).