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Front cover photography: Sveta Gora, a settlement with a franciscan monastery overlooking the Soča valley, renowned as a Marian pilgrimage site, is located near the Slovenia-Italy border, at the intersection of Alpine, Medditerranean and Dinaric landscapes (photograph: Jure Tičar).
Fotografija na naslovnici: Sveta Gora, naselje s frančiškanskim samostanom nad dolino Soče, ki je znano po marijanskem romarskem središču, leži na meji Slovenije in Italije ter na stiku alpskih, sredozemskih in dinarskih pokrajin (fotografija: Jure Tičar).

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LAND USE CHANGES IN SOUTHERN CROATIA (DALMATIA) SINCE THE BEGINNING OF THE 20TH CENTURY

Anđela Vrkić, Ante Blaće

GEOPORTAL, CROATIAN GEODETIC ADMINISTRATION

Ba(v)ljenac islet in Šibenik-Knin County. Intensive dry stone walling occurred in the late 19th century due to the cultivation of vineyards, resulting in its present-day nickname, »Fingerprint Island«.

DOI: https://doi.org/10.3986/AGS.13490
UDC: 911:711.14(497.58) "19/20"

Anđela Vrkić[1], Ante Blaće[2]

Land use changes in Southern Croatia (Dalmatia) since the beginning of the 20th century

ABSTRACT: This research analyzed land use changes in Southern Croatia over the past 120 years. The methodological approach employed analysis and chronological comparison of archival and statistical data, and geoprocessing of the Corine Land Cover geodatabase. In the period spanning from 1900 to 1945, agriculture was the main activity, accompanied by a notable decline in vineyards. The subsequent era, from 1945 to 1991, was characterized by the dominance of rapid industrialization, onset of land abandonment, and the reversion of former agricultural areas to natural vegetation. Since 1991, the trend of land abandonment and deruralization has persisted and intensified. As a result, shrubs and forests now claim the largest share of the researched area, solidifying a new landscape configuration.

KEYWORDS: land use, Southern Croatia, agriculture, land abandonment, succession of vegetation

Spremembe v rabi tal v južni Hrvaški (Dalmaciji) od začetka 20. stoletja

POVZETEK: Članek proučuje spremembe v rabi tal v južni Hrvaški v zadnjih 120 letih. Uporabljeni metodološki pristop vključuje analizo in kronološko primerjavo arhivskih in statističnih podatkov ter obdelavo prostorskih podatkov iz podatkovne zbirke Corine Land Cover. Med letoma 1900 in 1945 je bila glavna gospodarska dejavnost na tem območju kmetijstvo, značilen je bil tudi precejšen upad vinogradov. Obdobje med letoma 1945 in 1991 so zaznamovali prevlada hitre industrializacije, začetek opuščanja zemljišč in zaraščanje nekdanjih kmetijskih površin. Od leta 1991 se nadaljuje in krepi trend opuščanja zemljišč in deruralizacije. Posledično danes na večini proučevanega območja prevladujeta grmičevje in gozd, ki spreminjata podobo pokrajine.

KLJUČNE BESEDE: raba tal, južna Hrvaška, kmetijstvo, opuščanje zemljišč, ekološka sukcesija

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1 Introduction

Land use is a fundamental human activity, with diverse needs and requirements that vary across different regions of the Earth's surface (Ramankutty et al. 2006). Almost all of the Earth's surface have been altered, either directly or indirectly, by anthropogenic activities, particularly in the context of modern socio-economic development. The greatest impact is visible in areas that are permanently or intermittently inhabited, i.e. in the areas most economically valued and utilized (Marušić 2017). Land use and land cover changes (LULCC) stand out in recent studies as the two central processes through which human influence on the environment is most evident (Lambin et al. 2000). Originally rooted in the natural sciences, the study of LULCC changes now embraces an interdisciplinary approach due to the intricate interaction between humans and their environment. Land cover refers to biophysical structures on Earth's surface and just below it (Lambin et al. 2006). Remote sensing methods such as satellite images and photogrammetry are primarily used in land cover studies (Alqurashi and Kumar 2013; Colditz et al. 2014; Pricope et al. 2019; Buchner et al. 2020; MohanRajan et al. 2020; Zhu et al. 2022; Chen 2023). Unlike land cover, which is biophysically determined, land use is more complex defined by human activities aimed at creating, altering, or maintaining specific land covers (FAO 1998). The methodological approach is broader, encompassing remote sensing, cadastral data, fieldwork, surveys, agricultural statistics, and more (Meiyappan and Jain 2012; Lieskovský et al. 2018; Liu et al. 2018; Ettehadi Osgouei et al. 2022; Wang et al. 2022). In land use research smaller spatial units such as counties are usually studied, while land cover research is carried out for larger areas like countries or even continents. However, land use and land cover are used interchangeably, and the distinction between them often diminishes (Foški et al. 2018).

Large portion of land is devoted to agricultural production, currently covering approximately 43% of the Earth's surface (Ramankutty et al. 2018). But agriculture is marked by two opposing processes: the expansion of agricultural areas driven by the demand for agricultural products (food) and the abandonment of agricultural areas, especially in developed countries (Levers et al. 2018). Although significant urbanization took place globally in the 20th and 21st centuries, large areas continue to serve agricultural production.

Studies on land use changes on the territory of Southern Croatia were relatively rare, and often limited to smaller spatial units such as microregions, settlements and islands (Blaće 2014; Durbešić and Fuerst-Bjeliš 2016; Blaće 2017). Those studies often revolved around landscape changes and relied on data from cadastres, old maps, and agricultural censuses. Recent research has incorporated GIS technology. Šetka et al. (2021) analysed land use changes in the Lower Neretva river area (a region within Southern Croatia) using satellite imagery for the period from 1990 to 2020. Subsequently, they simulated LULCC changes in the same area up to 2035 based on various criteria (Šetka et al. 2023). In contrast, numerous studies have dealt with land use changes in other Mediterranean areas, such as parts of Italy (Falcucci et al. 2007), Spain (Millington et al. 2007; Cervera et al. 2019; Delgado-Artés et al. 2022), Mediterranean coast of France (Abadie et al. 2018) and Greece (Tzanopoulos and Vogiatzakis 2011; Schaich et al. 2015; Kefalas et al. 2019; Dimopoulos and Kizos 2020; Kefalas et al. 2020; Chouvardas et al. 2022). Coastal areas exhibit an increase in built-up areas at the expense of former agricultural and forested land, while inland regions often witness the conversion of agricultural land into urban areas and forests (Di Fazio et al. 2011; Salvati et al. 2014; Gallardo et al. 2023). Conversely, certain areas experience an expansion of agricultural land (Ruiz-Benito et al. 2010; Gemitzi et al. 2021; Gallardo et al. 2023) and peri-urban zones (Ustaoglu and Aydınoglu 2019). Additionally, agricultural land tends to become increasingly fragmented (Topal and Konakoğlu 2023). Despite variations in chronological scope and methodologies among these studies, they collectively underscore similarities in land use dynamics across diverse Mediterranean regions.

The paper aims to analyze land use changes in Southern Croatia from the early 20th century to the present, to quantify these changes and identify the most important drivers. This research fills the gap in comparison with other Mediterranean countries where LULCC studies are numerous. Our main hypothesis is that agricultural areas prevailed until the mid-20th century, while today the largest part of the land is covered by shrub/macchia and forest in various stages of development. These changes directly and indirectly reflect the large socio-economic shifts that occurred in Southern Croatia during the studied period and even indicate some environmental changes, such as forest fires.

2 Research area and methods

2.1 Research area

The research area, Southern Croatia, refers to the four southernmost Croatian counties: Zadar, Šibenik-Knin, Split-Dalmatia and Dubrovnik-Neretva (Figure 1, Table 1). This county division has been in place since 1997. However, considering the territorial changes during the 20th century, it was necessary to align the previous territorial units, which existed in the research area before 1997, with today's county boundaries. Southern Croatia is nearly coterminous with the historical region of Dalmatia, which was a territorial until 1918 and today exists only as a vernacular region.

The dominant geological features in Southern Croatia are limestone and dolomite layers, resulting in prevalent karst landforms and lack of arable land. Hypsometrically, the majority of the land lies at elevations up to 500 meters above sea level (Magaš 2013). Agricultural activities primarily took place in dolomite and flysch zones, while proper karst areas composed of limestone were used for grazing. Southern Croatia exhibits a varied climate, with temperate, warm, humid conditions featuring hot summers (Cfa) in the hinterland and Mediterranean climate with hot summers (Csa) along the coastline and islands. These climate and pedological differences reflect specifies of the agricultural production. The coastal regions and islands are renowned for their cultivation of vines and olives, while the hinterland has been more suitable for arable farming and livestock cultivation (Maleš and Mladar 1996). Therefore, the predominant land use categories throughout the studied period were pastures, ploughfields, vineyards, orchards, and olive groves, accompanied by the prevailing land cover of shrubs and forests.

2.2 Materials and methods

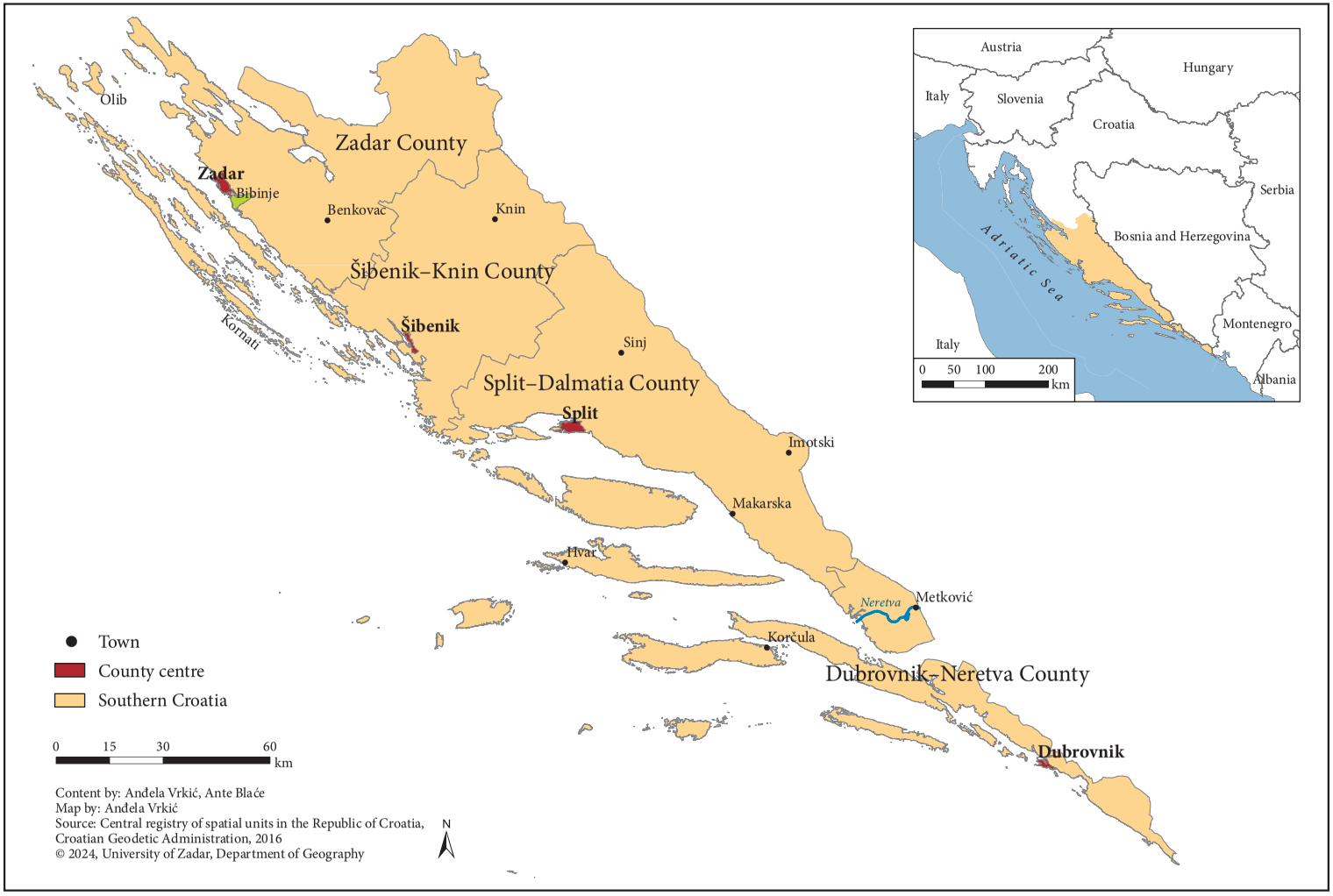
For the purpose of this research, various data sources related to land use during the 20th and 21st centuries were collected and compared. Due to variations in methodologies across different sources and time periods, some categories were adapted to suit better overall research.

For the period from 1900 to 1945, the main source used was the *Općinski rječnik za kraljevine i zemlje zastupane u Carevinskom vijeću* (C. KR. središnja … 1908). This source was processed based on the results of the national census conducted on December 31, 1900, reflecting the land use situation in 1896. Until 1950s, there were no more systematic census and data from the statistical reports on land use for 1921 and 1929 were utilized (Obrađena zemlja … 1924; Kolar Dimitrijević 1990). Subsequently, data from the Statistical yearbooks of the Federal/Socialist Republic of Yugoslavia during the 1945–1991 period were consulted (provided by Savezni zavod za statistiku). The Statistical yearbooks of Dalmatia (1976–1987) were used to illustrate land categories in 1970 and 1980 (provided by Zavod za društveno planiranje Zajednica Općina Split). It is important to note that data from the statistical yearbooks should be interpreted with caution

Table 1: Southern Croatia's counties, number of inhabitants and population density in 2021 (provided by the Croatian Bureau of Statistics 2022).

County	Area (km^2)	Population in 2021	Population density (inhabitants per km^2)
Zadar	3,646	160,340	44.0
Šibenik-Knin	2,984	96,624	32.4
Split-Dalmatia	4,540	425,412	93.7
Dubrovnik-Neretva	1,781	115,862	65.1
Total	12,951	798,238	61.6

Figure 1: Research area – Southern Croatia (Dalmatia) and localities mentioned in the text. ➤ p. 53


Olib
Zadar County
Zadar
Bibinje
Benkovac
Knin
Šibenik–Knin County
Šibenik
Kornati
Sinj
Split–Dalmatia County
Split
Imotski
Makarska
Hvar
Neretva
Metković
Korčula
Dubrovnik–Neretva County
Dubrovnik
Town
County centre
Southern Croatia
0 15 30 60
km
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Central registry of spatial units in the Republic of Croatia, Croatian Geodetic Administration, 2016
© 2024, University of Zadar, Department of Geography
N
Austria
Hungary
Italy
Slovenia
Croatia
Serbia
Bosnia and Herzegovina
Adriatic Sea
Montenegro
Italy
Albania
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since they are estimates, but they nonetheless provide valuable insights into land use trends during the latter half of the 20th century.

The Corine Land Cover (CLC) database, initiated by the European Union, was used to analyze land use in 1990, 2006, and 2018 as well as the changes that occurred during those periods. The creation of the CLC database relies on the visual interpretation of Landsat satellite images following the standard CLC methodology. The minimum mapping area is 25 hectares, with a 5-hectare threshold for the category cover change. The CLC nomenclature includes 44 categories at the EU level, divided into three levels, each representing a different land cover type (García-Álvarez et al. 2023).

The databases for all three years were retrieved from the Copernicus Land Monitoring Service website in geodatabase format. Subsequently, the data underwent geoprocessing within a GIS software (ArcGIS Desktop). Initially, the transformation of the projection coordinate system from ETRS 1989 LAEA to the projection coordinate reference system of the Republic of Croatia, HTRS96/TM, utilizing the *Project tool* was done. Following this step, the focus area of South Croatia, comprising four counties, was delineated by applying the *Clip tool*. To facilitate a clearer understanding of land use changes and enable comparison with previous periods, the original 36 CLC categories existing in Southern Croatia were reclassified into 8 distinct categories (Table 2). The reclassification was carried based on the methodology outlined by Kušan (2015). Subsequently, land cover and land use changes spanning from 1990 to 2006 and from 2006 to 2018 were analyzed and extracted using the *Intersect tool*.

All data and results were chronologically compared, displayed in tables and a graph, while the results from Corine Land Cover (for the period 1990–2018) were additionally depicted cartographically.

As a case study area, we selected Bibinje Municipality, located in the coastal part of Zadar County (Figure 1). We compared land cover of Bibinje derived from the Corine Land Cover (CLC) 2018 dataset with digital orthophoto (DOF) images from 2014–2016. The DOF is the official state map of Croatia and is produced at a scale of 1:5,000 for the entire territory of the country, with a pixel resolution of 0.50 meters. The CLC data was extracted from Figure 5, while the DOF images served as the basis for manual vectorization of land use categories using ArcGIS software.

Table 2: Reclassification of original Corine Land Cover categories.

Original CLC nomenclature	Reclassified categories
211 Non-irrigated arable land, 212 Permanently irrigated land, 242 Complex cultivation patterns, 243 Land principally occupied by agriculture, with significant areas of natural vegetation	Mixed agricultural land with natural vegetation
221 Vineyards	Vineyards
222 Fruit trees	Orchards
223 Olive groves	Olive groves
231 Pastures, 321 Natural grasslands	Pastures and grasslands
311 Broad-leaved forest, 312 Coniferous forest, 313 Mixed forest, 323 Sclerophyllous vegetation 324 Transitional woodland-shrub	Shrubs (macchia)* and forests**
111 Continuous urban fabric, 112 Discontinuous urban fabric, 121 Industrial or commercial units, 122 Road and rail networks and associated land, 123 Port areas, 124 Airports, 131 Mineral extraction sites, 132 Dump sites, 133 Construction sites, 141 Green urban areas, 142 Sport and leisure facilities, 322 Moors and heathland, 331 Beaches, dunes, sand, 332 Bare rocks, 333 Sparsely vegetated areas, 334 Burnt areas, 411 Inland marshes, 421 Salt marshes, 422 Salines, 423 Intertidal flats	Infertile land
511 Water courses, 512 Water bodies	Water bodies

* macchia = mediterranean shrubs

** forests = in different degradation stages

3 Results

3.1 Land use 1900–1945

In the period until 1918, the basic territorial units of the Kingdom of Dalmatia, which was part of the Austro-Hungarian Monarchy, were districts (Table 3). The primary source of the data at the beginning of the 20th century was the revision of land use from 1896 which, like other Austrian territories, was documented separately for the Kingdom of Dalmatia (Blaće 2015). The Dalmatian economy was mainly based on extensive agriculture, resulting in underdeveloped state of the region (Bralić and Kraljev 2011). Key activities were livestock farming in combination with arable farming, viticulture and olive growing (Ozimec et al. 2015).

The most common land use category was pastures, accounting for 46.1% of the area (Table 3). Traditionally, livestock farming was an important activity, especially in the hinterland (Matas 2015). Ploughfields covered the largest share of arable land, but in the districts of Šibenik, Split, Hvar, and Korčula, vineyards took precedence. Gardens represented 2.8% of the total area, a large figure primarily due to the 1896 revision's grouping of gardens with olive groves and orchards into a single category (Blaće 2015). Infertile land was calculated by subtracting all other categories from the total land area within each district, encompassing built-up areas, swamps, and karstified terrain. The Metković district was noteworthy for its infertile land, due to the predominantly swampy Neretva river delta at the time.

Table 3: Land use in Southern Croatia in 1900 (in ha) (Općinski rječnik . . . 1908).

		Arable land						
Districts	Total	Ploughfields	Gardens	Vineyards	Meadows	Pastures	Forests	Infertile
Zadar	143,503	15,655	4,864	10,354	1,285	75,619	30,600	5,126
Benkovac	158,086	20,507	422	2,240	586	61,305	66,080	6,946
Šibenik	96,229	7,917	4,455	14,099	212	51,450	15,094	3,002
Knin	140,807	21,711	534	4,488	1,554	73,082	36,289	3,149
Split	188,939	19,215	8,085	25,268	121	83,127	49,219	3,904
Sinj	133,615	17,904	308	629	5,098	69,373	37,915	2,388
Makarska	53,739	4,292	2,023	3,263	0	25,150	18,172	839
Imotski	64,641	9,544	242	1,192	704	37,392	14,120	1,447
Hvar	41,320	1,788	1,700	8,474	0	8,322	20,033	1,003
Metković	38,395	3,905	223	880	53	18,278	7,036	8,020
Korčula	59,023	1,001	4,477	6,386	0	12,783	33,262	1,114
Dubrovnik	77,748	5,827	5,958	2,854	23	35,047	26,084	1,955
TOTAL	1,196,045	129,266	33,291	80,127	9,636	550,928	353,904	38,893
Share (%)	100.0	10.8	2.8	6.7	0.8	46.1	29.6	3.3

Table 4: Land use in Southern Croatia in 1921 (in ha) (Obrađena zemlja . . . 1924).

		Arable land						
	Total	Ploughfields	Vineyards	Orchards	Meadows	Pastures	Forests	Infertile
	1,272,900	110,041	29,407	10,993	8,670	545,049	378,300	190,440
Share (%)	100.0	8.6	2.3	0.9	0.7	42.8	29.7	15.0

Land use in 1921 refers to the area of several newly established oblasts (territorial units) that mostly covered approximately same area as the abolished Kingdom of Dalmatia (Table 4). Notably, there was a considerable reduction in vineyard area, indicating significant vineyard loss due to the phylloxera epidemic at the end of the 19th century (Blaće et al. 2024), a phenomenon not apparent in the 1896 data. The most significant divergence lay in the infertile land categories between the two periods. In 1921, infertile land was computed by subtracting the sum of all other areas from the total. This notable increase is likely attributed to methodological differences in the census and spatial coverage. The 1896 revision was based on clearly specified tax zones, while 1921 lacked such clear spatial definitions.

The data for 1929 covered the area of Split and Dubrovnik oblasts within the Kingdom of Yugoslavia. This source differed methodologically from previous sources because land use data was obtained from the district-level data and each category's data was computed as absolute values from relative values. All categories were categorized as arable land, with forest and infertile land calculated by subtracting arable land from the total. Unlike 1921, the total land area was once again smaller. Due to the absence of forests, it is presumed that their area was included in the »residue« category, along with infertile land. Additionally, vineyard areas expanded, indicating a gradual recovery from the phylloxera epidemic (Table 5). Unlike 1900, where gardens held a larger share, this was not the case in 1929 primarily due to the fact that only gardens were listed here (probably along with some olive and fruit trees).

Pasture areas accounted for almost 50% of the area, especially in the hinterland and on the islands, reflecting the importance of livestock farming during the interwar period (Kolar-Dimitrijević 1990).

3.2 Land use 1945–1991

Following World War II, Croatia became a part of the Socialist Federal Republic of Yugoslavia. In Southern Croatia from the early 1900s until the 1960s, agriculture was the key economic activity. Predominantly rural populations often emigrated to coastal cities or abroad in search of improved living conditions. The 1960s marked a pivotal period when significant shifts began occurring, characterized by concurrent industrialization and land abandonment (Defilippis 2006).

Since 1960s, agricultural land in the Socialist Republic of Croatia experienced a slow but steady decline (Table 6). Ploughfields decreased while meadows and pastures expanded. These shifts were driven by land abandonment and the expansion of extensive land use (Malić 1983). Data from 1970 and 1980, encompassing the former Community of Municipalities of Split (new type of administrative units), indicated decreased agricultural areas across most categories, yet an increase in pastures, meadows, and grasslands, consistent with trends observed throughout the Socialist Republic of Croatia (Malić 1983). The total area of agricultural land in 1970 increased compared to 1960, mainly due to the inclusion of the pasture category. While reforestation processes due to land abandonment and depopulation were ongoing, extensive land use practices continued. The infertile land category primarily included fish ponds, reeds, and swamps, with a slightly increased share. The low share of infertile in 1970 and 1980 in comparison to 1960 is probably the consequence of different methodological procedures, and less of actual change.

Land use since 1990 was analyzed using the CLC methodology (Figure 2). All land categories related to agricultural production saw a considerable decrease in comparison to 1980, especially pastures and grasslands (Table 7). Shrubs and forests, which made up the largest share, were not limited to this specific category and were also present in the »mixed agricultural land with natural vegetation« category (Table 7). Due to the complex mosaic of small land plots where cultivated areas and Mediterranean vegetation intermingle, it is challenging to pinpoint their exact share. Nonetheless, it is assumed that shrubs and forests

Table 5: Land use in Southern Croatia in 1929 (in ha) (Kolar-Dimitrijević 1990).

	Total	Ploughfields	Gardens	Vineyards	Orchards	Meadows	Pastures	Swamps	Forests and infertile
	1,158,802	132,772	7,704	34,364	28,877	10,081	568,000	17,296	359,708
Share (%)	100.0	11.5	0.7	3.0	2.5	0.9	49.0	1.5	31.0

occupied at least 50% of these plots. Although vineyards, orchards, and olive groves also declined, they were also embedded within the mixed agricultural land with natural vegetation category. The extent of these categories was recorded only if they exceeded 25 hectares in size. The largest areas of olive groves, due to climatic conditions, were located on the coastline and islands. Vineyards were also cultivated in hinterlands, utilizing large acres of arable land, like in the vicinity of the town of Imotski. Ploughfields experienced a pronounced decline, but due to their inclusion in complex cultivation patterns, their total area could not be precisely quantified either. Infertile land, despite comprising a broader range of CLC categories, primarily consisted of urban (built-up) areas along the coastline and rocky karstic terrains.

3.3 Land use since 1991

This period commenced with destruction and population migration during the Croatian War of Independence (1991–1995), leading to large areas of land remaining uncultivated. After the war concluded, the processes of urbanization and coastal development continued, with mainly adverse demographic and economic consequences for the islands and the hinterland.

According to the CLC 2006 data, there were pronounced changes in land use in the whole research area compared to 1990 (Figure 3). Notably, the share of mixed agricultural land with natural vegetation, olive groves, shrubs and forests increased, while other land use categories experienced a decline (Table 8).

Table 6: Land use in Southern Croatia in 1960, 1970 and 1980 (in ha) (provided by the Croatian Bureau of Statistics).

		Arable land						
Year	Total	Ploughfields	Vineyards	Orchards	Meadows	Pastures	Forests	Infertile
1960	1,204,714	130,613	39,165	30,807	9,888	455,762	477,245	61,234
Share (%)	100.0	10.8	3.3	2.6	0.8	37.8	39.6	5.1
1970	1,205,818	123,200	32,502	27,543	8,271	548,089	459,777	6,436
Share (%)	100.0	10.2	2.7	2.3	0.7	45.5	38.1	0.5
1980	1,163,992	118,244	31,086	25,100	8,669	517,493	453,186	10,214
Share (%)	100.0	10.2	2.7	2.2	0.7	44.5	38.9	0.9

Table 7: Land use in Southern Croatia in 1990 (calculated from Corine Land Cover).

Category	Area (ha)	Share (%)
Mixed agricultural land with natural vegetation	243,474	18.7
Vineyards	15,767	1.2
Orchards	5,395	0.4
Olive groves	17,283	1.3
Pastures and grasslands	252,343	19.4
Shrubs (macchia) and forests	660,648	50.8
Infertile land	97,190	7.5
Water bodies	8,778	0.7
TOTAL	1,300,878	100.0

Figure 2: Land use in Southern Croatia in 1990. ➤ p. 58


Zadar
Šibenik
Split
Dubrovnik
Land use
Mixed agricultural land with natural vegetation
Vineyards
Orchards
Olive groves
Pastures and grasslands
Shrubs and forests
Infertile land
Water bodies
0 15 30 60 km
N
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Corine Land Cover, Copernicus Land Monitoring Service, 2020
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An interesting shift occurred in the category of olive groves, with an increase in their area, primarily due to more precise categorization compared to 1990. The shift in agricultural land was characterized not by an increase in complex cultivation patterns, but by land predominantly characterized as mixed arable land with substantial areas of natural vegetation. This change reflected the continued progression of vegetation succession, leading to an increase in the share of shrubs and forests. This was especially so in the hinterlands of Zadar and Šibenik-Knin Counties, heavily affected by war. Simultaneously, a decrease in the share of pastures and grasslands was likely due to the same reasons.

The total change in 2006 compared to 1990 was 160,198 ha. The ten largest changes accounted for 86.5% of the total changes (Figure 4, Table 9). The most prominent change included the transition from shrubs and forests to mixed agricultural land with natural vegetation. This transformation was not driven by intensified agriculture but rather the improved technical capabilities, especially satellite imagery, which allowed for a clearer distinction between areas previously categorized as shrubs and forests in 1990 and those more accurately classified as mixed agricultural land with natural vegetation in 2006. This process was evident on Olib Island (in Zadar County), where a substantial portion of shrubs and forests transformed into land primarily used for agriculture, with large areas of natural vegetation (Figures 4). Notably, native and non-native plants colonized areas formerly occupied by gardens, vineyards, and olive groves (Faričić and Magaš 2009).

Table 8: Land use in Southern Croatia in 2006 (calculated from Corine Land Cover).

Category	Area (ha)	Share (%)
Mixed agricultural land with natural vegetation	254,085	19.5
Vineyards	12,939	1.0
Orchards	4,391	0.3
Olive groves	20,212	1.6
Pastures and grasslands	248,731	19.1
Shrubs (macchia) and forests	662,205	50.9
Infertile land	90,628	7.0
Water bodies	8,770	0.7
TOTAL	1,301,960	100.0

Table 9: Largest land use changes in Southern Croatia 1990–2006 (calculated from Corine Land Cover).

Category change	Area (ha)	Share (%)
Shrubs and forests → Mixed agricultural land with natural vegetation	24,964	15.6
Pastures and grasslands → Shrubs and forests	24,404	15.2
Mixed agricultural land with natural vegetation → Shrubs and forests	17,995	11.2
Shrubs and forests → Pastures and grasslands	16,857	10.5
Infertile land → Pastures and grasslands	16,179	10.1
Infertile land → Shrubs and forests	9,241	5.8
Pastures and grasslands → Mixed agricultural land with natural vegetation	8,947	5.6
Shrubs and forests → Infertile land	7,786	4.9
Mixed agricultural land with natural vegetation → Infertile land	6,702	4.2
Pastures and grasslands → Infertile land	5,564	3.5

Figure 3: Land use in Southern Croatia in 2006. ► p. 60
Figure 4: Land use changes in Southern Croatia 1990–2006. ► p. 61


Zadar
Šibenik
Split
Dubrovnik
Land use
Mixed agricultural land with natural vegetation
Vineyards
Orchards
Olive groves
Pastures and grasslands
Shrubs and forests
Infertile land
Water bodies
0 15 30 60 km
N
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Corine Land Cover, Copernicus Land Monitoring Service, 2020
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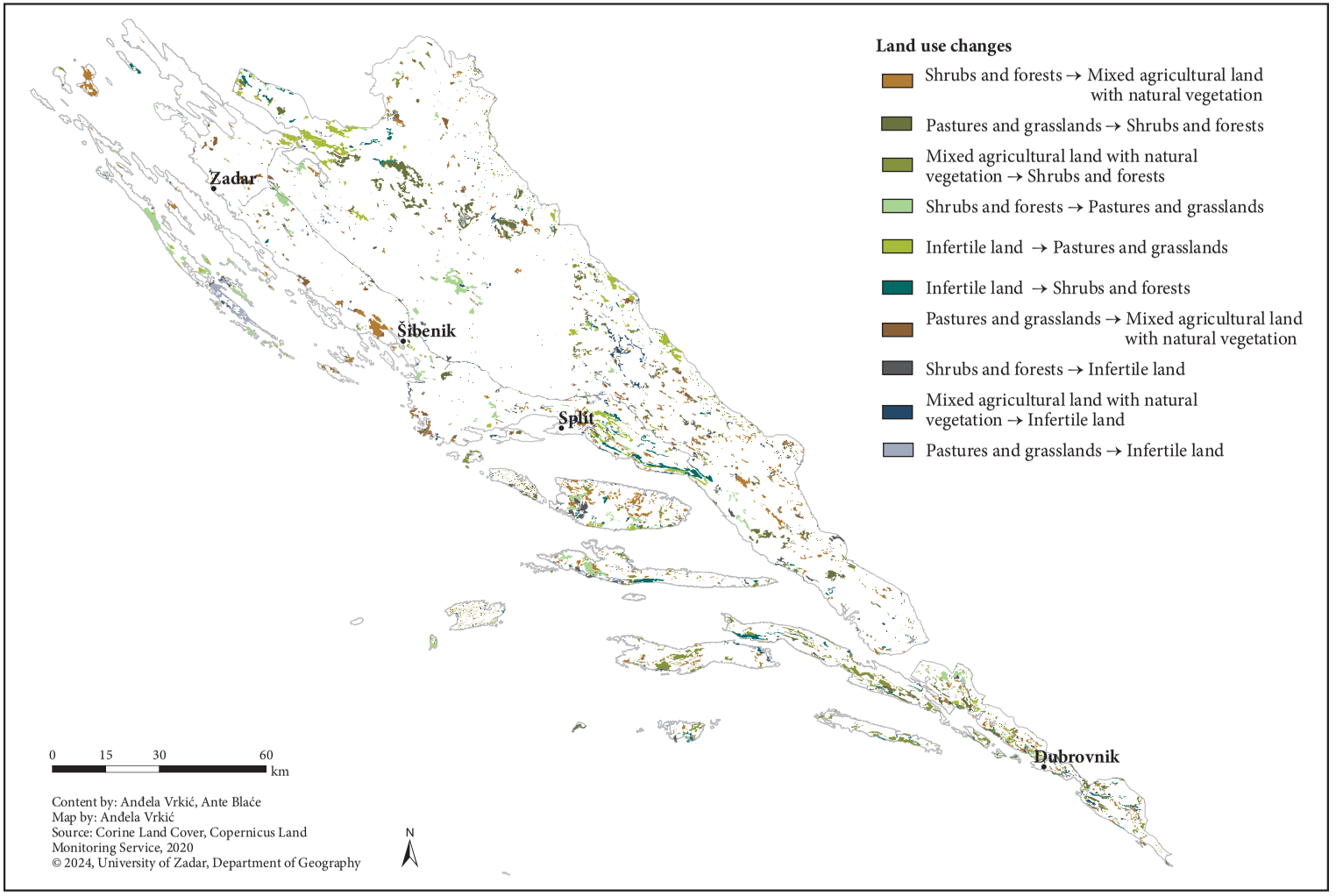
Land use changes
Shrubs and forests → Mixed agricultural land with natural vegetation
Pastures and grasslands → Shrubs and forests
Mixed agricultural land with natural vegetation → Shrubs and forests
Shrubs and forests → Pastures and grasslands
Infertile land → Pastures and grasslands
Infertile land → Shrubs and forests
Pastures and grasslands → Mixed agricultural land with natural vegetation
Shrubs and forests → Infertile land
Mixed agricultural land with natural vegetation → Infertile land
Pastures and grasslands → Infertile land
Zadar
Šibenik
Split
Dubrovnik
0 15 30 60
km
N
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Corine Land Cover, Copernicus Land Monitoring Service, 2020
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The shift from pastures and grasslands to shrubs and forests was most noticeable in the hinterland of Zadar and Šibenik-Knin Counties whereas changes from mixed agricultural land with natural vegetation to shrubs and forests were more widespread in the broader area of Dubrovnik-Neretva County. While the changes in Zadar and Šibenik-Knin were expected due to the continuous land abandonment and reforestation, the changes in Dubrovnik-Neretva reflected not only these trends but also the methodological challenges of distinguishing between these two categories. Changes of pastures and grasslands to infertile land were most pronounced on the Kornati Islands (Figure 4) where natural grasslands were transformed into areas with sparse vegetation. Given the rocky terrain and limited vegetation on the Kornati Islands, this categorization was appropriate, most likely as a result of improved classification.

The socio-economic processes that took place at the end of the 20th century continued in the early 21st century. The service sector, particularly tourism, became the main economic activity, with a strong presence along the coast and islands (Kapusta and Wiluś 2017). Simultaneously, the hinterland began developing a tourist-oriented offer only in recent years, centred on vacation homes (Ralica and Blaće 2021).

Compared to 2006, the vineyards and forests in 2018 had a smaller decrease in share, while the orchards, olive groves, and infertile land categories recorded an increase (Table 10). The increase in orchards and olive groves resulted from more precise categorization in comparison to mixed agricultural land with natural vegetation. Moreover, the expansion of crops producing high-value products such as olive oil and wine contributed to this increase. This was again noticeable along the coastline and on the islands within Split-Dalmatia and Dubrovnik-Neretva Counties. Apart from favourable physical conditions, these areas have a long tradition of cultivation, but the commercial aspect emerged only after Croatia's accession to the EU. The growth in the infertile land category was primarily associated with burnt areas, covering 14,405 hectares in 2018 (Figure 5).

Land use changes from 2006 to 2018 (Figure 6) were less extensive than in the preceding period. These changes encompassed 62,324 hectares, with the ten largest changes accounting for 83.9% of the total change (Table 11). The most substantial shift involved the transition from shrubs and forests to infertile land. This change primarily occurred in Zadar and Šibenik-Knin Counties, with a smaller portion taking place in Split-Dalmatia County (Figure 6). These transitions were mainly attributed to areas affected by wildfires. Additionally, a minor portion of this change was associated with the ongoing construction of the A1 highway in Split-Dalmatia and Dubrovnik-Neretva Counties. Wildfires are result of complex human-nature interactions and recognised as important driver of land cover in Mediterranean environments (Darques 2016). The findings regarding wildfire occurrences in Southern Croatia reveal that grasslands and shrubs (macchia) are the most susceptible vegetation types to fires, attributed to socio-demographic shifts such as agricultural abandonment and the growing impact of tourism, as well as climatic extremes such as heatwaves and droughts (Pavlek et al. 2017; Jajtić et al. 2019; Blaće et al. 2024). Based on our research, shrubs (including forests) and grasslands covered nearly 70% of Southern Croatia in 2018, indicating large areas vulnerable to wildfires.

Table 10: Land use in Southern Croatia in 2018 (calculated from Corine Land Cover).

Category change	Area (ha)	Share (%)
Mixed agricultural land with natural vegetation	247,240	19.0
Vineyards	11,694	0.9
Orchards	6,185	0.5
Olive groves	25,116	1.9
Pastures and grasslands	249,073	19.1
Shrubs (macchia) and forests	643,295	49.4
Infertile land	110,329	8.5
Water bodies	9,176	0.7
TOTAL	1,302,109	100.0

Figure 5: Land use in Southern Croatia in 2018. ► p. 63


Zadar
Šibenik
Split
Dubrovnik
Land use
Mixed agricultural land with natural vegetation
Vineyards
Orchards
Olive groves
Pastures and grasslands
Shrubs and forests
Infertile land
Water bodies
0 15 30 60 km
N
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Corine Land Cover, Copernicus Land Monitoring Service, 2020
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3.4 Case study – land use in Bibinje

The land use pattern in Bibinje reflects the characteristics typical for other coastal parts of Southern Croatia. Residential areas and tourist facilities are predominantly situated along the coastline, while the hinterland comprises primarily agricultural land, pastures, grasslands, shrubs and forests (Figure 7). Comparing CLC data with the DOF images (Figure 8, Table 12) reveals a notable difference in details. Due to the varying scales of 1:100,000 for CLC and 1:5,000 for DOF 2014–2016, this discrepancy is expected. However, despite this difference, the generalization of categories in the CLC data was deemed appropriate. Although CLC failed to explicitly classify pastures and grasslands, this can be attributed to the vegetation's resemblance to shrubs and forests, into which they were categorized. Similarly, vineyards and olive groves went undetected but often fell under the category of mixed agricultural land with natural vegetation. Additionally, some areas identified as vineyards, olive groves, and mixed agricultural land with natural vegetation were erroneously classified as infertile land. While CLC data may not be suitable for detailed analyses of smaller areas such as Bibinje, encompassing 1,446 hectares, it can still be valuable for studying larger regions like Southern Croatia. It seems that further advancement in remote sensing and the usage of UAVs (unmanned aerial vehicle) for small areas will yield more reliable results in land cover assessment. Comparison with cadastral maps is possible but it heavily depends on the alignment of the cadastral data with on-ground conditions, which is, for now, a rare case in Croatia.

The previously explained phenomena of shrub and forest expansion, as well as the increase in infertile (built-up) land, are visible in Figure 8. Over a 50-year period agricultural land has been decreasing, mirroring trends seen in many parts of Southern Croatia.

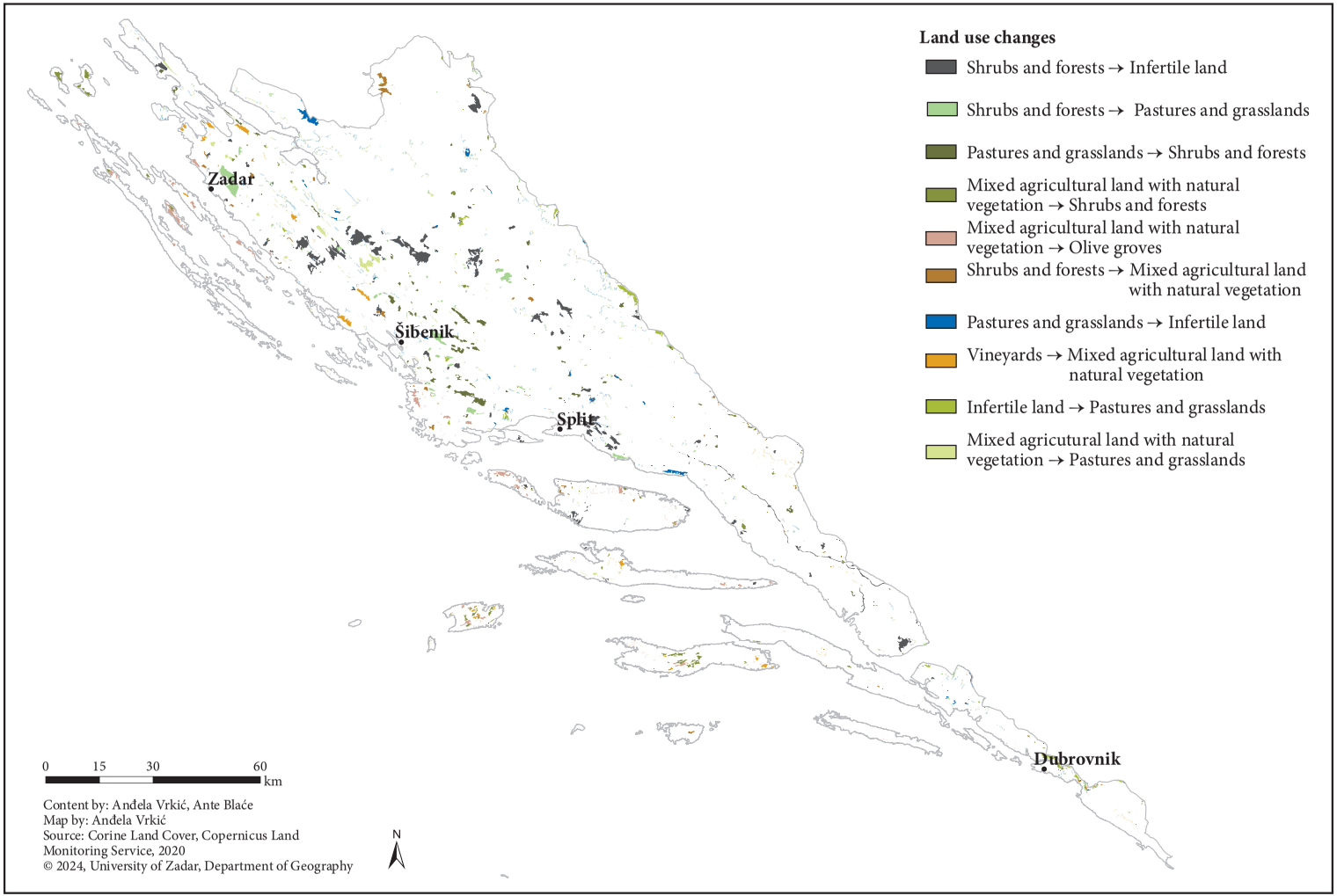
Table 11: Largest land use changes in Southern Croatia 2006–2018 (calculated from Corine Land Cover).

Category change	Area (ha)	Share (%)
Shrubs and forests → Infertile land	18,980	30.5
Shrubs and forests → Pastures and grasslands	6,195	9.9
Pastures and grasslands → Shrubs and forests	6,136	9.8
Mixed agricultural land with natural vegetation → Shrubs and forests	4,120	6.6
Mixed agricultural land with natural vegetation → Olive groves	4,053	6.5
Shrubs and forests → Mixed agricultural land with natural vegetation	3,052	4.9
Pastures and grasslands → Infertile land	2,629	4.2
Vineyards → Mixed agricultural land with natural vegetation	2,554	4.1
Infertile land → Pastures and grasslands	2,423	3.9
Mixed agricultural land with natural vegetation → Pasture and grasslands	2,162	3.5

Table 12: Land use in Bibinje (calculated from Corine Land Cover).

Category	DOF 2014-16 Area (ha)	Share (%)	CLC 2018 Area (ha)	Share (%)
Mixed agricultural land with natural vegetation	181	12.5	559	38.6
Vineyards	21	1.5	0	0.0
Olive groves	56	3.9	0	0.0
Pastures and grasslands	558	38.6	0	0.0
Shrubs and forests	401	27.7	514	35.5
Infertile land	228	15.8	373	25.8
TOTAL	1446	100.0	1446	100.0

Figure 6: Change in land use in Southern Croatia 2006–2018. ➤ p. 65
Figure 7: Land use in Bibinje. ➤ p. 66
Figure 8: Aerial photos of Bibinje for 1968 (top) and 2016 (bottom). ➤ p. 67


Land use changes
Shrubs and forests → Infertile land
Shrubs and forests → Pastures and grasslands
Pastures and grasslands → Shrubs and forests
Mixed agricultural land with natural vegetation → Shrubs and forests
Mixed agricultural land with natural vegetation → Olive groves
Shrubs and forests → Mixed agricultural land with natural vegetation
Pastures and grasslands → Infertile land
Vineyards → Mixed agricultural land with natural vegetation
Infertile land → Pastures and grasslands
Mixed agricutural land with natural vegetation → Pastures and grasslands
Zadar
Šibenik
Split
Dubrovnik
0 15 30 60
km
N
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Corine Land Cover, Copernicus Land Monitoring Service, 2020
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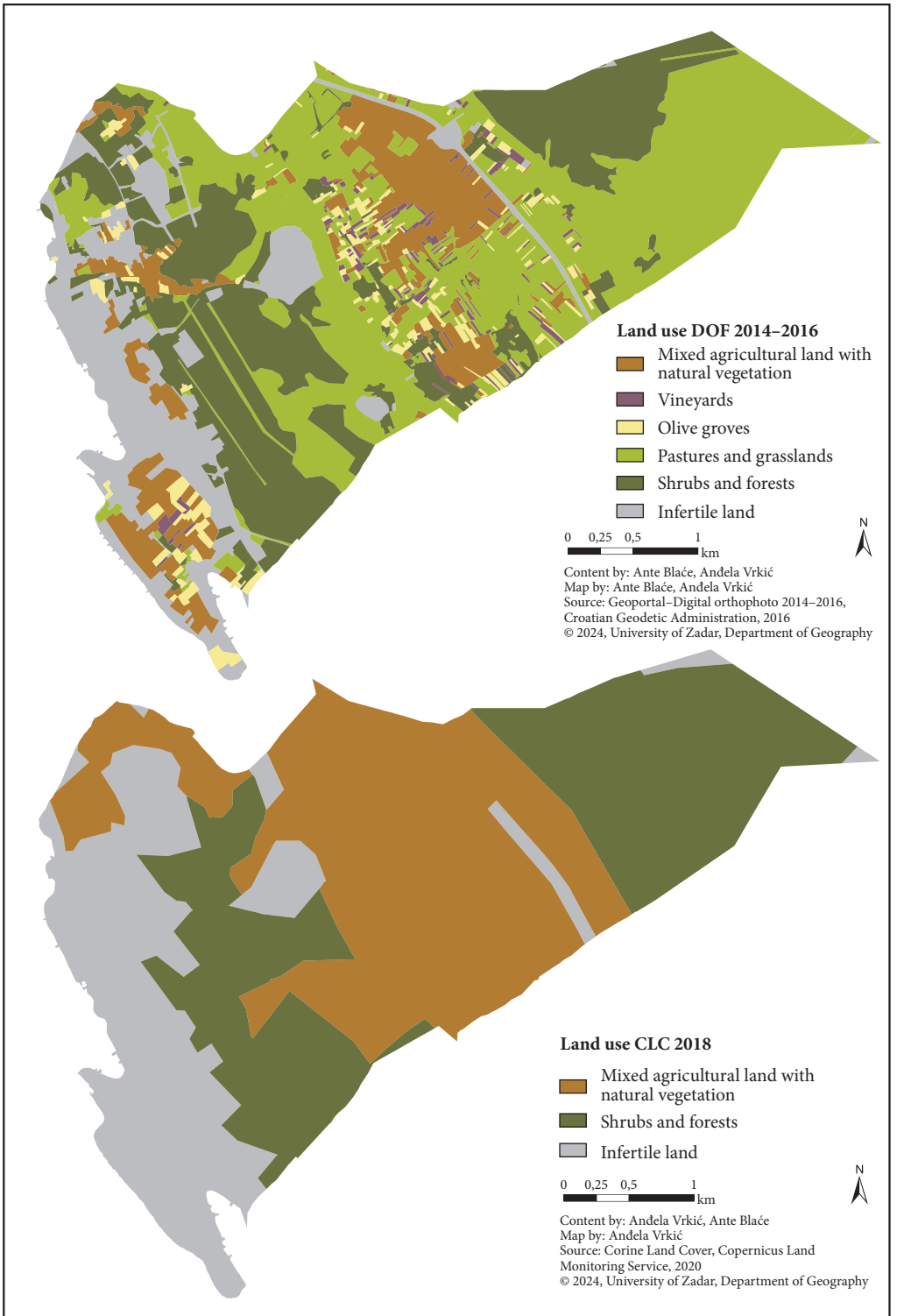
Land use DOF 2014–2016
Mixed agricultural land with natural vegetation
Vineyards
Olive groves
Pastures and grasslands
Shrubs and forests
Infertile land
0 0,25 0,5 1
km
N
Content by: Ante Blaće, Anđela Vrkić
Map by: Ante Blaće, Anđela Vrkić
Source: Geoportal–Digital orthophoto 2014–2016, Croatian Geodetic Administration, 2016
© 2024, University of Zadar, Department of Geography
Land use CLC 2018
Mixed agricultural land with natural vegetation
Shrubs and forests
Infertile land
0 0,25 0,5 1
km
N
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Corine Land Cover, Copernicus Land Monitoring Service, 2020
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Bibinje Municipality
0 0.25 0.5 1
km
N
Map by: Anđela Vrkić, Ante Blaće
Source: Geoportal, Digital ortophoto 2014–2016
Croatian Geodetic Administration, 2016
© 2024, University of Zadar, Department of Geography
GEOPORTAL
Bibinje Municipality
0 0.25 0.5 1
km
N
Map by: Anđela Vrkić, Ante Blaće
Source: Geoportal, Digital ortophoto 2014–2016
Croatian Geodetic Administration, 2016
© 2024, University of Zadar, Department of Geography

4 Discussion

In the first research period (1900–1945), Southern Croatia experienced pronounced changes in land use driven by political, economic, and social factors. The devastating impact of phylloxera led to a substantial loss of vineyards. The overcrowding of agrarian areas fuelled emigration from the islands and the hinterland to abroad. The second period (1945–1991) witnessed the profound alterations in land use, coinciding with major political and economic transformations. With the integration into socialist Yugoslavia, economic development in Southern Croatia concentrated around the coastal urban centers (Vresk 1985; Matas 2015). The process of land abandonment, initiated during the interwar period, accelerated from the 1960s onwards due to industrialization and partially collectivization of the land (Defilippis 2006). The third period (from 1991) began with the destructive impact of war, further exacerbating the processes of the previous era. Coastal cities continued to develop, while the islands and hinterland experienced a decline in both population and cultivated land. Political factors were manifested through the consequences of the war and the transition to a market economy. Economically, littoralization prevailed, leaving the hinterland at the periphery of economic development. Nowadays tourism is especially strong driver of land use changes, reflected in construction of numerous apartments for renting (Opačić 2012).

Changes in the land use categories by selected years clearly indicate a substantial decline in agricultural land often replaced by shrubs and forests (Figure 9). Vineyards, devastated by phylloxera, never fully recovered, leading to the cultivation of other crops (Faričić 2012). The exceptional increase in the infertile land category in 1921 can be attributed to different data collection methodologies rather than a drastic surge in built-up areas, swamps, etc.

Pastures and grasslands made up the largest share until the 1960s, started to decline. The expansion of olive trees and orchards was not only due to the more efficient detection of certain land categories through the CLC methodology but also due to increased cultivation. This was fuelled by subsidies in agriculture

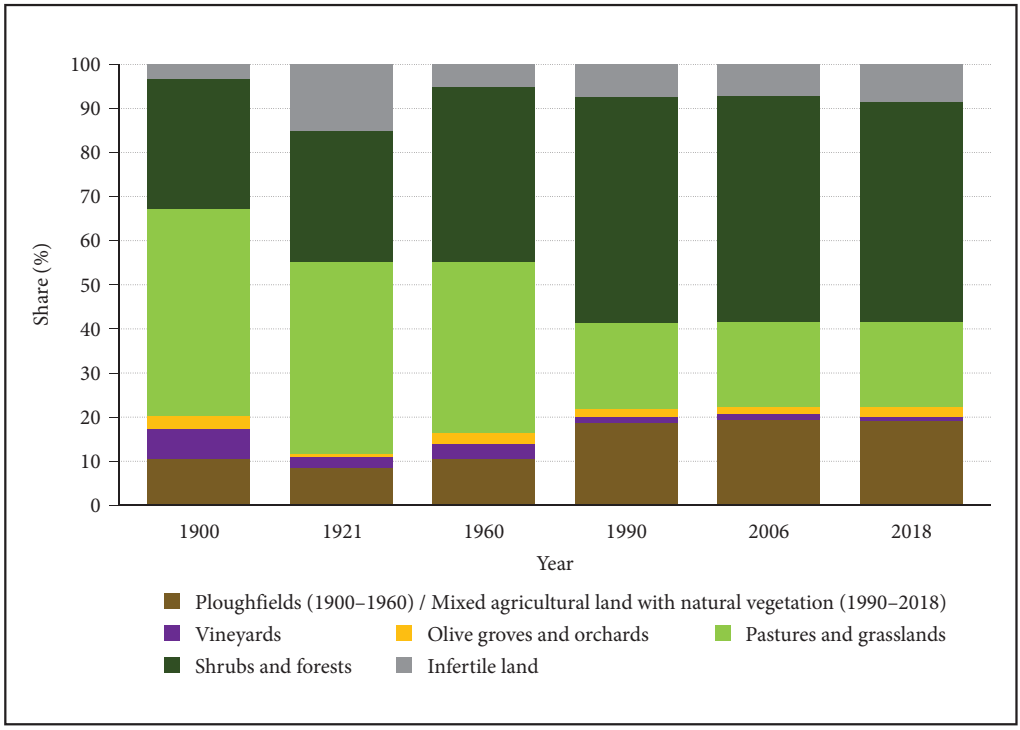

Figure 9: Share of land use categories in Southern Croatia 1900–2018.

(Očić et al. 2018), especially after Croatia joined the EU in 2013. Despite the apparent increase in ploughfields since 1990, it primarily consisted of mixed agricultural land with natural vegetation, where at least 50% was dominated by vegetation succession. Consequently, most categories during the studied period experienced reductions in their areas, while shrubs and forests expanded thus supporting the main hypothesis of this research.

Land use/land cover change research from other Mediterranean countries indicate primarily the expansion of shrubs and forests and the abandonment of agricultural areas due to social and economic factors (Peñuelas and Sardans 2021). Although the Mediterranean region had only a 10% share of forests in 2015, the distribution of forests varied by country. For instance, Israel had a 6% forest share, while Slovenia had 61% (Nocentini et al. 2022) as a consequence of different natural conditions. Forest expansion is evident, with Slovenia seeing its forested area grow from 39% in the first half of the 19th century to 61% in 2015 (Gabrovec and Kumer 2019).

Regionally, specific trends have emerged. Research conducted between 1960 and 2000 in Mediterranean parts of Italy (Falcucci et al. 2007) indicated the cessation of pasture grazing, reforestation, and the growth of urban areas, driven by tourism development and demographic growth. Greek island studies (Tzanopoulos and Vogiatzakis 2011; Schaich et al. 2015; Kefalas et al. 2019; Dimopoulos and Kizos 2020; Kefalas et al. 2020) indicated two major patterns: an increase in forests and scrublands and urbanization in lowland and coastal areas, primarily due to tourism. This is very similar to the processes in Southern Croatia.

In the Mediterranean Alicante region in Spain approximately one-third of agricultural land was abandoned and turned into macchia and urban areas between 1950s and 2000s. Forested areas doubled in size although their total area remained small (Symeonakis et al. 2007). Catalonia faced a long-term shift from deforestation and overexploitation during the 19th and first half of the 20th century followed by subsequent forest transitions driven by land abandonment since the 1950s (Cervera et al. 2019).

Abadie et al. (2018) found that in the French Mediterranean region, forest recovery occurred from 1860 to 2010 due to the abandonment of traditional agriculture and pastoralism. These changes were more prominent on remote and unproductive land, while accessible urban areas witnessed an increase in built-up areas. Gabrovec and Kumer (2019) and Gabrovec et al. (2020) concluded that the most significant land-use changes in Slovenia took place in the second half of the 20th century, driven by industrialization. Slovenia's accession to the EU in 2004 introduced common policies that influenced land use, with specificities like land fragmentation and dispersed settlements. Bičík et al. (2019) conducted somewhat similar study to this one, comparing land use changes in Czechia and Slovenia over the last two centuries, indicating much larger shares of arable land compared to Southern Croatia, reflecting the different physical and social characteristics of the study areas.

Research on land use changes in Southern Croatia also pointed to certain difficulties with data sources. The oldest source, Općinski rječnik (C. KR. središnja … 1908) turned out to be the most reliable. All other data sources up to CLC 1990 mainly relied on estimates and should be interpreted cautiously. However, they indicate certain land use trends that have occurred over the last 120 years. While the CLC methodology for 1990, 2006, and especially 2018 (benefiting from advancements in remote sensing) provided more reliable data on land use categories and changes between periods, it is not entirely precise database. Due to its mapping methodology, numerous changes in areas smaller than 5 hectares couldn't be adequately represented, leading to some generalization of results. This is expected because the CLC is by definition a generalized database whose primary task is the comparison of land use in Europe (Aune-Lundberg and Strand 2021). Another issue is related to mixed classes. Mixed classes tend to lack clear-cut information regarding the state of the land surface, necessitating researchers to carefully weigh the results. Although the reliability of CLC data at the sub-national level may raise concerns, its usage becomes justifiable in cases where other data sources are unavailable (Popovici et al. 2013). These issues with CLC are evident in our research, particularly concerning specific categories. For instance, the category of pastures and grasslands represents predominantly grasslands due to the limited extent of cattle breeding in Southern Croatia (Ozimec et al. 2015). Delineating between shrubs and forests poses a challenge, as it reflects agricultural abandonment, further complicating the differentiation between the two vegetation types. The category of mixed agricultural land with natural vegetation probably stands as the most intricate, embodying a mosaic of utilized and abandoned land, exacerbated by the 25 ha threshold. These dynamics and transitions are observable across the study area, particularly in hinterlands, mountainous regions, and sparsely populated areas within Zadar and Split-Dalmatia counties (Figure 4 and Figure 6). Southern Croatia, and

especially its rural areas, has dispersed settlements and diverse vegetation. Due to this, EU countries are developing national LULCC databases in large scale to provide reliable information for making political and professional decisions and for citizen's personal matters (Foški et al. 2018).

Corine Land Cover still remains the most dependable source for land classification in Croatian territory. Nonetheless, the implementation of the new LIFE CROLIS (CROatian Land Information System) will improve data integration and processing regarding land use and land cover from diverse sources. Except for management on different levels, it should also serve as a tool for reporting and calculating greenhouse gas emissions and sinks from the land use, land conversion and forestry sector (LULUCF). It is expected that LIFE CROLIS will become operational sometime after 2024.

5 Conclusion

In this research, we explored land use changes within Southern Croatia spanning from the early 20th century to 2018. Our analysis is structured into three distinct periods (1900–1945, 1945–1991, and post-1991) to align with the key socio-economic changes that unfolded throughout the 20th century. Over the course of the 20th century, the region witnessed profound transformations in land use. These changes were driven by a complex interaction of social and economic factors. The continuous advancement of remote sensing and the availability of comprehensive databases, offer promising opportunities for ongoing and more precise monitoring of land use trends in Southern Croatia and elsewhere. Despite the limitations of this study, it contributes to our better understanding of the intricate issues related to land use and landscape changes in the context of Croatia and the Mediterranean. Namely, the studied trends are more important than the precise quantification of land categories in each period because they are reflection of numerous social, economic, and environmental changes and problems that affect them.

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