

## Article

# Understanding of Forest Cover Dynamics in Traditional Landscapes: Mapping Trajectories of Changes in Mountain Territories (1824–2016), on the Example of Jeleniogórska Basin, Poland

Justyna Jaworek-Jakubska <sup>1,\*</sup> , Maciej Filipiak <sup>1</sup>  and Anna Napierała-Filipiak <sup>2</sup> 

<sup>1</sup> Institute of Landscape Architecture, The Faculty of Environmental Engineering and Geodesy, Wrocław University of Environmental and Life Sciences, ul. Grunwaldzka 55, 50-357 Wrocław, Poland; maciej.filipiak@upwr.edu.pl

<sup>2</sup> Institute of Dendrology, Polish Academy of Sciences, Laboratory of Ecology, ul. Parkowa 5, 62-035 Kórnik, Poland; annafil@man.poznan.pl

\* Correspondence: justyna.jaworek@upwr.edu.pl; Tel.: +48-71-320-55-75

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**Abstract:** Though on a global scale, for ecological reasons, increased forest cover is universally regarded as positive, on a local scale, the reforestation of arable land may pose threats to cultural landscapes by removing characteristic landscape features. Particularly vulnerable are marginal rural areas, e.g., mountain regions, where most traditional land use systems have survived and which are subject to the most spectacular land use change. The purpose of this article is to draw attention to the issue of the management of forest cover in historical cultural landscapes in mountain territories in Poland within the context of widespread land use change in Eastern Europe. Land cover data were obtained from historical and contemporary aerial photographs, as well as topographic maps from five time points between 1824 and 2016. The study was conducted by means of spatio-temporal forest cover trajectory analysis (LCTA), transition and time–depth analysis, and land cover change calculations that were made by means of ArcGIS. Our research indicates that the rate of change has risen considerably in the last two decades, and the current share of forest cover is much bigger than that reflected in the official data. Eight principal forest cover trajectory types were identified. The biggest area is occupied by woodland of long-term stability. Another large group is constituted by forests created on the basis of arable land and grassland as a result of simple conversion at one point in time, mainly in the years 1824–1886 and 1939–1994. At the same time, a sizeable group is made up by areas that have been subject to unplanned cyclical or dynamic changes during various periods. A very important group is comprised new forests that were created in 1994–2016, predominantly as a result of natural succession, that are often not included in official land classifications. The constant expansion of woodlands has led to a shrinking of historical former coppice woodlands. This indicates that the current landscape management mechanisms in Poland are inadequate for protecting the cultural landscape. The barriers include the lack of intersectoral cooperation and the overlooking of the historical context of landscapes. The present situation calls not only for verification of the existing forest policy but also for increasing the role and engagement of local communities, as well as making comprehensive local development plans, all of which may be helped by the findings of our study and of similar research.

**Keywords:** forest cover dynamic; land cover change; landscape trajectories; traditional landscapes; mountain territories

## 1. Introduction

Change in global forest cover has become a public matter that is being broadly discussed within the scientific community because it considerably affects ecosystem services, including biodiversity richness, climate regulation, carbon storage, and water supplies [1–6]. Though the entire world's forest area is steadily shrinking (mainly in developing countries), forest cover is growing in some regions of Asia, North America, and Europe as a result of broad afforestation programs and the natural expansion of forest in abandoned agricultural land [7–10]. Though increased forest cover is universally regarded as positive for ecological reasons [11,12], on a regional and local scale, the reforestation of arable land of low productivity may lead to smaller biodiversity and pose a threat to cultural landscapes, e.g., by removing characteristic landscape elements or deteriorating them through a lack of management [13–18]. Marginal rural areas (mountain territories, upland areas, and remote areas), where most traditional land use systems have survived, are particularly susceptible to the process [19]. The co-existing forest and agricultural practices have contributed to the creation of a characteristic land use form and biological diversity closely connected to complex landscape patterns [20,21]. Those are areas with diverse, small scale, and clearly structured patterns of land use that are typical of traditional landscapes [22]. They possess distinct identities linked to the character of the place or region [23].

Because of a rapid shrinking of historical cultural landscapes in Europe, interest has been growing in biocultural values in sustainable forest management (SFM) [17,24]. The term 'biocultural heritage,' introduced by the National Board of Forestry in 1999 (since 2006: The Swedish Forest Agency), was a reaction to the approach, particularly to forests, that had been perpetuated during the preceding decades and that overlooked the link between nature and culture [25]. Today, it is commonly accepted that biological and cultural diversity in Europe results from a combination of historical and ongoing environmental and land use processes and cultural heritage [20]. Consequently, studies dealing with sustainable forest management (SFM) contain more information about the history and traditional land use in a given area. A special role in this has been performed by the Ministerial Conferences on the Protection of Forests in Europe (MCPFE), and some decisive steps towards the inclusion of social and cultural values in SFM were the commitments of the Vienna Summit (2003) (which ended with the adoption of Vienna Resolutions [26]), as well as the meetings in Sweden (Sunne, 2005) and in Italy (Florence, 2006), which confirmed that the cultural values connected with forest landscape not only protect biodiversity but can also contribute to the development of rural areas [24]. The signatory states agreed to identify and assess local cultural heritage related to forestry and woodland landscapes, as well as to include biocultural heritage in forest and landscape management strategies to preserve the identity of different European forest regions [17,24].

Among the detailed MCPFE recommendations, apart from documenting cultural values and gathering information about forest history, attention is drawn to the need to monitor the processes of transformation [17,27]. Landscape change analysis is problematic because it is only an arbitrary expression of the available spatial data sources, the choice of spatial and temporal scales of the data, and analysis [28]. Despite all this, the systematic long-term spatio-temporal analysis of land cover/use change (over a period of several decades or even centuries) may constitute a satisfactory way of assessing landscapes. Such a possibility is offered by the landscape trajectory analysis (LCTA), which was developed by K  yh   and Sk  nes [29]. The authors, going beyond a simple description of changes based on a series of separate time slices, proposed a spatio-temporal framework indicating paths or trajectories of the elements that make up landscapes [30]. This enables a better description of changes that are very rarely simple conversions from one cover type to another, as they are rather continuous transitions of land through cyclical, linear, or reversible processes [31]. LCTA based on evaluating past landscape patterns and processes in the context of the present-day landscape allows for the illustration of changes as a dynamic process and not only as the states of landscapes patterns at different moments in time to be described [28,29,32]. LCTA was developed to assess landscape character and is used to support the management and conservation of valuable landscapes [29]. LCTA is widely used not only for assessing land use and land cover changes, e.g., [23,33–37], but also for examining valuable biotopes

and species (e.g., [28,38–40]), examining forest area changes (e.g., [31,41–46]), and for managing cultural landscape (e.g., [47,48]).

Until now, few European countries (e.g., the Netherlands, Scotland, Germany, Sweden, Estonia, Finland, and Latvia) have started to evaluate forest landscapes and their cultural values. The least known are still forest landscapes in Eastern Europe [17]. Though today forests are regarded as the dominant natural habitat across most of Europe [49], they have in fact been subject to considerable changes, which are reflected in their current degree of naturalness. Only 4% of forests are qualified as ‘undisturbed by men’, while the rest are forests with traces of intensive management (plantations: 9%) or less intensive management (semi-natural: 87%) [50]. Around 1800, intensive management brought about the disappearance of over half of Europe’s original forest cover [51]. Though the afforestation programs launched in the 19th century increased the share of forests and improved some environmental conditions, they simultaneously contributed to a number of negative changes, such as the common introduction of conifers, the simplification of forest structure, and the loss of biodiversity. In the 20th century, mountain areas were subject to changes of high intensity because of the restructuring of agriculture [51]. During the first decade following the implementation of the EU Common Agricultural Policy (CAP), the significant development of production and technology led to the intensification of agriculture. In turn, the forest sector was affected by the fact that wood production was strongly favored [16]. The policy led to the marginalization and depopulation of agricultural regions with less productive soils. A decline in the interest in traditional farming practices contributed to a growth in uncultivated areas, which over time turned into forests through natural succession [13,52]. It was only MacSharry’s reform (1992) that drew attention to the environment. The steps then taken in order to protect natural habitats, renaturalize, and plant new forests were based on the ‘degradation’ paradigm and emphasized the negative role of humans in the environment, which led to, among other things, overlooking cultural values in environmental policies [16].

In Eastern Europe, the interest in forest landscapes only grew in the 1990s after the era of communism [17]. The widespread land use changes initiated after 1989 have since become the object of numerous studies and scientific discussions [53–56]. Studies were enabled by the increasingly better availability of data from various historical periods and the ability to make use of techniques developed for remote sensing. Most of forest cover change detection at the national and regional scales in Eastern Europe is based on satellite imagery (e.g., [57,58]), as well as a combination of multiple data sets, e.g., satellite imagery and Corine Land Cover (as in [59]), aerial photos, and field surveys (e.g., [60]). For studies at the local level, depending on the size of the region and the examined period, a combination of contemporary data (such as satellite imagery and aerial photos) and historical sources (such as cadastral and topographical maps, e.g., [61,62]) have been used. High resolution data for forest succession on abandoned fields are provided by airborne laser scanning (ALS) [63].

Studies at the national level have shown that one of the predominant trends in land use change is an increase in forest cover in Eastern Europe. However, detailed studies at the regional level in Eastern Europe have shown substantial variations of forest cover change (1985–2012), especially within large countries [57]. This was confirmed by Poławski’s analyses [64], which showed that the land cover pattern evolutions in Poland had occurred in individual regions differently. The different pasts and affiliations of individual country parts to various state organisms in the years 1815–1914 (the Austrian Empire, Prussia and Russia), as well as in the interwar period (1918–1938), have had great impact on differences in land cover (including forests).

This shows that long-term forest cover dynamics should not only focus on studies at the global level but also on detailed and historical research at the local level. It is at that level that many decisions on forest policies and land use are made [31]. Planners, citizens, and stakeholders need to be made aware of the importance of the historical dimension of the present-day landscape in order to efficiently monitor, manage, and plan it [65,66].

Over the past two hundred years, Poland’s mountains, as border regions, have been subject to land-use changes on many occasions, as has been studied by many specialists (e.g., [14,61,67–73]).

The studies have shown that mountain landscapes stand out because of the presence of numerous relics and remnants of old, traditional pasture and agricultural landscapes, as well as valuable cultural heritage connected with recreation and tourism (e.g., spas). At the same time, after WWII, those areas underwent deep land use changes. Those resulted from both population changes (e.g., an exchange of the population in the Sudetes or a compulsory displacement in the Western Bieszczady Mountains) and a gradual depopulation connected with the efflux of people to more fertile regions, and, thus, the marginalization of the mountain areas [74]. The present increase in forest cover on marginal areas is not only connected with the national forest cover increase program but also with the implementation of the current agricultural policy, which is helped by various funding mechanisms offered by the CAP [29,33]. A large amount of uncultivated land is experiencing secondary forest succession [53,63].

A majority of spatio-temporal analyses of land use/cover in the mountain areas in Poland have been based on a two time point approach, and only few have focused on more intervals (e.g., [14,73]). The most frequently compared situation has been that of a one time period (e.g., [68,69]). Analyses of land use/cover change in the relation to topographic variables, including elevation, slope degree, and land accessibility, have also been carried out [61,73]. Additionally, the state of preservation of landscape relics (e.g., historical pattern of land use) connected with the former agricultural economy in the mountains has been examined [14,72]. Attempts have been made to identify the drivers of forest cover (e.g., [67]) and landscape changes (e.g., [75]). Though magnitude, the general direction of change, and change drivers have been established, comparatively little attention has been paid to the relation between contemporary and historical information concerning land cover, which is ensured by landscape change trajectory analysis.

Within this context, this article discusses characteristics of land cover change in mountain territories, focusing on the key forest cover path in the historical rural landscape during five time points between 1824 and 2016. The eastern part of Jeleniogórska Basin (Kotlina Jeleniogórska) was selected as the object of study; in it, similarly to other mountainous regions in Poland, the historical land use structure connected with traditional agriculture and forest management has survived. The aspect unique to the examined area is the fact that in the 19th century, the preserved medieval land use structures were incorporated into the neighboring landed properties (a total area of approximately 4000 ha) and transformed in the English style and the ornamental farm spirit. The creation of ornamental landscapes within large estates was typical of Western Poland, where because of fertile soil, industry, and—in the mountains—tourist values, numerous estates owned by Prussian or Polish aristocracy were set up (there are about 900 such facilities in Lower Silesia) [76].

Recently, the Jeleniogórska Basin, just like other mountainous areas in Poland, has been experiencing a systematic increase in woodland, as a result of which the character of the landscape has been gradually changing—expansive woodland areas are becoming predominant. The management of the area is problematic because it is subject to preservation of cultural heritage and various forms of nature preservation. Decisions made by individual institutions are dispersed and only focus on selected resources (e.g., rare natural habitats within a Natura 2000 sites or monuments, primarily architectural ones). Consequently, spatial planning, nature management, and forest management strategies overlook the history of forests and forest-related cultural values that have constituted an integral element of the historic parkland. In this context, it is necessary to expand our knowledge about the transformation of traditional landscapes, which will allow for the effective integration of cultural aspects in sustainable forest management.

The use of spatio-temporal analysis of forest cover change based on a sequence of digital maps in the four time period between 1824 and 2016 was to establish: (1) specific forest change trajectory types at a local scale in the entire investigated period, (2) whether it was possible to determine any dominant forest transition types, and (3) the spatio-temporal relations between the historical land cover with long-term cover continuity and areas with high dynamics. Ultimately, the identified principal forest cover conversion trends in relation to traditional and present forms of land use, which determine the character of the mountain landscape, are discussed.

## 2. Materials and Methods

### 2.1. Study Area

Jeleniogórska Basin, with an area of approximately 270 km<sup>2</sup> (Figure 1), is one of the most extensive basins in the Sudetes in Poland. The boundaries of the area are delineated by the Kaczawskie Mountains in the north, Izerskie Mountains in the west, the Giant Mountains (Karkonosze) in the south, and Rudawy Janowickie Mountains in the east. The bottom of the basin is at 320–450 m above sea level, but it is not flat—it is sprinkled with numerous individual residual hills (so-called ‘inselbergs’). There are a total of over 100 hills of varying height from 15–25 m to over 100 m [77]. The character of the forest-covered hills is unique for the whole of Poland, and they have been compared to the inselbergs found in the savannah regions of Africa and Australia [78].



Figure 1. Locality of the object of the study.

The predominant type of potential vegetation in Jeleniogórska Basin is the Central European hornbeam–oak forest (*Galio carpinetum betuli*) in the submontane poor and submontane rich varieties. On the peaks of the hills, a potential natural plant community is composed of an acidic oak forest (*Luzulo luzuloidis–Quercetum petraeae*), with a predominance of sessile oak present in the valleys and dips in the terrain-communities of the submontane alluvial forest (*Carici remota fraxinetum*) and montane alder forest (*Alnetum incanae*). The predominant tree stand species of the alluvial forest is the common ash, with an addition of the black alder, grey alder, and sycamore. The main component of an alder forest is the grey alder. All of the above-mentioned communities have survived fragmentarily. In the period from the 14th to the 18th centuries, as a result of subsequent settlements, most of the fertile forests were transformed into farmland; those that have survived, including those in poorer habitats, were, in general, considerably changed as a result of the artificial cultivation of spruce, which today still occupies the largest part of them [79,80].

Originally, the slopes of the mountains surrounding the basin were covered with beech forests, later replaced with spruce monocultures that are currently being rebuilt towards beech forest. The region's forest cover is small, at 14%. The forests form small and medium-sized complexes, the biggest of which are located north of Jelenia Góra. They occupy a total of about 24 km<sup>2</sup>, 60% of which are managed by Lasy Państwowe (State Forests). The ruling species is spruce, which occupies 60% of the area, with oak occupying 13% and birch occupying 6%. The average age of the tree stands is 79 years, the wood volume amounts to 304 m<sup>3</sup>/ha, and the mean annual wood growth with a thickness of over 7 cm exceeds 10 m<sup>3</sup>/ha/year. All values are slightly higher than the national averages. Spruce tree stands and younger deciduous and mixed stands have multi-layer structures. The average stand density



(the ratio of the area of the tree crown projection to the overall area of the tree stand) amounts to around  $0.8 \text{ m}^3$  [81].

Protection forests (forests that perform exclusively or (more frequently) additionally non-productive functions connected to the protection of land, waters, infrastructure, or land inhabited by humans and threatened by natural disasters such as floods) occupy 95% of the area [82]. An important element of non-forest biocenoses is the vegetation cover of meadows and pastures. Their constituent are rare plant species, often protected, e.g., orchids (*Orchis*), lily of the valley (*Convallaria maialis*), Siberian iris (*Iris siberica*), and stemless carline thistle (*Carlina acaulis*) [69]. It follows from the information provided on the potential natural vegetation of the Poland map [83] that in the area in question, non-forest biocenoses have a substitute character in relation to forest communities (they function temporarily where a forest has been destroyed by human activity or the forces of nature) [84].

The cultural landscape of Jeleniogórska Basin has a distinct pattern. Still visible is the typical pattern of a medieval mountain village, which has been preserved in an almost untouched form since the establishment of the village during the wide-ranging colonization efforts in the 13th and 14th centuries. It extends along a river or stream for many kilometers. Often, above the buildings, the historical layout of fields and forests has also survived. Blocks of arable land, meadows, and pastures form narrow strips separated by dirt roads, which were laid out along slopes (Figure S1). They extend from the buildings in the river valley to the boundary with the forests growing on the hill tops. Though the village layouts have almost survived in their medieval form, the present form of the cultural landscape is predominantly a result of human activities in the 19th century. It was during that time that Jeleniogórska Basin, located at the foot of the Giant Mountains, the highest mountains in Prussia, became a popular holiday destination for the ruling royal family and numerous aristocratic families from all over Europe. In line with the trends at the time, the residences and gardens were united with the surrounding agricultural and forest landscape in the English style. The historical layout of fields and forests, together with various rock formations, would be transformed into extensive parkland, which in the 19th century was referred to as the ‘Silesian Elysium’ [85].

For the study the eastern part of Jeleniogórska Basin was selected, which from the historical perspective constitutes a coherent area that is part of the former ‘Silesian Elysium.’ The area under study, encompassing 6536.56 ha, is subject to various forms of environmental protection (Rudawski Landscape Park, the Karpnickie Ponds Natura 2000 region) and cultural protection (Jeleniogórska Basin Cultural Park), while some of the residences and gardens have the status of a historical monument. The region constitutes a natural hinterland for two big mountain tourist stations: Karpacz and Szklarska Poręba, as well as for the biggest local city (Jelenia Góra) and the health resort Cieplice Śląskie.

## 2.2. Study Material

Land cover change detection is based on the combined use of multiple spatial data sets forming a space–time sequence (Table 1). The oldest topographic maps (so-called Urmesstischblatt; 1:25,000) from 1824 allow for the identification of elements and structures that are typical of traditional landscapes [86]. The transformations during the industrialization period are illustrated on topographic maps from 1886 and 1939. The post-war changes are depicted on orthophoto maps from 1994 and 2016. Additional information about the past land cover was obtained from a 1937 aerial photograph. The present classification of land cover was provided by a 1998 topographic map (1:25,000) and a digital topographic cartographic database (BDOT10k) from 2013. Information about the current land cover was verified during field observations in the years 2010–2011 and 2016–2017.

## 2.3. Land Cover Dynamics, Time Depth, and Trajectory Type Change

The spatio-temporal analysis of forest cover change in four time periods (T1–T2–T3–T4–T5) between 1824 and 2016 was carried out on the basis of land cover data obtained from digital topographic maps and orthophoto maps using ArcGIS 10.6. The following four land cover classes were defined: (A) forest and woodlands, (B) grassland, (C) arable land, and (D) built-up areas (with

rural green areas such as parks and gardens). In order to delineate land cover data for each time point, a retrospective method was used [28,35]. Field observations of the present landscape (in 2010–2011 and 2016–2017) enabled the verification of information about the less known land cover in the past.

**Table 1.** Sources of spatial data.

Material	Year	Scale	Source
Topographic map (Urmesstischblatt)	T1: 1824	1:25,000	Berlin State Library, Germany
Topographic map (Messtischblatt)	T2: 1886	1:25,000	Berlin State Library, Germany
Topographic map (Messtischblatt)	T3: 1939	1:25,000	Berlin State Library, Germany
Orthophoto map	T4: 1994	-	Provincial Centre for Geodesic and Cartographic Documentation, Poland
Orthophoto map	T5: 2016	-	Head Office of Head Office of Land Surveying and Cartography, Poland
Additional Sources of Data	Year	Scale	Source
Aerial photo	1937	1:25,000	Herder Institute in Marburg, Germany
Polish topographic map	1998	1:10,000	Provincial Centre for Geodesic and Cartographic Documentation
Topographic Cartographic Database (BDOT10k)	2013	-	Head Office of Land Surveying and Cartography

The spatio-temporal database created in the manner described above was used to calculate forest and non-forest areas for each time point and changes in the four time period (T1–T2–T3–T4–T5). In order to understand the overall spatio-temporal transformations in forest cover, a type of change trajectory analysis was conducted that enables the identification of specific ways in which land cover is transformed over time [28,29,32,36]. To that end, various spatial data were merged into one sequential spatio-temporal database. The main types of change trajectory were determined according to the following qualitative criteria: direction of change (stability, increase, and decrease during the examined period) and quantitative criteria (number of changes and different land cover classes during the examined period). Finally, the identified forest cover change trajectory types were characterized by taking into account the type of transition: (a) single conversion: one change between two classes in the whole time period (e.g., AABBB—where A is forest and woodlands and B is grassland); (b) cyclical conversion: rotation between two land cover classes (e.g., ABBA); and (c) dynamic conversion: many changes between many different land cover classes where no trend is strong enough (e.g., ABCDB—where C is arable land and D is built-up areas).

Land cover dynamics were statistically analyzed using cross-tabulation matrices [87–90]. Transition matrices enable the assessment of changes in land use classes (the transformation of the initial land cover into the final one) between two adjacent time layers [86,87]. They also enable the identification of stability, losses and gains of land use categories, and the determination of the total change in the landscape for a land use category understood as the sum of loss and gain [31]. Furthermore, in order to quantitatively measure the degree of change and no change between two adjacent time layers [86,87], the binary change index was calculated. Statistical data regarding the shares of areas with continuity and ones that were changing dynamically were estimated in relation to the age of individual land cover forms. In order to understand the historical context of the present landscape, time depth was analyzed [87]. The identification of the historical element and the structure of a present-day landscape within a given area enables the better understanding of the ‘historical landscape character’ and may become a tool for supporting the management of landscape change [47,48,91] and the natural environment [60].

### 3. Results

#### 3.1. Forest Cover Trajectory Types

Using the spatio-temporal database, 76 individual forest cover trajectory types were identified. After taking the classification criteria into account, the following eight forest cover trajectory types were separated (Table 2): (1) long-term stability, (2) single increase forest cover from grassland, (3) single increase forest cover from arable land, (4) dynamic increase forest cover from mixed agricultural land (grassland, arable land, and built-up area), (5) cyclical increasing forest cover, (6) single decrease forest cover into grassland, (7) dynamic decrease forest cover from mixed agricultural land (grassland, arable land, and built-up area), and (8) area that has never been forest.

**Table 2.** Forest cover change trajectory types.

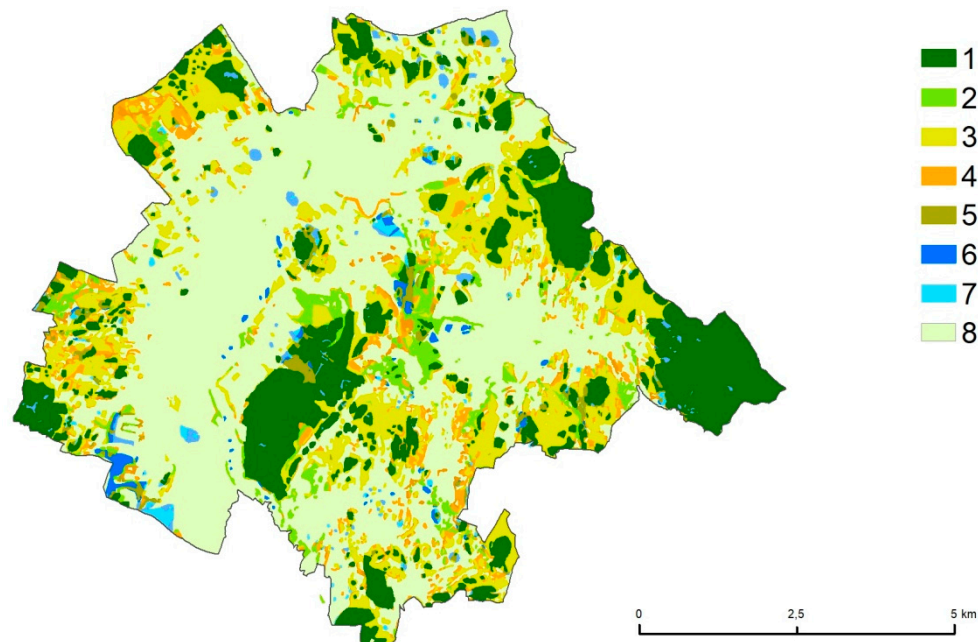
Forest Cover Trajectory Types		[%]	Description	Example *
1	Long-term stability	16.4	Long term forest cover without change	AAAAA
2	Single increase of forest cover from grassland	3.1	One point of change between forest and grassland; stable land cover before and after this point	BAAAA BBBAA
3	Single increase of forest cover from arable land	14.4	One point of change between forest and arable land with stable land cover before and after this point	CAAAA CAAAA
4	Dynamic increase of forest cover from mixed agricultural land	6.1	Many changes between many different land cover classes (grassland, arable land, and built-up area); no trend is strong enough	BCBBA BAACA
5	Cyclical increase of forest cover	1.3	Cyclical change rotation between forest and grassland or forest and arable land	ABBAA ACCAA
6	Single decrease of forest cover into grassland	1.9	One point of change between forest and grassland with stable land cover before and after this point	ABBBB AABBB
7	Dynamic decrease of forest cover into mixed agricultural land	1.1	Many changes between many different land cover classes (grassland, arable land, and built-up area); no trend is strong enough	ACBCC AACCB
8	Areas where occurrence of forest has never been recorded during the investigated period	55.7	Grassland, arable land or built up area	-

\* A: forest and woodlands; B: grassland; C: arable land; and D: built-up areas (with rural green areas: parks, gardens).

Nearly 28% of the land area has been subject to transformation over the last 192 years. The largest group of land was comprised of areas that belong to the single increase type (17.5%), where a simple conversion from one land type to another took place in one time period. As a result of such changes, the majority of forest cover was created from arable land (14.4% of the land area) or grassland (3.1% of the land area). Following the change, land cover was stable. The map with the pattern of trajectory types (Figure 2) shows that the single increase types cover extensive, compact areas grouped around



the most permanent forest covers (16.4% of land area) located in the highest parts of the land (above 370 MASL), which indicates a deliberate character of such afforestations. It was also established that such a type of change accounts for present-day forests created in the first three periods (from 1824 to 1994): these forests accounted for 90% of forest increase in T1, 80% in T2, and 66% in T3.



**Figure 2.** Distribution of forest cover change trajectory types: (1) Long-term stability, (2) single increase forest cover from grassland, (3) single increase forest cover from arable land, (4) dynamic increase forest cover from mixed agricultural land, (5) cyclical increasing forest cover, (6) single decrease forest cover into grassland, (7) dynamic decrease forest cover from mixed agricultural land, and (8) areas where the occurrence of forests has never been recorded during the investigated period.

Another group of changes is comprised of dynamic increases from mixed agriculture (grassland, agriculture, and dispersed built-up areas), which occupies 7.4% of land area. An analysis of individual forest cover trajectory changes showed that the biggest group, the dynamic and cyclical increase of forest (4.9%), accounted for areas that ultimately transformed into forest during the most recent period (1994–2016). These areas accounted for nearly 76% of the forest increase in T4. New forests were created in areas that had previously been subject to dynamic changes between arable land, grassland, or built-up areas (6.1% of land area) or as a result of rotation (1.3%) from arable land (0.7%) or grassland (0.6%).

All in all, a decrease in forest has affected 3.0% of the total land area, of which 1.9% are forest areas that disappeared at one time point in favor of grassland, arable land, or built-up areas, and those areas remained stable until 2016. The remaining former forest areas (1.1%) experienced multiple land cover changes in the period under study. The reduction principally occurred during the first and the second time period and was focused on forests in river valleys (Figure 2). This may have been connected with the drainage system work conducted in the 19th century.

### 3.2. Dynamics of Land Cover between 1824 and 2016

More data regarding the nature and dynamics of the changes in individual periods were obtained from an analysis of the data presented in Table 3, Table 4, and Figure 3, as well as in the land cover transition matrices (Table 5). The analysis indicated that during all of the studied periods, forests generally increased their areas mainly at the expense of arable land and meadows, but, at the same

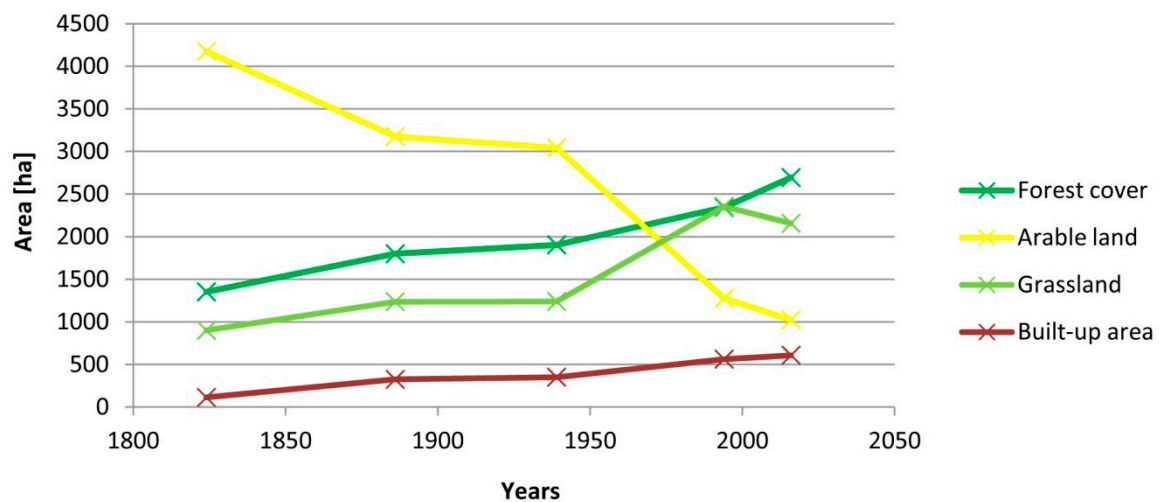
time, some of the existing forest areas were transformed into such land use forms. Both the scale and mutual proportions of the changes in individual periods differed greatly.

**Table 3.** Land cover change (1824–2016).

Land Cover Type		T1		T2		T3		T4		T5	
		[ha]	[%]	[ha]	[%]	[ha]	[%]	[ha]	[%]	[ha]	[%]
A	Forest cover	1352.0	20.7	1798.8	27.50	1903.4	29.1	2345	35.9	2693	41.2
	Coniferous	-	-	686.3	10.5	764.7	11.7	119.9	1.8	113.3	1.7
	Deciduous	-	-	218.0	3.3	205.6	3.1	307.5	4.7	555.5	8.5
	Mixed	-	-	894.5	13.7	933.1	14.3	1917	29.3	2024	31.0
B	Arable land	4175.3	63.9	3175.1	48.6	3043.2	46.6	1277	19.5	1024	15.7
C	Grassland	900.2	13.8	1236.1	18.9	1239.4	19.0	2355	36	2156	33.8
D	Built-up area	112.5	1.7	324.23	5	350.6	5.36	562.1	8.6	607.9	9.3

**Table 4.** Intensity of changes [m<sup>2</sup>/year].

Land Cover Type		T1–T2	T2–T3	T3–T4	T4–T5
A	Forest cover	7.21	1.97	8.02	15.85
	Coniferous	-	1.48	−11.72	−0.30
	Deciduous	-	−0.23	1.85	11.27
	Mixed	-	0.73	17.89	4.88
B	Arable land	−16.13	−2.49	−32.11	−11.50
C	Grassland	5.42	0.06	20.29	−9.04
D	Built-up area	3.42	0.50	3.85	2.08



**Figure 3.** Change in forest cover (ha) in the studied area in the years 1824–2016 against other land cover form changes.

**Table 5.** Land cover transition matrices (1824–2016).

Area in 1886												
	Forests		Grassland		Arable Land		Built-Up Area		Total Area 1824		Loss	
Area in 1824	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Forest	1119.8	17.1	97.5	1.5	136.7	2.1	0.0	0.0	1354.0	20.7	234.23	3.6
Grassland	107.9	1.7	502.7	7.7	225.3	3.5	65.4	1.0	901.3	13.8	398.6	6.1
Arable land	574.8	8.8	619.6	9.5	2768.3	42.4	214.0	3.3	4176.7	63.9	1408.4	21.5
Built-up area	0.00	0.00	17.8	0.3	48.0	0.7	45.0	0.7	110.9	1.7	65.9	1.0
Total area 1886	1802.5	27.6	1237.7	18.9	3178.4	48.6	324.4	5.0				
Gain	682.7	10.4	734.9	11.3	410.1	6.3	279.4	4.3				
Area in 1930												
	Forests		Grassland		Arable Land		Built-Up Area		Total Area 1886		Loss	
Area in 1886	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Forest	1761.8	27.0	26.5	0.4	12.0	0.2	0.2	0.0	1800.2	27.5	38.68	0.6
Grassland	25.1	0.4	1169.8	17.9	36.8	0.6	2.8	0.0	1234.6	18.9	64.7	1.0
Arable land	112.7	1.7	38.8	0.6	2998.4	45.9	27.7	0.4	3177.7	48.6	179.3	2.7
Built-up area	0.0	0.0	3.8	0.1	6.0	0.1	319.9	4.9	329.7	5.0	9.8	0.2
Total area 1930	1899.5	29.1	1238.9	19.0	3047.3	46.7	350.6	5.4				
Gain	137.8	2.1	69.1	1.0	54.8	0.8	30.8	0.5				
Area in 1996												
	Forests		Grassland		Arable Land		Built-Up Area		Total Area 1930		Loss	
Area in 1930	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Forest	1858.2	28.4	32.0	0.5	8.7	0.1	1.3	0.0	1900.2	29.1	42.09	0.6
Grassland	136.5	2.1	868.0	13.3	175.0	2.7	64.1	1.0	1243.6	19.0	375.6	5.8
Arable land	352.4	5.4	1374.5	21.0	1082.6	16.6	236.3	3.6	3045.8	46.6	1963.2	30.0
Built-up area	1.4	0.02	78.6	1.2	8.9	0.1	261.3	4.0	350.2	5.4	88.9	1.4
Total area 1996	2348.5	35.9	2353.2	36.0	1275.1	19.5	563.1	8.6				
Gain	490.3	7.5	1485.2	22.7	192.6	3.0	301.7	4.6				
Area in 2016												
	Forests		Grassland		Arable Land		Built-Up Area		Total Area 1996		Loss	
Area in 1996	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Forest	2291.8	35.1	51.5	0.8	1.9	0.0	1.0	0.0	2346.2	35.9	54.38	0.8
Grassland	339.1	5.2	1951.1	29.9	29.1	0.4	35.4	0.5	2354.7	36.0	403.6	6.2
Arable land	60.4	0.9	207.9	3.2	978.6	15.0	27.8	0.4	1274.7	19.5	296.1	4.5
Built-up area	0.5	0.01	1.1	0.02	19.6	0.3	544.2	8.3	565.4	8.6	21.2	0.3
Total area 2016	2691.9	41.2	2211.6	33.8	1029.1	15.7	608.4	9.3				
Gain	400.0	6.1	260.5	4.0	50.5	0.8	64.2	1.0				

In the first period, which lasted for 62 years from 1824 to 1886 (T1–T2), occurred relatively big land use changes and a large general increase in forest areas, which grew by 20.5%, and its share in the total area rose from 20.75% to 26.7%. It came about mainly at the expense of agricultural land, and 575 ha of it became forest most likely because of artificial afforestation. This was indicated by a considerable share of coniferous trees in 1886, i.e., with a composition that significantly differed from the natural one for the studied area. During the same period, nearly 137 ha of forest (the biggest area in the entire investigated period) were converted into arable land. In the years of 1824–1886, between 96.7 and 107.9 ha of meadows changed into forest, depending on the area. The second period, lasting for 44 years from 1886 to 1939 (T2–T3), was characterized by considerably smaller dynamics in forest growth and land use changes. On average, the forest areas grew by only 2.0 ha per year. Forests increased their area thanks to afforestation of 112.7 ha of arable land, while only 12 ha of them changed to that land use form. Interestingly enough, the forest–meadow swap balance was slightly more advantageous for meadows (the corresponding figures were 25.1 and 26.5 ha, respectively). Perhaps the smaller intensity of change was connected with the stagnation caused by WWI, which

occurred in the second half of the period under study. A rather long period—55 years from 1939 to 1994 (T3–T4)—was characterized by a change dynamic bigger than that of the previous period, despite the fact that WWII took place during its first part, which was unfavorable to forest economy. After the war, the population, ownership relationships, and land use and management in the studied area changed. Throughout the period, the forest area grew by 8.0 ha per year, and the forest share in total area rose from 29.1% to 35.9%.

The main source of the new forest area was, as before, arable land, which ‘gave away’ over 352 ha to forests while ‘taking away’ only about 9 ha of land from them. During the period, the role of meadows in increasing forest cover also increased. The land swap balance tipped markedly towards forests (104.5 ha). Despite that, the total area of meadows did not decrease, because the loss in favor of forests was set off by new meadows created from arable land.

During the examined period, there was a considerable drop in the area of coniferous forests, which in the region under study—as already mentioned in the introduction—are mainly associated with spruce monocultures. On the other hand, the area covered by deciduous forests, especially mixed ones, grew.

The last of the determined periods, covering the years 1994–2016, was generally characterized by a slightly smaller dynamic of land use changes but a significant growth in forest areas, with a record-high intensity of changes at 15.6 ha/year. In contrast to the previous periods, most forests were created not by the conversion of agricultural land but areas occupied by meadows (339.1 ha). At the same time, 51.5 ha of forests turned into meadows. Additionally, unlike in the previous period, the above-mentioned loss was not fully compensated for by arable land, and so the total area of meadows was reduced. 60.4 ha of forest were converted from arable land, and only less than 2 ha of forest were converted into arable land.

Of note is a significant increase in the area covered by deciduous forests, which, considering the artificial afforestation reduction trend during the last dozen years or so, indicates that new forests are being created largely due to natural succession (the composition of the new forests is dominated by pioneer species of the genera *Betula*, *Populus*, and *Alnus*). An increase in built-up areas from 112.5 ha in 1824 to 607.9 ha in 2016 had no significant impact on forest resources. During the entire period, built-up areas took up a total of approximately 2.5 ha of the existing forested area, losing 1.9 ha to forests (0.6 ha in favor of built-up areas).

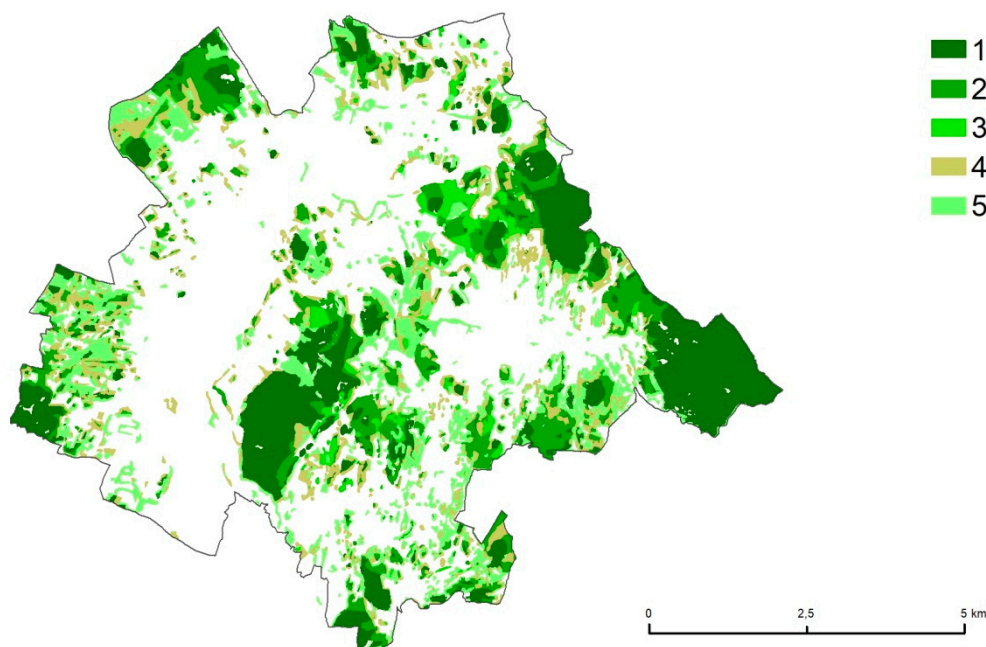
An analysis of a quantitative share of unchanged and changed areas and the binary change index in adjacent time layers confirmed that the biggest land cover changes took place in the following two periods: T1–T2 and T3–T4 (Table 6). Periods T2–T3 and T4–T5 had similar binary change indices, which attested to a larger share of areas with no change. The small index value during the last period, despite a significant growth in forest area, was mainly a result of slight changes in the relation of arable land to meadows (Table 5).

**Table 6.** Binary changed index of land cover.

Time Period	Unchanged [%]	Changed [%]	Binary Changed Index
1824–1886	67.9	32.2	0.4
1886–1939	95.6	4.4	0.9
1939–1994	62.3	37.8	0.2
1994–2016	88.2	11.9	0.8

A time depth analysis (Figure 4.) enabled the age of the forest cover in the present landscape to be determined. Though the areas with the biggest share were those with long-term stability (16.4%), it should be pointed out that large forest complexes were rebuilt on many occasions, first towards coniferous forests (until 1939) and subsequently towards mixed and deciduous forests. In this class of objects, of the biggest natural and cultural values were small and medium forests, respectively (up to 1 and 10 ha), with a large percentage of deciduous trees that grow on hill peaks with various

rock formations (with a visible bedrock) that are the least useful for agriculture. Those can be divided into: (1) former coppices in pastures, which provided shade for farm animals (Figures S2–S4), and (2) former coppices incorporated into ornamental farms as adornments for agricultural or forest areas, emphasizing views of the nearby mountainous regions (Figures S5 and S6).



**Figure 4.** Time depth: (1) pre-1824, (2) 1824–1886, (3) 1886–1939, (4) 1939–1994, and (5) 1994–2016.

A considerable area was found to be occupied by forests originating from the years 1824–1886 (9.4%) or 1939–1994 (6.3%) that were created as a result of successive afforestation programs. A comparison of a time–depth map with LCTA findings indicated that apart from planned afforestation efforts, especially after 1939, there were also areas subject to dynamic and cyclical changes, thus attesting to their impermanence and probably spontaneous origin (Figure S7).

#### 4. Discussion

Our analysis of forest cover change dynamics and trajectories allowed us to trace and understand successive states of land use history and landscape transformations in Jeleniogórska Basin over a period of nearly 200 years. It was confirmed that a significant forest cover increase occurred in the years 1824–1886 (from 20.7% to 27.5%) and 1939–1994 (from 29.1% to 35.9%). The growth in forest cover and land cover changes was reflected the socioeconomic and political changes in the Sudetes. Generally, the increase in forest cover in the Sudetes since the beginning of the 19th century has been similar to that in today's Western Poland. In the Sudetes, similarly to the entirety of Prussia, in the early 19th century, steps were taken to increase areas occupied by high-productivity coniferous forests that were established on the principle of a so-called highest ground rent. In the Sudetes, an additional motivating factor for afforestation efforts was the worsening living conditions. Overpopulated villages and the excessive exploitation of agricultural land at higher elevations led to catastrophic flooding and soil erosion [92]. In line with the forest arrangement methods prevalent at the time, which focused on generating the highest possible income for the owners, foreign species of lowland spruce, which were characterized by fast wood growth, were planted. This led to the creation of tree stands that were uniform in terms of age and species that had some environmental implications—in particular, a reduced retention and protection capability that caused an increased frequency of flooding [93,94] and a decreased resistance of trees to climatic and pathogenic factors, which in turn indirectly led to the ecological disaster connected with the destruction of forests in the Sudetes in the 1970s and 80s.



The second period of a considerable growth in forest area (1930–1996) was connected with planned afforestation carried out by the Polish state that was already within its new boundaries after WWII, when the country's forest cover grew from 22% to 28% in the years 1950–1990. During that time, because the forest cover rate was low, it was important to boost it to the optimum level from the natural and economic perspective [64]. In the Sudetes, an additional reason for the growth in the percentage of land covered by forests was the abandonment of arable land, which underwent natural succession over time. This was linked to the depopulation of the Sudetes, which had started towards the end of the 19th century. Initially, the reasons were economic (outflux of people to dynamically developing towns, cities, and industry), and subsequently socio-political, connected to population replacement and the depopulation of rural areas in the years 1950–1960. [92]. According to Pająkiewicz [95], the number of people working in agriculture dropped by 21% in the years 1970–78. The changes resulted, on the one hand, from the low profitability of agricultural production and, on the other hand, from strong impact of industry concentrated in towns, cities, and other major settlements in Jeleniogórska Basin. Furthermore, the non-indigenous population that came to the mountain regions in the post-war period from central or eastern Poland or Ukraine predominantly originated from lowland areas and so did not know how to manage in difficult mountain conditions [79,96–99].

The forest cover increase in the examined region was smaller than that in the other parts of the Sudetes. A significant impact on land cover change intensity after 1945 was exerted by post-war re-settlement, followed by depopulation. Changes of high intensity occurred in the Polish Eastern Sudetes [72], as well as the Sudetes in the Czech Republic [100], where some places have seen total resettlement of villages. Phenomena of similar intensity have been observed in the Eastern Carpathians following compulsory resettlement. However, as noticed by Kozak [101], some local differences are also noticeable here. Apart from places with a high forest cover increase (>20%), there are some with a medium forest cover increase (10%–15%), related to a stagnant or gradually declining population, and areas with a low forest cover increase (<10%), related to an increase in population. The forest cover ratio in the region subject to examination rose by 12% (1939–2016), which indicated that the process was not as spectacular as in other parts of the Sudetes and was rather not a result of abrupt depopulation. Only some of the locations in Jeleniogórska Basin depopulated in the post-war period.

A new outlook on forest cover changes in Jeleniogórska Basin in the post-war period was provided by an analysis of the change intensity. The rate of change markedly rose in the years 1994–2016, when the forest area grew by 17 ha (0.24%) per year, while earlier it oscillated between 2.0 ha (0.03%) and 8.0 ha (0.12%). For the sake of comparison, in the Carpathians during the entire post-war period, the annual forest cover change rate amounted to 0.38%–2.15% [67].

New and valuable information for formulating future historical landscape protection and management strategies was also provided by the forest cover change trajectory and time depth analysis. The biggest area was found to be occupied by long-term stability forests. As much as 16.4% of the total area and 40% of the present forest area were found to be occupied by forests that have existed uninterruptedly at least since 1824. Another large group is constituted by forests created on the basis of arable land (14.4%) or grassland (3.1%) as a result of simple conversion at one point of time, mainly during the first or third period under study. It was established that the type of change in question was predominant until 1994 (this applied, on average, to as much as 77% of the forests created during the period), which indicated a planned nature of the forest cover growth. A considerable group is made up of areas with cyclical (1.3%) or dynamic changes (decrease or increase of 7.2%). Their importance rose in the last period, when as many as 74% of forest increases occurred on such land. New forests were created on agricultural land that had previously been subject to multiple changes (e.g., rotation between arable land and grassland). A considerable variability seen in the lack of a predominant trend in land cover types and fragmentation of the areas indicated that they were used on a temporary basis without any long-term planning.

Parts of the new forests were probably created by natural succession, which was also hinted by oral information provided by forest guards concerning insignificant afforestation efforts in the area

in question. This certainly applied to almost 14% of the new forest areas not included in the official databases (BDOT10k and GUS—Central Statistical Office), 2018. The growth in forest cover and the drop in agricultural land area since 1989 is typical of Eastern Europe, where interest in agriculture and agricultural use of land, in particular on low-quality land, has been on the decrease [56]. During this period, for economic reasons, out-migration from rural to urban areas has occurred [53]. Forest succession on abandoned farmland has been widespread and led to increased forest cover. The most recent studies in the Polish Carpathians [63] have shown that the average overall secondary forest succession rate, indicating farmland abandonment, is  $13.9\% \pm 7.7\%$ —though the values ranged from 1.7% to 38.4% locally.

Our study has shown that agriculture has become substantially less important in the examined region, which provides a chance for a further increase in forest resources. At the same time, the factor whose role in limiting forest areas in mountain regions is growing is the need to protect cultural landscapes and attractive views, which is at least partly related to the tourist character of such territories. The limiting role of this factor cannot, however, be compared with that fulfilled by agriculture until recently. The compromise between cultural and natural elements brings about the need to assess the latter. The assessment is greatly helped by the knowledge of their history, and such data are provided by our study.

Our study has also found that the history of individual forest patches varies greatly. Some of them have existed uninterruptedly at least since 1824. Usually, they occupy areas that are located at higher altitudes and are of very limited use to agriculture. Those are relics of former agricultural and forest landscaping traditions that are frequently connected with grazing farm animals. In the years 1830–1880, they were incorporated into parkland as elements forming interior and distant views of mountain ranges. Today, because of their permanence, they form an important element of cultural landscapes that determines the distinct identity of places. When carrying out their ultimate assessment, however, their present and historical tree stand compositions, as well as their conformance to the potential ones, should be checked. It is also worth remembering that forests located on hill tops in local conditions generally represent (also potentially) less valuable forms of deciduous forests—most often the so-called acidic mountain oak forests, with sessile oak as the predominant species. This means that they can only partly be regarded as an equivalent to the lost forest areas from the lower locations, which were mainly a richer form of oak–hornbeam forests, with the predominance of pedunculate oak. It is also worth emphasizing that the deforestation of the Sudetes, which was effectively resisted by the areas described here, has led to a number of negative changes in the natural environment, the most prominent ones being more frequent flooding and soil erosion [72]. Therefore, a full recreation of the 19th-century system of agricultural and forest areas is not recommended today.

A considerable portion of the forest areas created until 1994 came from planned afforestation that was carried out more or less intensively. Forest stands with large shares of spruce or simply its monocultures were principally created in the 19th century and in the early 20th century as a result of the then universally implemented German forest policy aimed at quickly producing construction timber by growing coniferous species [17]. That contributed to a permanent absorption of characteristic small and medium-sized relic forests, which ultimately changed the nature of the landscape. A sizeable portion of such tree stands, particularly the oldest ones, have now been rebuilt into deciduous ones; however, it should be remembered that the cultivation of coniferous species in fertile, low habitats leads to considerable changes in the composition of soil organisms, especially in the case of monocultures. In such cases, even a few dozen years of cultivation also changes soil type through a podsolization process. Generally, however, rebuilt monocultures as plant communities should be evaluated to higher than still existing monocultures, and those, should usually be elevated to be higher than most of areas occupied by meadows and, especially, arable land [102]. Agricultural cultivation practically destroys all components of the forest biocenosis. It is universally accepted that the reconstruction of the composition of soil mycobiota typical of a forest takes at least one tree generation.

In the last of the periods under study, a significant increase in the forest area of the examined region occurred as a result of both planned and unplanned processes; in the latter case, it was usually through natural forest succession. An advantage of such a community is, more often than not, its considerable resilience to various climatic factors, while a drawback is its composition that differs materially from potential natural vegetation. As a rule, it is made up of pioneer species—birches, alders, poplars, and aspens. Admittedly, natural succession leads to the creation of a community with features of potential vegetation, but the process takes lots of time, especially if species that are characteristic of the ultimate (climax) stage of succession do not grow nearby. When assessing natural succession to the abandonment of meadows, fields, or pastures from the biodiversity point of view, one should consider the fact that floristic variety increases at the very early stages of natural succession. Later on, at the successive stages, it tends to decrease due to the invasion of aggressive pioneer species that force out species typical of earlier, species-rich mountain meadows or pastures [13].

Another aspect of spontaneously forming forests is their non-formal character. Often a birch stand over a dozen meters high and with a significant crown cover is listed in a cadaster as a meadow or a field. In such a situation, it can easily be reclassified, as, for instance, intended for building purposes. This means that at least some of the areas with forest-like characters that have been created in recent years can only be temporary. Despite the above-mentioned drawbacks, from the perspective of the protection of natural resources, they still constitute a higher value than agricultural land and should be left as they are wherever possible. The process of succession changes can be accelerated by artificially introducing climax species, especially the large-seeded oaks and silver fir that are currently being reintroduced in the Sudetes [103]. However, it should be remembered that spontaneously forming forests and tree plantings pose a threat to cultural landscapes where forests are considerably fragmented and the historical land use system has become less discernible. Such a situation is particularly unfavorable when the landscape is predominated by small patches of meadows, forests, and farmland. Then, forest expansion may lead to increased landscape homogeneity and, ultimately, to a reduced diversity of plant communities and animal habitats [13]. For that reason, among others, the new forests should be under control and management.

Forest landscape management in an area protected because of natural or cultural values is problematic for many reasons. Because in Poland forests are universally regarded as the most natural ecosystems, the management of forests (especially ones protected because of their natural values) ignores the available knowledge about the history of land use and the associated biocultural heritage. An additional barrier is created by the distribution of competences between various institutions and bodies, which limits the capability to manage cultural landscapes in an integral way (focus on natural and cultural resources as opposed to landscape). In turn, official databases lack information about biocultural heritage. Registers of monuments only include architectural or garden art monuments, as well as information about the natural environment (though only protected areas).

Furthermore, official spatial data on land use structure and forest cover do not take the actual areas of abandoned arable land and forests created as a result of natural succession into account. The scale of the process is not known accurately, and only aggregated data are available [63]. Apart from institutional problems, the comprehensive management of forests in areas valuable due to landscape is also hindered by the land ownership structure. In Jeleniogórska Basin, large and medium-sized forest complexes are owned by Lasy Państwowe (State Forests). On the other hand, historical coppices are usually located on private arable land. Additionally, succession areas are to be predominantly found on private or commune agricultural land. In Poland, only now is the problem being noticed, e.g., recently in Lower Silesia in the context of forest management in an area located within a nature reserve and a Natura 2000 region, as well as on the site of a former ornamental landscape at Książ. The lack of a wide-ranging discussion on mutual relations between cultural and biological diversity in Poland resembles the situation in Sweden in the 1990s, as described by Aronsson [25].

Our findings indicated that not only does the current forest policy needs to be verified but also the role and involvement of local communities should be increased, especially in the context of the more and

more common abandonment of arable land. The expansion of knowledge about the history of forests and the impact of the former forest and agricultural practices on the present forest structure, as well as awareness of the implications of the present processes for cultural landscape can facilitate the making of decisions regarding the selection of optimum planning tools and management techniques. An important aspect is the making of local communities aware of what economic, social, and environmental benefits can be derived from the protection and preservation of specific forest patterns and woodland landscapes, as well as the associated aesthetic and historical values. The biggest opportunity for Jeleniogórska Basin is the development of ecological agriculture, agrotourism, and recreation.

The inclusion of traditional knowledge about the former agricultural and forest practices in sustainable forest management and local agricultural practices is a necessary step towards preserving an important part of the European cultural heritage [17]. What is more, it can offer insights into possible approaches to dealing with climate changes in the coming years [104]. Future sustainable forest management strategies should consider, for instance, the preservation or restoration of elements of traditional forests and woodland landscape patterns in the form of relic coppice in pastures and meadows, as well as at places of historical or scenic importance. Such steps have been undertaken in Great Britain, where the preserved forests (coppicing, pollarding, and wood pastures) have become the most iconic features of the landscape. In turn, former coppice woodlands absorbed into large forest complexes should be taken into account when setting up tourist walking routes in Jeleniogórska Basin. Such practices have been introduced, e.g., in the Netherlands [105]. When creating new buffer strips, it is worth making use of traditional forest-related knowledge and restoring the varied coppice structure, mainly to favor biodiversity. Coppice management has been reintroduced, e.g., in Great Britain and in the Netherlands [17]. Detailed guidelines and a range of possible activities at the national, regional, and local levels are also presented in “Guidelines for the implementation of social and cultural values in sustainable forest management” by Agnoletti et al. [27].

## 5. Conclusions

To sum up, our forest trajectory changes and time–depth analysis confirmed that within the forest landscape of Jeleniogórska Basin, there have survived areas whose borders have not changed since the 19th century. Though the historic forests and former coppice woodlands were the main constituent of the former parkland (Silesian Elysium) and constituted its iconic features, today they are only regarded as natural elements. The fact that the historical agricultural and forest practices had their share in creating biological and cultural diversity, as well as aesthetic values, is overlooked. The presented findings of our analysis of spatio-temporal forest cover dynamics and change trajectories may prove very useful for identifying and establishing the individual features of a given forest region and formulating plans and actions for sustainable forest management.

An analysis of dynamics and forest trajectory changes showed that the forest cover change dynamics have greatly accelerated during the last two decades, and the magnitude is significantly bigger than that shown in the official data, which do not account for some of the forests created by natural succession. Land cover changes have permanently affected the nature of the Jeleniogórska Basin landscape during the last 200 years. As a result of planned afforestation in the 19th and 20th centuries, small patches of forest have been absorbed by large forest complexes, often spruce monocultures. The blurring of the historical land use system continued in the 20th century, as part of not only planned afforestation but also spontaneous processes. Part of the abandoned agricultural land has been subject to multi-directional changes (cyclical and dynamic), without a clearly defined trend. In the early 21st century, a majority of the abandoned fields and meadows underwent secondary forest succession. Often, those new forests and tree plantings have not been included in official classifications of land as ‘forest land’ and are temporary in nature, which hinders cultural landscape conservation and planning.

It should be pointed out, however, that although each mountain region has its unique character, a majority of the issues discussed here are universal in nature to greater or lesser extents. Of particular interest is the significant expansion of the area of non-formal forests in the 20th century (specifically

its last 20–25 years). As it turns out, the process applies not only to regions experiencing economic stagnation that are located in mountain or submontane areas but also to other places where the role of agriculture is weakening. An example is a highly dynamic urban area [106]. Additionally in this case, apart from pointing out the positive aspects of spontaneous formation of forest-like areas, attention is drawn to the urgent need to bring them under control and long-term planning.

Currently, forest landscape management is hindered by the lack of interdepartmental cooperation between forest management, the preservation of monuments, and the protection of nature. Individual institutions are focused on protecting and managing selected landscapes elements, and none of them take a broader landscape context into account.

Future sustainable forest management strategies should be based on a multi-functional approach, and forests should fulfil economic, protective, and social aims that significantly contribute to preserving biodiversity, improving the quality of life, and adapting to climate change. Within this context, cultural, aesthetic, and spiritual aspects of forests may become to people a bridge between forestry and other social needs. Consequently, when formulating future forest management strategies for Jeleniogórska Basin, the following are recommended:

1. To consider the possibility of preserving or restoring traditional coppice structure on agricultural land, with characteristic small and medium-sized tree plantings on hill tops that will contribute to emphasizing the nature of former parkland, preserving biodiversity, and boosting visual attractiveness, all of which are of importance to the tourist development of the region.
2. To make use of traditional knowledge about forest management and structure when formulating optimum solutions for adapting to climate changes in the coming years.
3. To shape the optimum structure for forest and agricultural landscapes to improve the quality of life of inhabitants and to provide conditions for the development of local ecological agriculture, agrotourism, and recreation.
4. To undertake interdisciplinary and suprasectoral cooperation with the involvement of representatives of various scientific circles, institutions, and government authorities, as well as local communities, which will contribute to making use of knowledge about the history and cultural values of forests for purposes related to spatial planning and forest and nature management plans.
5. To promote interdisciplinary studies aimed at identifying and classifying the biocultural heritage of agricultural and forest areas.
6. To promote initiatives aimed at popularizing the history of traditional land use in the region among the local community members, which is of particular importance in the case of Lower Silesia, which experienced population exchange after 1945.

**Supplementary Materials:** The following are available online at <http://www.mdpi.com/1999-4907/11/8/867/s1>. Figure S1: Historic land use-system, Mysłakowice (Erdmmandorf), 1886, Figure S2: Surviving historical tree planting in a pasture, Bukowiec (Buchwald), 2012, Figure S3: Forests and pasture tree plantings, Wojanów (Schildau), 2012, Figure S4: Forest on the hill peak Trzcińsko (Rohrlach), 2012, Figure S5: Former pasture tree plantings incorporated into ornamental farm, Bukowiec (Buchwald), 2012, Figure S6: Ornamental forests and pasture tree plantings, Łomnica (Lomnitz), 2012, Figure S7. Former pasture tree plantings and an area of natural succession on former agricultural land, Wojanów (Schildau), 2012.

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