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Article

Driving Forces of Forest Landscape Change in Ślęża Landscape Park (Southwestern Poland) in Period 1883-2013

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Abstract: Changes in forest landscapes have been connected with human activity for centuries, which can be considered as one of the main driving forces of change in the global perspective. The spatial distribution of forests changes along with the geopolitical situation, demographic changes, intensification of agriculture, urbanization or changes in the land use policy. However, due to the limited availability of historical data, the driving forces of changes in forest landscapes are most often considered in relation to recent decades, without taking into account long-term analyzes. The aim of this paper is to determine the impact of natural and socio-economic factors on changes in forest landscapes within the protected area – Ślęża Landscape Park and its buffer zone in the aspect of long-term analyzes covering the period of 140 years (1883-2013). The comparison of historical and current maps, demographic data on 4 different periods as well as natural and location factors by using the ArcGIS software allowed analyzing selected driving forces of forest landscape transformations. We took into account natural factors like altitude, slope, exposure of the hillside and socio-economic drivers like population changes, distances to centers of municipalities, main roads and built-up areas.

Keywords: driving forces; landscape change; landscape dynamics; forest landscape; land use; land cover; landscape change index

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1. Introduction

On a global scale, human beings have been the main driving force for the transformation of the Earth's surface for several hundred years [1]. People significantly influenced landscape changes by implementing different needs. The effect of it we can see nowadays. For the last few decades these changes have been intensified due to strong socio-economic changes, including changes in agriculture, industry or transport [2]. These transformations are particularly evident in the countries of Central and Eastern Europe, where profound political and socio-economic changes took place [3]. The significance of the changes that followed the fall of communism is particularly emphasized [4-5]. Changes resulting from enlargement of the European Union in 2004 are also analyzed [6]. Both traditional agricultural landscapes [7-9], urban and industrial [10-13] have become strong transformations, as well as landscapes with high value [14-15]. Changes in forest landscapes and in the immediate vicinity of forests [16-19] are particularly noticeable. So far, in many cases, landscape change studies were limited only to identifying the size and type of transformations, ignoring the identification of factors that could have a significant impact on the landscape. Meanwhile, understanding the phenomena that lie behind a specific transformation is crucial in the context of conservation and sustainable landscape management [20]. It is one of the idea on which the analysis of driving forces of landscape changes is based [21]. It allowed to classify the main driving forces and categories of phenomena that have impact on shaping the landscape. The reason for many changes is urbanization, especially in suburban areas [22-23] which causes more and more intensive transformations. As the result of it the percentage of urbanized landscapes increases, at the expense of natural and semi natural landscapes. Other causes of changes in landscapes include also intensification of agriculture, succession of forests in abandoned areas, increased demand for service areas, development of renewable energy sources or creation of protected areas [24]. Land use policy of local authorities is also a frequent driving force of landscape change [25]. This often leads to the degradation of historically shaped landscapes that are part of the local cultural heritage, which should be an element of protection in the land use policy [26].

The acceleration of these changes in recent decades has also been noticed by the Council of Europe. The answer to this phenomenon was the European Landscape Convention [27]. The signatories of this convention, including Poland, have recognized the landscape as an important part of quality of life and a key element of the well-being of society, for which every person is responsible for protection, shaping and planning. However, despite the ratification by Poland of this convention and the obligation to implement its provisions to the Polish law. That's why no landscape and its changes in the scale of the whole country have been evaluated so that it is not possible to identify the forces and pressures that caused the transformations and their level of intensity. In this aspect a method for determination of the landscape change index has been developed [28]. However, these studies are conducted locally and not in the context of the whole country. Knowledge in this field is particularly important where the purpose and function of particular areas changes frequently, which is the result of adapting space to current social and economic needs. The areas of tourist investment are particularly located within or close to areas that are attractive in terms of visual appearance, often protected by one of the landscape protection forms. An example of this type of areas in Poland are landscape parks – areas with high landscape values, covering both forest areas as well as areas of arable land, rural settlements, and sometimes also small towns. In the context of this form of protection, the necessity of monitoring and planning changes in the landscape is emphasized [29-30].

When conducting research on landscape changes, we should always be aware that the condition of the landscape, which we are currently observing, is a physiognomic reflection and synthesis of changes caused by a number of different factors. This became the basis for the concept of driving forces for landscape changes [21, 31] also known as drives [32] or key processes [33]. These are the factors that caused noticeable changes in the landscape and have significantly influenced the direction of its further transformations. They were divided into five basic groups: socio-economic, political, technological, cultural and natural/spatial [21]. Analyzes of the causes of changes in the landscape may concern different spatial scales and different time periods. The result is also the identification of the main actors of change (people / institutions), which have a decisive influence on the change of landscape [34-35]. This research trend has been considered in many European countries. The analysis of driving forces concerned, in particular, landscapes in Switzerland [36], Germany [37], Slovakia [38-39], the Mediterranean landscape [40-41] or across Europe [42]. In the context of forest areas, analysis of driving forces usually also included areas of entire countries or regions [43-45]. Smaller areas were rarely analyzed [46]. Although in the past years, interest in research on the driving forces of landscape changes has increased significantly, there is still a lack of examples of this type of research in some European Union countries, including Poland [47]. A case study of the Ślęża Landscape Park and its buffer zone, where the protected landscape of recognized value and an important element of the Lower Silesia's cultural heritage in Poland were analyzed, supplements the knowledge of the driving forces of landscape changes in the part of Europe that is less well recognized in this respect.

For the needs of the research we assumed that forest landscape is a landscape perceived by people which is a mosaic of various land cover types with dominance of forests and which provide goods and services related to forest. The main goal of our research was to determine the impact of basic driving forces - natural and socio-economic on changes in forest landscapes in the aspect of long-term analyzes covering the period of 140 years (1883-2013). To simplify the way of defining the boundaries of forest landscapes we decided to choose as a case study area Ślęża Landscape Park and its buffer zone. We assumed that both the perception zone as well as provided goods and services related to the forest landscape of the Ślęża Massif are limited to surrounding protected area and the buffer zone. In order to achieve the intended goal, we performed comparative analyzes of topographic maps, demographic and location data available in the analyzed period, together with a summary of historical events, which we supplemented with the analysis of natural factors in the ArcGIS software. We took into account only those time sections, where all the necessary data were available.

To identify and understand the driving forces of changes in forest landscapes in the Ślęża Landscape Park and its buffer zone, our detailed objectives were:

1. determination of the quantitative changes in forest and non-forest area in 3 time intervals, covering periods 40-50 years - 1883(89)-1936(38), 1936(38)-1977, 1977-2013;
2. assessment in which time section the change of forest landscapes in the analyzed area was more intensive by determining the landscape change index (LCI);
3. classification of types of forest landscapes transformations in the studied area;
4. identification of the main driving forces that caused changes in forest landscapes.

2. Materials and Methods

2.1. Case study area

The area of our research was the Ślęża Landscape Park - one of 12 protected areas of this type in Lower Silesia with a total area, including a buffer zone, of 158.07 km^2. In terms of administration (Figure 1), it is located in the central part of the Lower Silesian Voivodship, in the south-western part of Poland. The research area covers the areas of communes located around the highest hill of Przedgórze Sudeckie - Ślęża. The largest part of the park covers the area of the Sobótka commune (about 50%) and the Łagiewniki commune (about 32%). The remaining part is located within the boundaries of the Jordanów Śląski, Dzierżoniów and Marcinowice communes. The research area is classified as the Wrocław Metropolitan Area due to its location about 40 km southwest of the capital of the region - Wrocław. The park consists of three main parts. The largest complex is the highest peak of the Sudeckie Przedgórze - Ślęża (717 m a.s.l.) separated by the Tąpadła Pass and the Sulistrowicki Stream Valley from Radunia (573 m a.s.l.), and part of the Oleszeńskie Hills. In the north-eastern part there is Sobótka - the only one small town within the borders of the study area. To the south-east of Ślęża there is a complex that includes Jańska Góra (253 m a.s.l.), and to the south-west of Ślęża there is a part covering the Wzgórza Kiełczyńskie. In total, all three parts of park occupy an area of 76.78 km2. Within the boundaries of the research area there are areas with altitudes from 114 m a.s.l. (Sulistrowicki Creek valley) up to 717 m a.s.l.. (top of Ślęża mountain). They are connected with each other with an area of 81.29 km2 - a buffer zone around the landscape park, which protects it against external threats resulting from human activity. The Ślęża Landscape Park was created on June 8, 1988 in order to preserve the landscape of the Ślęża Massif, including preservation of the local character and scale of development in historically shaped settlement units and undeveloped spaces in the open forest and meadow landscape and to protect diversified natural, geological and geomorphological values [48]. For centuries, the villages within the research area were mainly agricultural, today this function has changed into leisure and recreation – the area of the landscape park, and in particular its buffer zone have become a very popular location for summer homes for richer residents of Wrocław. The transformation of the landscape of the research area took place in relation to forest areas, agricultural areas, built-up areas and others. Forest areas have also been transformed due to the management of forest resources and the progressing process of forest succession. Currently, the area within the limits of the Ślęża Landscape Park is predominantly covered by forests (about 62%), which occupies the slopes of Ślęża, Radunia and the surrounding hills. Lower slopes and flat areas within the boundaries of the study area are used for agricultural purposes. The only city is located in the northern part of the landscape park. The remaining units of

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the settlement system are villages evenly distributed around hills among agricultural and forest areas. In total, areas covered with forest within the boundaries of the landscape park and its buffer zone currently occupy over 33%, and areas not covered with forest 67%, of which 59% is agricultural land, 7% is built-up areas, and 1% are other areas.

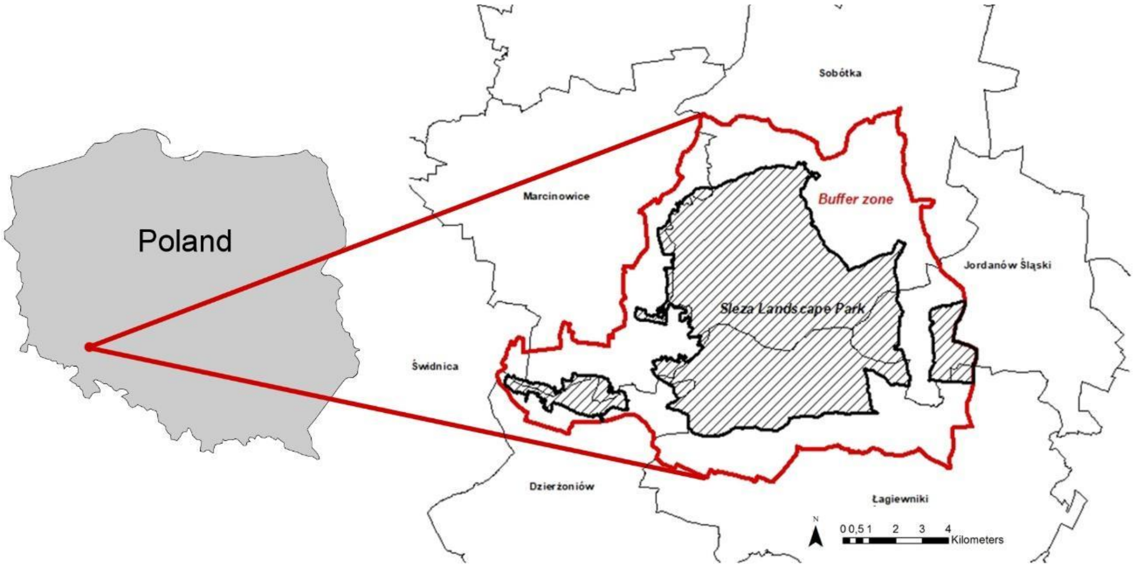

Figure 1. Location of research area

In terms of types of forest in the Park there is a division into two parts. The Ślęża Massif is overgrown with *Galio odorati-Fagetum* and *Luzulo pilosae-Fagetum* with the dominant of *Fagus sylvatica*. However, they have been preserved in a small part of their potential occurrence. Most of them were replaced by the monoculture of *Picea abies* formed in the 19th century with a dense forest stand, often devoid of undergrowth. The part of the Ślęża Massif is also covered with *Quercetea robori-petraeae* dominated by *Quercus petraea* with an admixture of *Pinus sylvestris*. The best-developed fragments of this type of forest are located on the northern and eastern part of the Park. In the northern part there is also a fragment of an old and well-preserved *Tilio platyphyllis-Acerion pseudoplatani* with rich forest undergrowth. The peak parts of the Oleszeńskie Hills, and in particular Radunia mountain overgrown with *Potentillo albae-Quercetum* and the pine forest. On the top of Radunia we can find sparse forest with the dominance of *Quercus petraea* with an unusual, dwarf form. In the remaining area there are economic forests with the dominance of *Pinus sylvestris* and admixture of *Quercus robur* and *Betula pendula*. In the forest communities of the Ślęża Landscape Park, there are also species of foreign origin such as *Pseudotsuga menziessi* or *Robinia pseudoaccacia*. Small clusters of mid-field shelters dominate the area, and small and scattered clusters of *Alnus glutinosa* and *Fraxinus excelsior* form the riparian habitat located in the valleys of small rivers. However, at the foot of hills there are numerous orchards, mostly of *Cerasus sp*., particularly attractive in spring during flowering. Some areas, formerly used for agriculture, undergo spontaneous succession gradually overgrowing, usually with *Betula pendula* [49].

2.2. Identification of changes in forest landscapes

To determine the quantitative changes in the area of forest landscapes, an adequate cartographic materials was first collected. The period of time considered in the research is dictated by the availability of good-quality cartographic materials, which made it possible to analyze changes in land cover within the boundaries of the research area. We decided to choose a series of topographic maps with the same scales (1: 25,000), which will represent 4 different time sections. We divided the analyzed period into three intervals covering approx. 40-50 years and analyzed the changes for

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1883(89)-1936(38), 1936(38)-1977 and 1977-2013. Such selection of cartographic materials made it possible to compare the data received in ArcMap 10.2.2 with each other for each period. The full collection of maps is included in Table 1.

Table 1. Collected cartographic materials on a scale of 1: 25,000 used to analyze changes in forest landscapes

Map type	Map sheets	Year
Topographische Karte (Meßtischblatt)	Zobten	1883
	Jordansmühl	1889
	Weizenrodau	1885
	Lauterbach	1883
	Mörschelwitz	1884
Topographische Karte (Meßtischblatt)	Zobten am Berge	1938
	Jordansmühl	1938
	Weizenrodau	1936
	Lauterbach	1936
	Rosenborn	1937
Topographic map of Poland	Sobótka, Mysłaków, Dzierżoniów, Jordanów Śląski, Kobierzyce	1977
Database of Topographic Objects		2013

For all historical maps used for the analysis georeferencing was given. First, a network of ground control points was evenly distributed throughout the study area. They were the least volatile elements in the landscape like the top of hills, intersections of main roads and historical buildings preserved to this day. The newest database of topographic objects form 2013 was the reference layer for the remaining maps. A rubber sheeting method of transformation called "spline" was used to calibrate the maps. It gave the best calibration results from all methods available in ArcMap 10.2.2. This type of transformation is recommended when ground control points are important and exact registration is required, however, it causes significant distortions of the maps [50-51] that can be overcome by using a dense grid of ground control points.

To analyze the changes of forest landscapes in the study area, maps showing the most visible elements in the landscape were made. Land cover was divided into two groups - areas covered with forest and areas not covered with forest. In addition, the maps show the layout of major roads and railways. In total, landscape composition was classified into 8 cover types:

A. Forest area (FA):

1. Mature forest areas, covering all areas covered with forest except young forest areas (MFA)
2. Young forest areas covering all reforested woodland areas (YFA)

B. Non-forest area (NFA):

1. Water areas, including all water reservoirs and main watercourses (WA)
2. Agricultural land covering all arable land, meadows, pastures and orchards (AL)
3. Rural development areas, including built-up and recreational areas within all villages (RA)
4. Urban development areas, including built-up areas and recreation areas in the city of Sobótka (UA)
5. Mining areas, including existing quarries and material storage areas (MA)

6. Other areas, this category applies to all other unclassified areas, such as landfills or forest parking lots (OA)

On the basis on drawn land cover maps for each time section a database was prepared contained the area of each type of land cover and its percentage share in relation to the entire analyzed area in each of the time sections. Changes in each land cover type were calculated as:

$$\Delta A_i = A_{t+1} - A_t, \qquad (1)$$

where:

ΔA_i - change in area of each type of land cover [ha]

A_{t+1} - area covered with each type of land cover during the time interval t + 1 [ha]

A_t - area covered with each type of land cover during the time interval t [ha]

In order to calculate the landscape change index (LCI) for each period, it was necessary to specify parameters showing changes in the percentage share of areas covered by each of land cover type. It was calculated as:

$$CA_i = 100x(A_{t+1} - A_t)/TA, \qquad (2)$$

where:

CA_i - changes in percentage share of areas covered by each land cover type in relation to the total area of research [%]

A_{t+1} - area covered with each type of land cover during the time interval t + 1 [ha]

A_t - area covered with each type of land cover during the time interval t [ha]

TA - total area of research [ha]

It allowed to determine the landscape change index (LCI) in each of the time intervals. It is defined as absolute values of changes in land cover elements having the greatest impact on landscape perception, assuming that both the increase and decrease of these values causes a change in the landscape [28]. It was calculated for each period of time by multiplying a factor of one-half by the sum of absolute values of changes in percentage share of areas covered by each land type cover in relation to the whole analyzed area. Summing absolute values of change of each land cover type essentially doubled the index so the LCI included a factor of one-half to reflect the actual level of change in properly way. LCI was calculated as:

$$LCI_t = \frac{1}{2} \times \sum_{i=1}^{n} |CAi| \qquad (3)$$

where:

LCI_t - landscape change index in each time interval

$|CA_i|$ - absolute value of change in percentage share of areas covered by each land cover type in relation to the whole analyzed area

Another element of the analysis was the identification of the nature and scale of individual changes related to forests covered research area. For this purpose, all polygons which were detected as change by using Clip tool in ArcGIS software were analyzed in terms of type of transformation and its total and average area. It allowed to create a classification of types and subtypes of changes in forest landscapes that took place in the Ślęża Landscape Park in the analyzed time intervals. This classification includes 3 types of changes and a total of 9 subtypes of changes related to forest landscapes:

A. Transformations within forest landscapes (temporary deforestation, maturation of forest):
   A1. Change of mature forest area into young forest area (MFA-YFA)
   A2. Change of young forest area into mature forest (YFA-MFA)

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B. Transformation of forest landscapes into non-forest landscapes (permanent deforestation):
  B1. Change of mature forest area into agricultural land (MFA-AL)
  B2. Change of mature forest area into rural development area (MFA-RA)
  B3. Change of mature forest area into urban development area (MFA-UA)
  B4. Change of mature forest area into mining area (MFA-MA)

C. Transformation of non-forest landscapes into forest landscapes(afforestation):
  C1. Change of agricultural land into young forest area (AL-YFA)
  C2. Change of agricultural land into mature forest area (AL-MFA)
  C3. Change of mining area to mature forest area (MA-MFA)

2.3. Driving forces of changes in forest landscapes

Based on the analysis of source documents - land cover maps from analyzed time sections, population censuses, local chronicles and data obtained on the basis of a digital elevation model (DEM), a potential classification of driving forces was developed that could affect changes in forest landscapes within the research area. In particular, the natural factors associated with topography and socio-economic factors were analyzed. The first group includes data obtained on the basis of analyzes of the digital elevation model (DEM) with a mesh resolution of 1x1 m obtained on the basis of a laser scanning point (LIDAR) with an average height error of 0.2 m. Digital elevation model was the basis for constructing maps of altitude, slope and exposure of hillsides by using ArcMAP 10.2.2 software with 3D Analyst extension. The second group of driving forces contains demographic changes, which were determined on the basis of demographic data collected from the population censuses of 1885, 1941, 1978, 2011 for individual villages within the boundaries of the study area. Other forces included in the socioeconomic group were distance to the main roads, 5 nearest municipalities (Sobótka, Marcinowice, Jordanów Śląski, Łagiewniki, Dzierżoniów) and built-up areas, calculated from the axis of roads, the central part of villages and towns obtained on the basis of the land cover maps developed in the first stage of research for different periods of time. The geopolitical situation in particular periods of time as well as the main historical, cultural and technological events which could be the indirect cause of the changes were also described. The main sources of data were literature and chronicles of events. The complete list of analyzed driving forces and data sources is included in Table 2.

Table 2. Analyzed driving forces of changes in forest landscapes

Group of driving forces	Type of driving force	Data source
Natural	Slope grade	Map of slope grade from DEM
	Exopsure of the hillside	Map of the hillside exposure from DEM
	Altitude	Map of altitude from DEM
Socioeconomic	Demographic changes	Population censuses from 1885, 1941, 1978, 2011
	Distance to the main roads	Land cover maps from 1883(89), 1936(38), 1977, 2013
	Distance to the municipal village	Land cover maps from 1883(89), 1936(38), 1977, 2013
	The distance to the built-up area	Land cover from 1883(89), 1936(38), 1977, 2013
Political	Political events - national and local	Chronicles of events, literature

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Cultural	Cultural events, social changes	Chronicles of events, literature
Technological	Changes in crop technology and forest management	Chronicles of events, literature

Last step was to prepare a characteristics of driving forces of landscape change for each observed type of change within the forest landscapes in each of the time intervals. Each polygon that underwent the transformations was described in terms of the dominant slope, exposure of the hillside, altitude, demographic changes of nearest villages and towns, distance to nearest major towns (with headquarter of commune council), main roads (national, provincial and county roads) and built-up areas. Then collected data was analyzed in terms of the frequency of specific features in relation to classification of changes in forest landscapes. In this way for each type of changes the main driving forces of landscape changes were determined.

3. Results

3.1. Changes in forest and non-forest land cover in years 1883(89)-2013

In order to determine the changes that took place in the landscape, four land cover maps showing the main elements of the landscape of the research area in the analyzed periods of time were prepared (Figure 2). Analyzing the changes taking place within forest-covered areas, one can notice a systematic increase in the area covered by forests in particular periods, mainly at the expense of the area used for agriculture. Within the areas covered by the forest, there were also significant transformations - some areas were temporarily deforested, some of the young forests reached a mature age. In the analyzed period, the area of rural and urban development and mining areas also increased. The table of changes in individual periods is presented in Table 3.

Table 3. Area of land cover types within the boundaries of the research area between 1883(89)-2013

Year	Forest area			Non-forest area				
	MFA [ha]	YFA [ha]	WA [ha]	AL [ha]	RA [ha]	UA [ha]	MA [ha]	OA [ha]
1883(89)	4107,1	527,9	14,1	10409,7	706,9	35,3	6,0	0,0
	25,98%	3,34%	0,09%	65,86%	4,47%	0,22%	0,04%	0,00%
1936(38)	4702,4	0,0	15,6	10238,8	750,4	87,6	12,2	0,0
	29,75%	0,00%	0,10%	64,77%	4,75%	0,55%	0,08%	0,00%
1977	4795,4	258,2	22,6	9772,0	679,7	212,0	67,1	0,0
	30,34%	1,63%	0,14%	61,82%	4,30%	1,34%	0,42%	0,00%
2013	5234,3	109,1	28,5	9227,8	774,1	317,9	111,4	3,9
	33,11%	0,69%	0,18%	58,38%	4,90%	2,01%	0,70%	0,02%

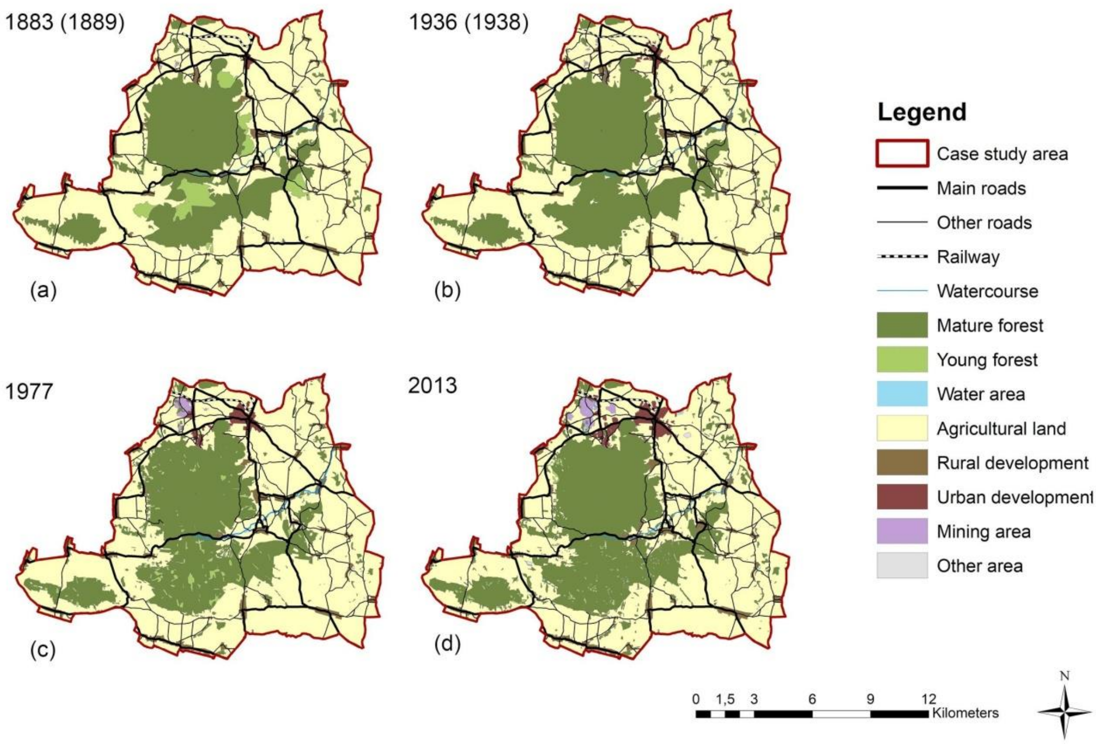

Figure 2. Changes in land cover of research area between 1883(89)-2013: (**a**) Map of land cover in 1883(89); (**b**) Map of land cover in 1936(38); (**c**) Map of land cover in 1977; (**d**) Map of land cover in 2013.

In comparison with 1883(89), the area covered with forests increased by 7.13% in relation to the whole research area. In the first of the analyzed time intervals - 1883(89)-1936(38) - there is a slight increase in the area covered with forests from 29.32% to 29.75%. However, at that time there were transformations within the forest structure - significant areas of young forests occupying 3.34% of the study area, which were planted at the end of the 19th century, have already developed a mature structure. The largest increase (2.22%) of the forest area in relation to the whole research area was recorded between 1936(38) and 1977, of which 1.63% are areas of young forests. A similar increase occurred in the period 1977-2013 - the area of forest areas increased by 1.83%, reaching the value of 33.11%. Among the areas not covered by the forest, there was a systematic increase in the areas of rural development, with the exception of the period 1936(38)-1977, when part of the rural areas were included in the city limits of Sobótka. In the same period, the mining area also significantly increased, a similar situation took place in the period 1977-2013. This is related to the expansion of one of the largest granite mines in Lower Silesia, located in the northern part of the study area. Agricultural areas decreased systematically in all periods. The largest decreases occurred in the periods 1936(38)-1977 and 1977-2013, in both cases by approx. 3%. The dynamics of changes within each type of land cover are shown in the indicators contained in table 4. The largest changes within the areas covered by the forest are characterized by the period 1883(89)-1936(38). The landscape change index (LCI) for this period of time was more than twice as high as the index for the period 1977-2013 and more than three times higher than in 1936(38)-1977. Significantly lower dynamics of changes concerned areas not covered by forest in the period 1883(89)-1936(38). The LCI was almost three times lower than in the subsequent analyzed periods. Taking into account the whole area of research, it can be noticed that the LCI in the period 1883(89)-1936(38) is comparable with the indicator from the period 1977-2013. In the first of these periods, the changes concerned mainly areas covered with forest, and in the second of these, mainly changes in areas not covered by forests.

Table 4. Dynamic of changes in land cover of the research area between 1883(89)-2013

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Time interval	Indicator	Forest area		Non-forest area					
		MFA	YFA	WA	AL	RA	UA	MA	OA
1883(89)-1936(38)	ΔA [ha]	595,3	-527,9	1,5	-170,9	43,5	52,3	6,2	0,0
	CA [%]	3,77	-3,34	0,01	-1,08	0,28	0,33	0,04	0,00
	LCI	**3,55**		**0,87**					
1936(38)-1977	ΔA [ha]	93,0	258,2	7,0	-466,8	-70,7	124,4	54,9	0,0
	CA [%]	0,59	1,63	0,04	-2,95	-0,45	0,79	0,35	0,00
	LCI	**1,11**		**2,29**					
1977-2013	ΔA [ha]	438,9	-149,1	5,9	-544,2	94,4	105,9	44,3	3,9
	CA [%]	2,78	-0,94	0,04	-3,44	0,60	0,67	0,28	0,02
	LCI	**1,86**		**2,53**					

Analysis of quantitative changes within forest landscapes, despite providing information on the scale of transformations in the analyzed time periods, does not describe the nature of the changes taking place. Therefore, as part of the research, we have also attempted to characterize the types of transformations within forest landscapes based on the adopted classification. We have found a total of 1302 areas that have changed since 1883(89). In the period 1883(89) -1936(38) the vast majority of the recorded transformations (almost 60%) is a change from areas originally used for agriculture to areas of mature forests. However, these were areas with an average polygon area of 2.6 hectares. The largest areas concern transformation within forest areas. The changes observed in 9 places with an average wing area of 57.5 ha are related to the maturation process of forests planted at the end of the 19th century. No new areas of young forests or new plantings were found in the remaining mining areas. In 1936 (38) -1977, 493 polygon changes were recorded. About half of the transformations are again connected with the abandonment of agricultural land process and the forest succession that is progressing in these areas. In 102 places there was also temporary deforestation - new areas of young forests with an average area of 2.1 ha appeared in places of mature forests. During this period, permanent deforestation is also noticeable in 106 places with an average size of 1.0 ha. However, no deforestation related to the location of new rural and urban buildings was recorded. The third of the analyzed time periods 1977-2013 is characterized by the largest total number of changes (737). The transformations concern patches with medium areas of 0.4 ha in the case of deforestation related to new rural development areas up to 2.1 ha in the case of transformation of young forests into mature forests. During this period, an even greater number of changes can be observed regarding the abandonment of further areas used for agriculture replaced with mature forest, although this occurred on a smaller total area than in the previous period. There were many temporary deforestations within the areas of mature forests and permanent deforestation in order to acquire new areas for agricultural activity. More than in previous periods, deforestation was recorded in order to acquire new areas for development and mining. A complete list of change types and subtypes is provided in Table 5.

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Table 5. Types and subtypes of forest landscape changes between 1883(89)-2013; NP: number of polygons; AS: average size of polygon; TA: total area of change.

Type of change	Subtype of change	1883(89)-1936(38)			1936(38)-1977			1977-2013		
		NP [pcs]	AS [ha]	TA [ha]	NP [pcs]	AS [ha]	TA [ha]	NP [pcs]	AS [ha]	TA [ha]
A	A1	0	0,0	0,0	112	2,1	235,2	129	0,6	82,1
	A2	9	57,5	517,7	0	0,0	0,0	116	2,1	248,8
B	B1	10	3,5	34,9	106	1,0	108,4	93	1,2	112,0
	B2	3	0,6	1,8	0	0,0	0,0	24	0,4	9,2
	B3	0	0,0	0,0	0	0,0	0,0	5	0,6	3,0
	B4	7	0,3	1,8	2	3,4	6,7	7	1,8	12,3
C	C1	0	0,0	0,0	15	0,9	14,1	26	0,8	19,6
	C2	44	2,6	116,0	243	1,6	396,2	328	0,9	310,1
	C3	0	0,0	0,0	14	0,2	2,5	9	0,4	3,7
Total number/area of changes		73	-	672,2	492	-	763,1	737	-	800,8

3.2. Driving forces of changes in forest landscapes between 1883(89)-2013

Before analyzing the driving forces of landscape changes within the research area, it should be mentioned that the Ślęża mountain has been a special place for the inhabitants of Lower Silesia since ancient times. Raised above the surrounding flat areas, it was once a place of pagan sun worship of the local tribes. At the top, the god of the sun was supposed to have its headquarters, hence the mountain was called the "Silesian Olympus". Today, the Ślęża Massif is a protected area as a landscape park, and partly as a Natura 2000 area. It enjoys great popularity among tourists as well as among the residents of the largest city in the region - Wrocław. The surrounding landscape is a factor attracting the rich inhabitants of the city, who build their second homes here. Due to the rich deposits of granite, it is also an area that has been associated with the mining for years.

3.2.1. Natural driving forces of landscape change

The natural driving forces of change include mainly climate, topography, soil types and natural phenomena, which can change the landscape very quickly and dramatically [34]. Climate change can only be an indirect driving force of change in analyzed case study. Within the research area no natural phenomena were observed in the analyzed period that could direct affect landscape changes, except for small local floods caused by heavy rains in 1964, 1997 and 2013. Type of soil did not affect the changes in forest landscapes in the whole Sudety and Przedgorze Sudeckie area [52] that's why we did not take this factor into account. Therefore, due to the kind of the research area, we assumed that among natural driving forces, the topography could be one of those that most influenced the forest landscape changes in analyzed period of time. Based on the digital elevation model (DEM), we have prepared the maps of altitude, hillside exposure and slope grade (Figure 3). It allowed to analyze the relationship between types of identified changes in particular time intervals and the landform features.

In the first analyzed period 1883(89)-1936(38) the most of the changes (27.40%) concerned areas located at an average altitude of 250 to 300 m a.s.l.. Similar level of changes were observed at an altitude of 200-250 m a.s.l.. - 23.29% and at an altitude of less than 200 m a.s.l. - 20.55%. A much smaller percentage of changes concerned areas at altitude from 300 to 350 m a.s.l. (16.44%) and from 350 to 400 m a.s.l. (9.59%). There were almost no changes at altitudes higher than 400 m a.s.l. Transformations within forest areas (type A) were mainly observed in the range 200-250 m a.s.l. It was different in the case of changes of forest landscapes into non-forest (type B), because such changes were recorded mainly at altitudes lower than 200 m a.s.l. The changes in the B2 subtype were the exception. It was connected with the extension of the mountain shelters in the Ślęża Massif.

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Changes of non-forest landscapes into forest landscapes (type C) were noticeable mainly in the range from 200 to 250 m a.s.l. and 250 to 300 m a.s.l.

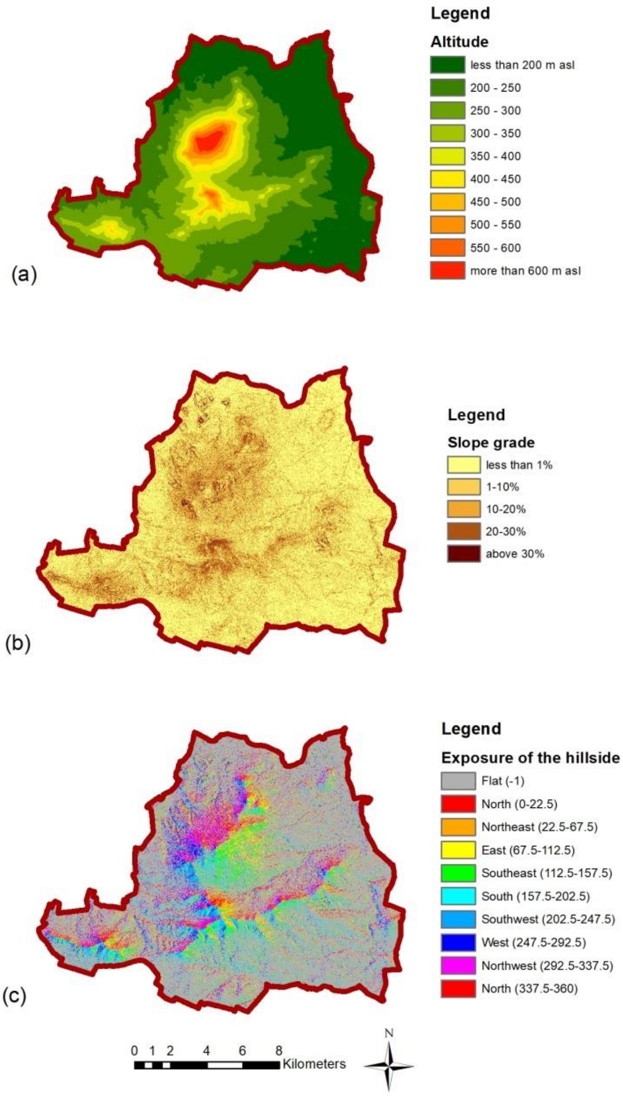

Figure 3. Maps of analyzed natural driving forces of landscape change: (**a**) Map of altitude; (**b**) Map of slope grade; (**c**) Map of hillside exposure.

In the next period 1936(38)-1977 it was noticeable the reduction the percentage of changes to 14.23% which concern transformations at altitude less than 200 m a.s.l. More changes were observed in the ranges from 200-250 m a.s.l. (28.86%) and 250-300 m a.s.l. (29.88%). The percentage of transformations at altitudes above 350 m increased as a result of changes within forest landscapes (type A). The largest number of such changes occurred mainly at altitude from 250 to 350 m a.s.l. Transformations of forest landscapes into non-forest (type B) and non-forest landscapes into forest (type C) dominated at altitude from 200 to 300 m a.s.l.

A similar percentage of changes is noticeable in the third analyzed period 1977-2013. Most changes were in the ranges from 200 to 250 m a.s.l. (27.68%) and 250-300 m a.s.l. (26.73%), while in areas below 200 m a.s.l. the changes were slightly more frequent (16.15%) than in the previous period. On the other hand, the percentage of changes observed at altitudes higher than 350 m a.s.l. has increased. The highest location of transformation were observed at altitude 550-600 m a.s.l. When we look at the types of changes, it can be noticed that transformations within forest areas (type A) started to dominate at 300-350 m a.s.l., while a larger percentage of forest landscape transformations into non-forest ones (type B) was recorded at lower altitude form 200 to 250 m a.s.l.

The second analyzed factor was the average slope of the changed area. In each of the analyzed periods, about 65% of observed changes concerned areas with an average slope in the range of 1-

10%, while 31% of landscape transformations took place on slopes with an average grade of 20-30%. The situation is similar for the third factor – the dominant hillside exposure. The percentage share of changes was at a similar level in all analyzed periods of time. Among the areas where the flat surface doesn't dominate the most changes were observed on the northern and north-eastern exposure of the hillside (from 4.11% to 10.96% of all changes), and the least on the western, north-western and south-western exposure of the hillside (from 0 to 2.85% of all changes).

3.2.2. Socioeconomic driving forces of landscape change

The group of socioeconomic driving forces of landscape changes includes, among others population changes [53] or distances to roads, well-known facilities, places or local service centers [54]. In the context of population changes we analyzed number of inhabitants of 30 villages and Sobótka city located within research area. The basis for it were population censuses from years close to analyzed time intervals – 1885, 1941, 1978 and 2011.

The number of people living in the study area in 1885 was 17727. The majority were rural population where lived 15383 people. Only 2,344 people lived in Sobótka city at that time. The number of residents grew slightly to 17819 in 1941. The increase in the population of the city of Sobótka to 3412 inhabitants was noticeable as the effect of migration from neighboring rural areas. The number of inhabitants of rural part of the study area significantly decreased to 1978 as a result of population losses and mass displacement of native inhabitants in the post-war period. The total population was 15772 in 1978. 6043 people lived in the Sobótka city and 9729 in the rural areas. There was an increase in the total population to 16,339 people in 2013. The population of the city of Sobótka increased to 7030 people, and the number of inhabitants of rural areas decreased to 9.369 people. The changes of population of each village in rural part of study area are shown in Figure 4.

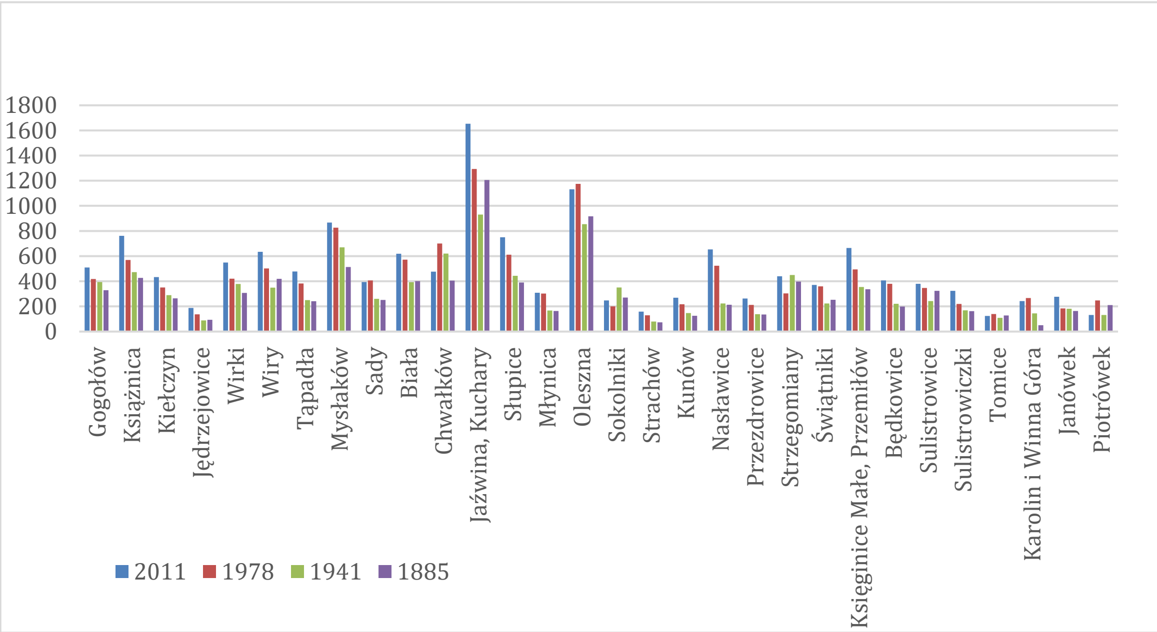

Figure 4. Population changes in rural areas of Ślęża Landscape Park

The next step was to analyze the distribution of the observed changes in particular precincts. It showed that the most of the transformations were identified within Sobótka precinct, where Ślęża mountain is located, and within Jaźwina, Tąpadła and Słupice precinct, where the Radunia mountain is located. Calculations the number of changes per 1 ha showed that the most changes were recorded in Sady, Sulistrowiczki, Biała and Tąpadła, and the least in the areas of Tomice, Janówek, Oleszna and Strzegomiany Comparison of this indicator with population changes showed that the least changes were observed in those areas where the number of inhabitants in particular periods did not change significantly. The largest number of changes were identified in those precincts where population changes were more noticeable.

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To answer the question whether distances to roads, built-up areas and centers of municipalities could have been one of the driving forces of forest landscape changes, each polygon was classified into appropriate distance classes based on prepared maps (Figure 5).

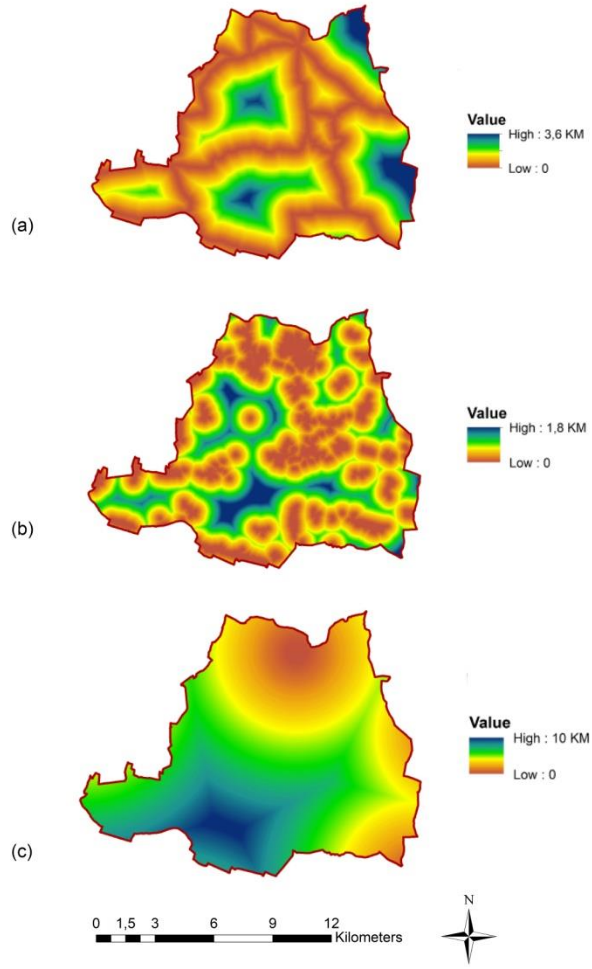

Figure 5. Maps of analyzed socioeconomic driving forces of landscape change: (**a**) Map of distance to main roads; (**b**) Map of distance to built-up area; (**c**) Map of distance to the center of municipalities

The first analyzed factor was the distance of areas that have changed from the centers of the surrounding municipalities. Five locations were considered – Sobótka, located within the research area, Łagiewniki, Marcinowice, Jordanów Śląski and Dzierżoniów, located outside the research area. In all analyzed periods, the highest percentage of changes concerned areas located at a distance of 6-8 km from the centers of municipalities (from 32.88% to 39.43% of all changes). The fewest changes were observed at a distance of less than 2 km from the center of municipalities (from 2.74% to 3.80%) because only 1 municipality is located within the research area. The largest differences between the analyzed periods were noticed in the case of location of the changes at a distance more than 8 km. In the period before World War II, the percentage of this type of transformations was 27.4%, in the next period decreased to 17.89% and in 2013 it increased to 24.02%. Changes in the forest areas (type A) were most frequently found at distances of 6-8 km and more than 8 km from the centers of municipalities. The percentage of changes at a distance more than 8 km increased in each subsequent period. Changes of forest landscapes into non-forest (type B) can be observed at a similar level in distances 4-6 and 6-8 km from the centers of municipalities. In the case of transformations of non-forest landscapes into forest landscapes (type C), the vast majority concern the distance of 6-8 km.

The second factor that could have influenced landscape changes was the distance from the main roads. In this context, changes were most frequently observed in all analyzed periods at distances up to 500 m (from 31.91 to 35.62% of all changes) and from 500 to 1000 m from main roads (from 28.77% to 39.73%). However, when we compared the periods, a systematic increase in the percentage of

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changes at greater distances from the main roads is noticeable. At a distance of 1500-2000 m, the percentage of changes increased from 4.11% in 1883(89) to 10.85% in 2013, and in the distance of 2000-2500 m from 0% in 1883(89) to 4.21 % in 2013. The percentage of changes observed at a distance of 500-1000 m from main roads decreased from 39.73% in 1883 (89) to 28.77% in 2013. The dominance of changes within forest-covered areas (type A) is characteristic at distances of 500 to 1500 m from the main roads although in the larger distances the increase of the change effect is noticeable. Transformations from forest landscapes into non-forest ones (type B) were recorded mainly at a distance of less than 500 m and from non-forest to forest landscapes (type C) also at a distance of 500 to 1000 m from the main roads.

The last element of the analysis was the distance of observed changes from built-up areas. In this aspect the ratio of changes located less than 250 m from built-up areas (about 30%) is maintained at a similar level in all periods On the other hand, the percentage of changes at a distance of 250-500 m decreased systematically from 30.14% in 1883 (89) to 21.44% in 2013. In the same time the transformations located in distances greater than 750 m from built-up areas increased. Most changes in forest areas (type A) could be observed at a distance of 750-1000 m from built-up areas, fewer were located at distances of 500-750 m and 1000-1250 m. The vast majority of forest landscapes transformations into non-forest (type B) covered areas less than 250 m from built-up areas. Similarly, in the case of changes in non-forest into forest landscapes (type C), the highest percentage of changes was observed at a distance of less than 250 m, as well as at a distance of 250 to 500 m from built-up areas.

3.2.3. Political, cultural and technological driving forces of landscape change

In order to fully understand the changes that took place in forest landscapes during the discussed period of time, it is also important to consider changes in the broader context of the political environment, cultural and technological events. The political and technological driving forces of landscape changes in 1883(89) -1936(38) include the change in forest management policy. After a period of very strong forest exploitation in the 18th century and the beginning of the 19th century, the defeat of Austria (1866) and France (1871), the demand for wood in Prussia decreased significantly. Additionally, as a result of the inflow of capital from war contributions, the sale of state forests was stopped. At the end of the 19th century the Prussian government started to buy the forests from the Polish owners. Gradually due to the use of the development of modern forestry sciences, which occurred at the end of the 19th century, the level of forest cover increased. The reason for this was a favorable tax policy, as a result of which large areas of land of poor quality, unsuitable for agriculture were afforested The use of appropriate tax rates indirectly protected forest landscapes, especially in mountain areas [55]. This situation persisted until the outbreak of the First World War, which was another important political event affecting landscape changes. Other important technnological event was new railway line from Wrocław to Sobótka built in 1885. The line was extended in 1898 to Świdnica. It influenced the development of the city in the northern part, but also enabled the intensification of the extraction of minerals. At the beginning of the 20th century, a new hostel was built on the top of Ślęża and a view tower on the top of Wieżyca, which contributed to increasing the interest of tourists arriving by rail from Wrocław [56]. During the period of strong development of the German economy at the end of the 1930s, and then during the Second World War, the demand for wood increased again and as a result some areas were deforested. After the end of Second World War, the geopolitical situation changed completely. Lower Silesia has become a part of Poland. The population was displaced - people from the eastern part of pre-war Poland came to the research area. As a result of the development of natural sciences, the top of Ślęża mountain has been protected since 1954 as a nature reserve. A year later, a mine management company was set up in the northern part of the research area, and thanks to that a strong development of the mineral extraction area took place. In 1973, two neighboring rural areas were included in the city limits of Sobótka. In the last analyzed period there were also important political and cultural changes. In 1989, the political system in Poland changed, ending the period of communism over 40 years. An important event that indirectly stopped some forest landscape changes was also the establishment

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of a landscape park of the entire area of the Ślęża Massif in 1988. Gradually, society's consciousness about natural values began to change. In 2004, Poland joined the European Union, which was another indirect cause of change. Due to the subsidies for afforested poor quality arable land within the study area, new forest areas have begun to appear quickly.

4. Discussion

Land cover analyzes showed that the area covered by forests within the present limits of Ślęża Landscape Park increased systematically from 29.32% at the end of the 19th century to 33.80% in 2013. A similar situation took place in the context of the entire Sudeten area [52]. Research indicates an increase in forest area from 30.4% in the 18th century to 36.4% in the 20th century. Increase of the area covered with forests is observed also in other mountain areas in Poland. The example of this process may be the Beskid Mountains, where area with the dominance of forest landscapes also increased [57]. However, despite the increase of the forest area, the percentage of forest-covered area still remains smaller than in other mountain and foothill areas [58], at the same time it is higher than in lowland areas [43]. This is the effect of rather low altitude of the area, which favors agricultural land use, especially it concerns areas below 200 m a.s.l.

The level of changes of forest and non-forest landscapes in particular periods indexed by landscape change index is difficult to compare with other research results, because studies using this index have not been used to analyze historical data, but only contemporary data [39]. Considering the nature of the indicator used, based on relative data obtained on the basis of cartographic analyzes, its comparison with other areas would be possible only if the same source materials were used. One should also be aware that the source materials, although they have the same scale, differ in terms of their purpose (administrative, military maps, etc.), the used signs or the degree of data generalization. In addition, the analysis may have some errors, which may be the result of inaccuracies during georeferencing, errors during the map creation or their processing. It should be assumed that the accuracy of the data increases when more advanced methods for interpretation and processing of field or aerial data can be used. Therefore, there is a difference in the number of changes read on the basis of prepared land cover maps. It grows in successive periods. In the first analyzed time interval only 73 polygons representing changes in land cover have been identified, in the second period 492 and in the third 737. Because of differences in possibilities to obtained data of the same scale and degree of data generalization results of research should be interpreted with use of relative rather than absolute data [59].

In the context of analyzes of the character of changes and their driving forces, it should be emphasized that topography remains the basic factor determining the land cover of the research area. The slopes of Ślęża and surrounding hills have been covered with forests for years, settlement areas are developing at the foot of hills, while arable land dominates in flat areas. As the basic driving force behind changes in forest landscapes, weak soils are mentioned in literature [60], however, as shown by Szymura et al. [52] in the area of the Sudety soil types did not have a significant impact on landscape changes. Investigations of the driving forces of changes in forest landscapes mainly concern the Carpathian area [19,58,61], less frequently its Polish part [57,62]. There is little research on the area of the Sudetes and their foothills. Generally, there is a lack of research in Poland that would allow comparison of obtained results with other research. This is confirmed by Plieninger et al. [47] who show that from 144 analyzed articles which identify driving forces of landscape change across Europe only 4 refer to case studies located in Poland. In neighboring Germany, Czech Republic or Slovakia the number of such studies is much higher.

5. Conclusions

The studies of the area covering present borders of Ślęża Landscape Park relating to the landscape changes in the period 1883(89)-2013 show that the percentage of area covered by forest has systematically grown since the end of the 19th century. Determination of the landscape change index for areas covered with forest revealed that the highest value concerned the first analyzed period of time 1883(89) -1936(38). In the second period 1936(38) -1977 it was over three times lower, and in the following 1977-2013 two times lower. It shows that the scale of changes in landscape in the first period was the highest. Here we should look for the main driving forces of changing forest landscapes. In this case these socio-economic forces were the most important, which is confirmed by the sources of literature. Significant changes in the area covered with forest were the result of afforestation in large areas in the second half of the 19th century and the process of forest maturing in the following years. This was the result of the development of forestry science in Prussia, the introduction of favorable taxes for owners of afforested lands that are of little use to agriculture. It indirectly protected forests from deforestation. In the analyzed period of time, the area of arable land was systematically decreasing, and the development of rural and urban areas as well as mining areas took place. Landscape change index shows more changes within areas not covered by forest in the period 1977-2013, when the development of rural and urban development areas on arable land was the largest.

Analysis of selected natural driving forces of landscape changes revealed that the features of terrain are a decisive factor in the structure of forest landscapes and their changes. Transformations within areas covered by forest (type A) in the first analyzed period concerned the altitude of 200-250 m a.s.l., in the next occurred mainly at the altitude of 250-350 m a.s.l., and in the third period they began to dominate at the altitude of 300-350 m a.s.l. It can be noticed that in each subsequent period changes were identified higher. Changes of forest landscapes into non-forest (type B) and non-forest to forest landscapes (type C) dominate in all periods at the altitude of 200-300 m a.s.l. On the lower-lying areas, these changes are less frequent due to the increased area of arable land. The landscape remains little changed at altitudes greater than 350 m a.s.l. More susceptible to the changes are areas with a slope from 1 to 10% and the north and north-eastern exposure of hillside which characterized by less sunlight.

Analysis of selected socio-economic driving forces of landscape change showed that stabilization of the population in the analyzed period had an impact on reducing the number of changes observed in the landscape. In areas where changes in the population were greater, more landscape changes were also observed. Transformations in forest-covered areas were the most common in the areas farthest away from the centers of municipalities, at distances of 6-8 km and over 8 km. Distances of 4-6 km and 6-8 km dominated in the case of other types of changes. The distance to main roads and built-up areas is also important for the distribution of change types. Transformations within forest landscapes usually occurred at a distance of 500-1500 m from main roads and 500-1250 m from built-up areas. Changes of forest landscapes into non-forest dominates at distance less than 500 m from main roads and less than 250 m from the built-up areas. Changes of non-forest landscapes into forests were commonly identified at a distance of 0-1000 m from major roads and at a distance of 0-500 m from building areas.

In the case of other driving forces, the construction of the railway line at the end of the 19th century was very important driving force behind landscape changes. It also resulted in a significant increase in the population within the Strzeblów village (today, part of Sobótka city). The establishment of nature reserve covering the highest part of Sleza mountain was also affected by limiting changes in landscapes at altitudes higher than 400 m. The effect of it are more frequent changes within forest areas on the slopes of Radunia mountain. The background for changes in the landscape were geopolitical transformations after the First and Second World Wars, the fall of communism and the accession of Poland to the European Union. Gradually, the material status of the population increased, and access to various types of goods, including cars, was facilitated, which significantly increased anthropopression on valuable areas in terms of landscape values.

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