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Spatial, Functional, and Landscape Changes in a Medium-Sized Post-Industrial City Based on Aerial Photo Analysis: The Case of Gorlice (Poland)

Dorota Wantuch-Matla [1,*], Sławomir Dorocki [2] and Rafał Kroczak [3]

[1] Faculty of Architecture, Cracow University of Technology, 30-084 Kraków, Poland
[2] Institute of Law and Economics, Pedagogical University of Krakow, 30-084 Kraków, Poland; sdorocki@up.krakow.pl
[3] Institute of Biology and Earth Sciences, Pedagogical University of Krakow, 30-084 Kraków, Poland; rafal.kroczak@up.krakow.pl
* Correspondence: dorota.wantuch-matla@pk.edu.pl

Abstract: The article presents the spatial-functional transformations of a medium-sized post-industrial city in the context of the decline in the industrial function which used to occupy a prominent position in the city. The research attempts to answer the following questions: (1) What has been reflected in the spatial and functional development of the city and its landscape by the dynamic transformations in the industrial sector that have taken place since the 1970s, playing out in the broad context of the specific political and socio-economic conditions? and (2) how is the city dealing with post-industrial sites—are we dealing with a 'post-industrial scar' or a process of their adaptation to the needs of the present? Analyses were initiated to identify differences in spatial and landscape structure from 1966 to the present. To this end, a land cover analysis was carried out based on available sets of aerial photographs taken in four selected years within the study period, as well as a calculation of the index of variation. Graphical and GIS software (QGIS 3.28.4 version) and methods of statistical data analysis were used. To come up with a full picture of transformations in the second half of the 20th century, an outline of the historical spatial development of Gorlice and the local oil and engineering industry was presented. The results of the research confirm the relationship between the functional and spatial development of the city and the transformation and condition of its industrial function.

Keywords: aerial photo analysis; city; Gorlice; land cover; landscape; landscape changes; land use planning; Lesser Poland Region; Malopolska; medium-sized city; Poland; post-industrial heritage; spatial-functional changes

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1. Introduction

The industrialisation of cities, whether it was the first one on the turn of the eighteenth/nineteenth century or occurred in subsequent centuries (Industry 2.0) [1] always leaves lasting and long-term traces in the development of their spatial structures, as well as in their history and the characteristics of their communities [2]. The experience of the transformation of an industrial city into a city from which the industrial function begins to withdraw is often an experience of social, spatial, and functional trauma. It is a kind of shock caused by the transition from the prosperity of the city to its decline and unemployment, and the leaving of 'post-industrial scars' in the city's landscape [3,4]—including abandoned sites and post-industrial buildings. The oil crisis of the first half of the 1970s and the ensuing economic recession coupled with a collapse of a single, stable, and global financial system forced the replacement of rigid and rather inflexible forms of production organisation with more flexible and adaptable ones [5,6].

Much of the literature on this aspect is devoted to large cities, particularly since it has become evident that the overwhelming majority of the globe's population lives in

cities [7–9]. Meanwhile, the fact that as much as 56% of the world's population live in medium and small cities [10] of 5000–100,000 inhabitants is somewhat less frequently addressed [11]. Small- and medium-sized cities (SMSTs) play an important role in their region, and their specific administrative, morphological, and local policy-related conditions require more research [12].

In the context of contemporary socio-economic and climatic challenges, we are also witnessing an increasing importance of the multifaceted notion of urban resilience in the sense of resilience and the ability to respond to negative, sudden events and changes [13]. Undoubtedly, the process is worth considering not only in the context of global urban centres, but also the medium and small ones [14]. The situation of an industrial decline also observed in smaller European centres in the last decades of the 20th century can serve as an interesting case study. Many cities are still struggling today, as they are challenged by various consequences of the industrial collapse arising from their strong dependence on industrial function, strong specialisation, lower rank in the administrative hierarchy, smaller budgets, demographic collapse, outflow of inhabitants to larger cities, and lack of concepts for new developments, etc. [15]. Their situation at particular moments in history should be viewed as a kind of continuum of natural and historical as well as political factors [16] (p. 13). A collapse of the industry leaves traces in space as well as in the socio-economic layer. This is critical for the local labour market and the city's finances, while leaving behind areas of technical infrastructure. In turn, the infrastructure represents a serious issue related to the degradation of the natural environment [17].

In Poland, the development of many industrial centres of various scales occurred in the period before and after World War II. A particularly strong stimulus for the development of the industrial function in small and medium-sized cities was a Four-Year Plan, the national economic development plan, which entailed setting up of the so-called Central Industrial District. The development of infrastructure and industry affected the development of many underdeveloped towns and cities (gasification, electrification, etc.), as well as the creation of many new valuable spatial connections of a supra-regional nature [18–21]. Socialist plans, related to the reconstruction of cities or the strategic distribution of industrial centres across the country, also served as an important element of industrial development in Poland [22]. This picture is superimposed on the socio-economic transformations that took place after 1989 and encompassed the whole of Eastern Europe [23].

In this context, the case of the city of Gorlice (Figure 1), analysed in the study, is a unique kind of "decline study", which also provides an opportunity to observe and assess post factum transformations. This is because it is a centre whose industrial function developed on the basis of locally existing natural resources. The industrial function continued to develop even after the resource extraction ended, according to the concept of path dependence [24–26]. Small-scale industrial and manufacturing functions had developed locally for hundreds of years [27] (pp. 13–53) [28,29]. They were mainly related to textile crafts, as well as trade and non-agricultural activities. At the turn of the nineteenth and twentieth centuries, based on the discovered oil deposits, Gorlice became one of the most powerful industrial centres both locally and supra-locally and regionally, as part of the then Austro-Hungarian Galicia (Figure 2). The 1860s marked the beginning of what is referred to as the 'Golden Age of Oil' in the Gorlice region. The oil industry helped to transform all aspects of the local socio-economic life, transforming the landscape from rural to industrial [30]. At the dawn of the twentieth century, Gorlice was a thriving industrial centre in the Subcarpathian region, where one of the region's largest oil refineries and a drilling tool factory were built after the discovery of rich oil deposits in the area. At the end of the 19th century, the population of Gorlice was more than 6000, which, at the time, meant that it ranked among the largest cities in Galicia [31]. This process also influenced the growth of the region's human capital and the professional activation of the region's inhabitants [32].

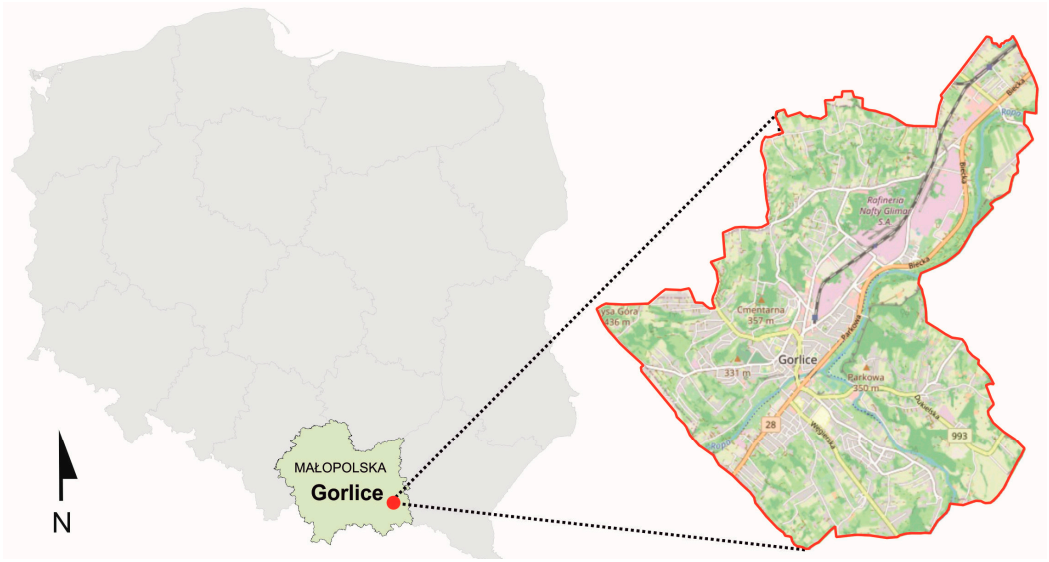

Figure 1. Location of Gorlice city and Malopolska Region in Poland (original work prepared with elements of Google Maps imagery).

Figure 2. The view of the Gorlice city hill with the Ropa river. (Source: National Digital Archives. Public Domain. Access: 14 March 2023).

Subsequent historical events, such as the First World War, political changes in the mid- and late 20th century, and economic turbulence, ultimately led to the decline of the oil industry and the drilling industry, and to significant changes in the Gorlice's key functions.

However, note that the local oil extraction, processing and mining industries were at the core of the city's economic development. The prosperity of the city is closely linked to the development of this industry and falls into the second half of the 20th century. In 1945, 1200 people worked in Gorlice's industry, while 6499 people worked there in

1956 [33]. In 1979, during the period of the greatest development of the industrial function, almost 80% of the city's employees worked in this sector. In 1988, the Glinik Drilling and Mining Machinery Factory alone employed 6903, while the refinery in Glinik Mariampolski (Gorlice) employed 882 people [34]. Note that the employees of Gorlice's industrial plants also came from neighbouring municipalities, in particular those located to the south, west, and east of the city. In 1957, about 60% of the employees of the industrial plants in Gorlice were farm owners and, thus, residents of nearby villages [33]. In the 1970s, Gorlice became the main industrial centre in south-eastern Poland [35]. Apart from the mining-related factories, the development of the Gorlice industrial centre was also based on the household appliance manufacturing and woodworking industries, which in total gave employment to more than 10,000 people in the 1970s [36].

Employment in industry remained very high (11,893 people in 1981, which accounted for 67% of the city's total workforce), and the number of employees was almost the same as in the city of Nowy Sącz—2.5 times the size of Gorlice (12,300 people employed in industry in 1981, 32% of the city's total workforce) [37].

As industry developed, the morphology of the city changed. Housing estates for the workforce were built alongside the industrial plants. The service infrastructure for the new residents also developed, including a new hospital. In the following years, new housing estates were built on the outskirts of the city. Furthermore, single-family housing on the outskirts of the city was developing [38].

Despite the rather buoyant development of the oil industry in Gorlice in the 1980s and 1990s, there was a gradual decline in the share of employment in this sector of the economy, which particularly intensified in the period from 1988 to 1995 [37]. Finally, at the beginning of the 21st century, as a result of socio-economic changes, Gorlice collapsed as an industrial city. During this period, employment fell by half, from 20,276 in 1981 to 11,259 in 2003 [37]. In parallel, the impoverishment of the entire population of the region spread, mainly as a consequence of increasing unemployment which, early in the 21st century, was one of the highest in the region [39].

The objective of the research analyses presented in this paper was to answer the following questions: (1) what reflection in the spatial and functional development of the city and its landscape came from the rapid transformations in the industrial sector since the 1970s, playing out in the broad context of specific political and socio-economic conditions? (2) how is the city coping with post-industrial areas—are we dealing with a 'post-industrial scar' or a process of their adaptation to the realities of the present day? This study fills a research gap in the existing analyses of the land use change in small and medium-sized post-industrial towns in Central and Eastern Europe.

2. State of Research

The issues of development and functional and spatial, but also socio-economic transformations in Polish small and medium-sized cities have aroused particular interest among researchers in the twenty years of post-1989 system transformation. An exceptionally large number of publications come from this period [14,15]. This is because, at that time, Poland was undergoing transformations that were relatively easy to present on the example of the smallest centres. For example, a close-down of a large industrial plant often led to a complete change in the economic profile of a city, much faster than the development of services and commercial activities in cities. During the analysed period, the agricultural function in cities clearly weakened or even disappeared [15,40–47]. Research by the Central Statistical Office (CSO) in 2016 showed that small cities (less than 20,000 inhabitants) accounted for as much as 80% of all cities in Poland [48]. Available data on the CSO resources website indicate that, in 2021, there were 354 medium-sized cities (20–100,000 inhabitants) (including 206 cities in urban–rural municipalities), of which 24 centres had between 20–35,000 inhabitants [48]. Their large number is an important argument for the continuation of studying their transformations and condition.

The issue of urban functions and the study of their transformation became the subject of extensive discussion at the turn of the 20th century, when the foundations of urban planning as a science of building and designing cities were being developed [49]. The topic of the functions of cities and their distribution in the spatial structure of cities is an issue that has been described quite widely and extensively for decades in various approaches, e.g., settlement geography [50–54] and economic [55,56], demographic [57,58], sociological [59,60], and urban planning [54,61–63]. The functions of a city can be researched by using a variety of methods, including urban land use analysis [64], population employment analysis, and the demographic structure of populations living in or using an area [65]. Contemporary research also brings many innovative methods for the identification and transformation of urban functional zones, using, among others, remote sensing imagery, GIS technology, density estimations, cluster analysis, etc. [66]. In the urban planning approach reflected in urban planning documents (zoning and development plans), the main urban functions are usually listed, including downtown (central), service (social and public administration, commercial), industrial, manufacturing and warehousing, technical, communication, open or green spaces, and residential of different intensities and typologies [62,64,67]. These classifications sometimes vary depending on the purpose of the application and local specificities and planning considerations [66,68].

Typically, the topic of the transformation of the industrial function in small and medium-sized cities appears in the context of examples of brownfield redevelopment [3,14,69–73]. There are also publications analysing single or compiled examples of transformation in selected centres [74]. Many publications deal with successful scenarios for the transformation of post-industrial sites and their adaptation to modern conditions and new functions and needs [75–78]. However, we can also find some that examine changes in the agricultural landscape on the fringes of urban sprawl [79,80].

The use of archival and contemporary aerial photography is a method offering valuable information on past or baseline landscape conditions, making them useful for mapping, understanding, and monitoring change over time [80–82]. Images of this type have been used for many decades in scientific research in a variety of approaches, including, but not limited to, observations of the transformation of urban structures [83–85], including on the basis of comparisons of historical and contemporary images [86], land use and land cover transformations [64,87,88], and landscape ecology and transformation [80,89–93]. Significantly, there is a publication presenting the results of a land cover structure study based on aerial photographs for Gorlice. However, it only analyses the central part of the city and its surroundings and three images from different years: 1915, 1997, and 2009 [94]. Research on the development of the urban industrial area as the main axis of reference in relation to the development directions of other categories has not yet been carried out.

In the above context, one may conclude that the case of the city of Gorlice awaits a multi-level and complex description. As for transformations of the local urban layout, valuable information on spatial and architectural transformations of the city is provided by publications authored or co-authored by the former city architect of Gorlice, Józef Barut [27,28]. The theme of the functional and spatial development of the city of Gorlice in urban planning and conservation terms has so far been most thoroughly described by Kazimierz Kuśnierz in his publication, making a very detailed analysis and synthesis of historical knowledge about the city, as well as archival cartographic and iconographic data [95]. The publication 'Jaśliska in the Middle Ages against the background of the cities of the former Biecki district' [96] may also be used as a valuable reference. There are also some publications focusing on the architecture and landscape architecture of the city of Gorlice, including local cemeteries and war cemeteries [97–99]. Publications on Gorlice, however, often appear in a historical context, in particular in the context of the World War One and one of the greatest battles of that time, fought in 1915 [98–101]. There are, however, rather more publications on the industrial development of Gorlice in the context of similar processes occurring in the Małopolska region [30,102,103], with some of them referring exclusively to Gorlice. Similarly, there are promotional materials and studies describing

the development of the city and the events that followed against the background of local socio-cultural conditions [29,104]. Maria Dobrowolska wrote about the development of industry in Gorlice from a geographical perspective in the 1960s as part of her research on the geography of settlements in southern Małopolska [105]. In view of such an interestingly conditioned case of a small post-industrial city, like Gorlice, the lack of studies in English is definitely noticeable.

3. Materials and Methods

This study focused on the area within the administrative boundaries of the city of Gorlice. The study included an analysis identifying differences in spatial and landscape structure from 1966 to the present. The temporal scope of the study was determined by the availability of aerial photographs for the study area, presented on the National Geoportal website [106]. The availability of the photographs was also a condition for distinguishing four analysed historical moments, specifically 1966, 1977, 2000, and 2020. Within that time frame, there is a date which marks the political and system change in Poland: 1989 was the start of the phase of regression in Gorlice's industry.

The aerial photographs of individual fragments of the city were collated into a single image using the Adobe Photoshop graphics programme, then imported into QGIS using the Georeferencer function and processed to carry out an estimated, quantitative, and simplified analysis of spatial, functional, and landscape transformations. In the process, 3 main typological groups relating to generalised land use categories were selected. In the group focused on the built-up of the land, there were (a) higher density built-up areas (dark brown) characterising the city centre, but also located outside it, (b) medium- and low-density built-up areas (light brown), and (c) industrial–service built-up areas (purple). In the group of biologically active areas, there were (a) forest areas (dark green), (b) areas of cultivated fields and meadows (light yellow), (c) other green areas (medium green), and (d) rivers. In the third group, there were road transportation routes and squares and paved areas as communication areas (Figure 3).

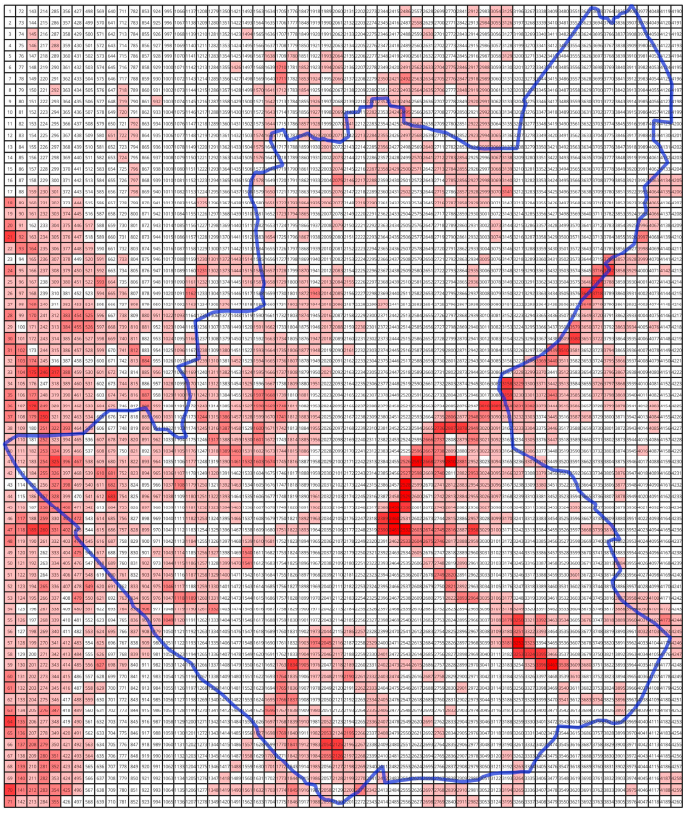

Figure 3. Layout of polygons with sample control values (original work).

It is worth mentioning at this point that the generalisation of the LC classification adopted in the study is based on data from the Polish Database of Topographic Objects (BDOT10k), which is a collection of digitised spatial information with a wide thematic scope. For LC, it provides for 3 main levels of classification: land cover classification (level 1), by object class name (level 2), and by object names (level 3, the most detailed). Within level 2, there exist twelve classes: surface waters, built-up areas, forests and wooded areas, bushes, permanent cultivation, grassland vegetation and agricultural crops, land under roads, railways and airports, unused lands, squares, landfills, pit and heap, and other undeveloped land. Most of them are too detailed to be distinguished from the aerial imagery, and, furthermore, too detailed to give an adequate image of the functional changes over time. Given the limitations of the possibilities of the aerial photo interpretation process, for the purposes of the study it was decided to create even more capacious categories (Table 1). Categories were created to take into account those aspects most relevant to making the assumed observations of changes in the structure and main functions of urban areas and their landscape specificity (e.g., low- and high-density built-up areas).

Table 1. Colour coding for land cover interpretation of aerial photographs (original work). Areas designated as those of medium and low density also include a variety of functional types: single-family housing, multi-family housing, mixed-use, commercial and public services, etc. The predominant type here is single-family housing, including farmsteads.

MAIN TYPOLOGICAL GROUPS RELATING TO GENERALISED LAND USE CATEGORIES AND THEIR COLOR CODING		
BUILT-UP AREAS		
a.		higher density built-up areas
b.		medium density built-up areas
c.		industrial service built-up areas
BIOLOGICALLY ACTIVE AREAS		
a.		areas of cultivated fields and meadows
b.		forest areas
c.		other green areas
d.		rivers, streams
COMMUNICATION AREAS		
a.		road transportation routes, squares and paved areas

The downtown development area marked in the maps prepared for the occasion (a yellow line) is located in the zone protecting the historic urban layout of the so-called Old Town Complex, which is, at the same time, an archaeological supervision zone, identified in the local spatial development plan (SIP). Higher intensity development areas cover both the centre of Gorlice and its surroundings. They are characterised by a large formal and functional diversity. The above-mentioned Old Town Complex is dominated by services, multi-family housing, and public services, with a small admixture of low-intensity development. The predominant development in the area tends to be compact and quartered, although there is also multi-family block housing, as well as public utilities and services in the near vicinity of the central part of the city.

On the basis of the typology, vector land cover maps were produced for the individual periods, and subsequently transformed into raster form (1 × 1 m). A grid of regular squares with a side of 100 m (2493 polygons covering the entire city area) was then created, which was superimposed on the land cover map, and the share of each class in the grid was checked (Figure 3). This was repeated for each period. All calculations were made in QGIS

software (3.28.4 version), in the ETRS89/Poland CS92 coordinate system (EPSG code 2180). A data table was then created, showing a given land cover type occupying a part of the area of a given polygon. Relative values were then calculated to exclude differences in square footage in the case of boundary polygons where the city boundary runs through.

In order to determine the most powerful changes in the land cover in the city of Gorlice, the land cover structure change (LC) (1) index was used [107]. For this purpose, the change in land cover structure was calculated for the analysed based on the odds ratio and the logit function. Equation (1) is as follows:

$$LC = \sum_{n=1}^{n=N} \left| \frac{\log\left(\frac{P_n(A)}{1-P_n(A)}\right)}{\log\left(\frac{P_n(B)}{1-P_n(B)}\right)} \right| \quad (1)$$

where P(A) is the share of area in the base year; P(B) is the share of area in the next period analysed; n is the land cover type.

The LC index is a universal indicator for determining changes in structure, and it is commonly used in analyses related to shareholding.

In order to avoid dividing by zero, the minimum value of the feature for the study area was substituted, and further divided by half when there was no contribution from a given feature. The absolute value was calculated from the resulting log-transformed values to sum them up to obtain the LC index. The greater the value of the index, the greater the change in the land cover structure during the study period. The higher the value of the index, the greater the change in the contribution of the individual variables analysed, which in this case was the contribution to land cover of the individual polygons.

SAS Studio was used for graphic illustration of the land cover changes by the LC index value.

When collating the area occupied by industry, a decline since the end of the 20th century was apparent. Therefore, in order to determine the relationship between the decrease in area occupied by industry and the increase in area of other types, a canonical correlation was applied at the level of the 2493 created polygons, which ensured statistical significance.

4. Historical Background

Gorlice is a medieval city located in the Malopolska Region, on high escarpments at the confluence of the Ropa and Sękówka Rivers, in the area of the Beskid Niski in the Carpathian Mountains [Ill. XX]. Over the centuries, the city has built up its rich and eventful—for its relatively small size and seemingly secluded location—history.

Its present urban layout is, to a large extent the result of changes and fluctuations in its economic nature, in particular with regard to the large-scale oil and engineering industry, which used to be the backbone of the local labour market. The location of the city is estimated to have been chosen in the second half of the 14th century. A rich hydrographic system served as an important "backbone" for the settlement developing around the city, and villages were originally usually located along small tributaries of the Ropa River. Numerous trade routes led through the vicinity of Gorlice, which had a positive impact on the dynamics of development. Until the 19th century, Gorlice was an important trade centre on the route to southern Europe and a centre for the development of the weaving industry. The fact that, in the 18th century, half of the city's population was Jewish and engaged in crafts and trade may attest to the city's craftsmanship, as this was the highest proportion among the cities in western Malopolska [107].

Although oil spills had been found in the area for centuries, it was not until the last decades of the 19th century that the oil industry developed intensively in the surrounding area. An important role in the development of the oil industry was played by Ignacy Łukasiewicz, a pharmacist, and the founder of the first oil mine and inventor of the world's first oil lamp. Between 1883 and 1885, William H. MacGarvey, together with his partner, the Austrian banker John Bergheim, established one of the largest refineries in the suburban

village of Glinik Mariampolski [29]. The village was incorporated into the administrative boundaries of the city of Gorlice in 1954—since the end of the 19th century, however, it has been the setting for many important historical events and spatial changes of significant local and supra-local importance [31]. Later, the thriving "Glinik" Drilling and Mining Machinery Factory gradually developed next to the refinery [108]. The factory was still partly in operation until the end of the 20th century [109,110].

In 1884, thanks to the actions of MacGarvey and his partner, an important railway line with a station in Glinik Mariampolski and Zagórzany, together with a siding to the refinery, was opened, connecting Gorlice with the route of the Galician Transversal Railway, which provided ample opportunities for the exchange of goods with European countries [29] (p. 30). In 1895, the Bergheim & MacGarvey company obtained permission from the Austrian Ministry of the Interior to establish the so-called Galician Carpathian Joint Stock Company as a continuation of the company. Its headquarters invariably remained in Glinik Mariampolski [104]. From 1877, the National Oil Society of Galicia was established, with MacGarvey as its vice-president [28] (pp. 223–224).

These developments made Gorlice a centre already seen as crucial for the development of this industrial sector in the region. The first decade of the 20th century saw the opening of the drilling and mining machinery factory. Further development of the factory was hampered by the outbreak of the First World War and the fact that the front line of the Austro–Russian front ran through the Gorlice area [98] (pp. 41–49).

During the warfare of 1914–15, the buildings of the refinery and the factory suffered (massive fires in the refinery, damage to the roofing), but to a relatively minor extent, in contrast to the urban inner city, 80% of which was reportedly destroyed. The industrial facilities were restored to operation shortly after the war turmoil subsided [104] (p. 36) [99] (pp. 81–82).

In the interwar period, Gorlice's industry also suffered the consequences of a global economic crisis. Due to reduced interest in the purchase of drilling equipment, not only sales but also the employment conditions of the workers deteriorated during this period. Shortly after the outbreak of the Second World War, in 1939, the industrial area of Glinik was taken over by "Deutche Rohögruben Verwaltung Erdölkommission beim Oberkommando der Wermacht" military administration, and this part of the city was then called "Bohrgarätefabrik Glinik". In the following years, the German management of the factory changed, until it finally came under the trusteeship of the "Karpathen Öl Aktiengesellshaft" company and remained in the hands of the occupying forces until the very end of the war. During the war period, the factory was very active. It was a period of high oil production, important for the war effort [104] (pp. 60–62) (Figure 4a–c).

The period after the Second World War was a time of gradual revival of the refinery and factory and the rebuilding of post-war damage (during the liberation of the Gorlice area, unfortunately, some of the industrial buildings suffered in the aerial bombardment). Quite quickly, however, the necessary renovations were made, and in the new post-war reality the factory was restructured on the basis of new socialist ideas and principles. A socialised plant was established now called "The Central Oil Workshops in Glinik Mariampolski". In 1951, Glinik entered a phase of prosperity, being at that time the only such huge plant for the production of drilling machinery and equipment in Poland. The plant's management cared for its employees in many ways. In the late 1950s and early 1960s, around 100 plots of land of around 200 m^2 were marked out on the slopes of a hill near the plant to serve as allotments for the employees and their families to grow fruit and vegetables (food supplies) and for recreation or socialising. The 1970s saw the construction of new workers' housing estates. In tandem with the development of housing was the expansion of the industrial estate to cover ever larger areas, continuing until the end of the 1980s. The glory days the factory were interrupted in the 1980s, when the country was shaken by political events and the piling up of economic difficulties [85]. Soon (the change in regime in 1989) [111], there was a transition from a centrally managed economy to the market-driven system, which in

the next decade resulted in enormous turbulence—restructurings, ownership changes, and layoffs in large industrial plants in Poland [104] (pp. 138–147).

Figure 4. Old images of the MacGarvey's refinery (years 1915–1939): (**a**) View from the east and Ropa river side, (**b**) refinery chimneys and view towards the city centre, and (**c**) the interiors of a machine factory. Source: The National Digital Archives. Public domain.

5. Spatial and Functional Development of the City

The heart of the city is clearly its oldest, most downtown part, with a valuable, preserved medieval spatial layout of streets and squares [112], the architectural fabric of which was very severely damaged during the warfare of the Austro–Russian front in 1915 [95,98] and subsequently rebuilt taking into account the original layout (with only minor interference).

In the more than 600 years of development of the urban structure of Gorlice, seven periods can be distinguished: (1) pre-locational (estimated from about the 13th century to the middle of the 14th century), (2) locational (second half of the 14th century), (3) period of development and economic boom until 1657 ending with the destruction of the city by the Swedes, (4) period until the end of the 18th century including the reconstruction of the city and the expansion of the city centre, (5) the whole 19th century until the beginning of the 20th century, i.e., the period of intensive spatial development of the city going hand in hand with the development of factories and oil and machine industry, (6) the interwar period and the years of World War II, including the reconstruction of the city destroyed in the Battle of Gorlice, and the German occupation of Gorlice, and (7) the period of the city's development after World War II.

According to the metrological analysis and other studies by Kazimierz Kusnierz [95], the area of the location of the city was 250 × 250 m in dimension—a nine-field urban layout based on the measuring module of "1 Cracovian rope" (approx. 44.7 m). The centre of the layout was the city square, measuring 90 × 90 m based on two main streets forming a part of the trade routes running north to south (the so-called Kraków and Hungarian routes) and east to west (the so-called Biecz route), and three subordinate streets (Figure 5a). At the end of this period, the city also gained a system of defensive fortifications, which have not survived to the present day (Figure 5b). The period between the beginning of the 15th century and the middle of the 17th century was a time of both densification of buildings within the walls and expansion of suburban areas with residential, craft, and trade functions. In the villages around Gorlice, especially to the north, new manor houses were built and manor farms expanded. Unfortunately, at the end of this period, the city centre and its suburbs were severely damaged by the invasion of the Swedish army (1659) (Figure 5c). The beginning of the 18th century saw significant changes to the urban layout. There was a regulation of the Ropa River and its movement away from the city slopes towards the eastern, right bank part of the river. This gave the city more land under the hill, where further development of buildings and commercial functions, etc. took place. The earlier north–south alignment of the trade routes next to Dworzysko Square was transformed, and a new street axis cut through the city's urban layout cutting through the square and running towards the Ropa had the dimensions of a valley. This axis remains among the most characteristic elements of the city centre layout. From this point onwards, the city expanded in all directions, accompanied by the expansion of the surrounding settlements (Figure 5d). The period from the 19th century until the beginning of the 20th century was characterised by a rather spontaneous development of the suburbs with new sprawling residential areas (districts), the extension of new arterial roads, and the completion of the existing street grid. The local development of industry became an important determinant of spatial change. Since MacGarvey started his activity in Gorlice at the turn of the 20th century, industrial areas expanded on the north-eastern outskirts of the city, at the interface with the village of Glinik Mariampolski on former meadows, manors, and forests (Figure 5e) [112] (pp. 19–24) [113,114]. In the period before the First World War, residential areas in the vicinity of the MacGarvey factory also gradually expanded. They were developed as both the first workers' settlements with basic social infrastructure and single-family housing. After the Second World War, as Poland entered the period of socialist realism, the development of the nationalised factory fuelled the expansion of housing estates, and the Gorlice industrial areas continuer to grow. In 1979, the factory employed 7883 workers, and by providing them with a residential environment, it played the largest city-forming role of all enterprises existing in Gorlice at the time [104].

The 1980s saw the rapid growth of the city, also linked to the incorporation of neighbouring villages into the city. As can be seen from the graph presenting the growth in the population (Figures 6 and 7), the period of prosperity lasted until the mid-1990s, when a positive increase in the city's population was recorded. These changes in the population growth of Gorlice can be linked to the onset of problems experienced by industrial plants located in the city.

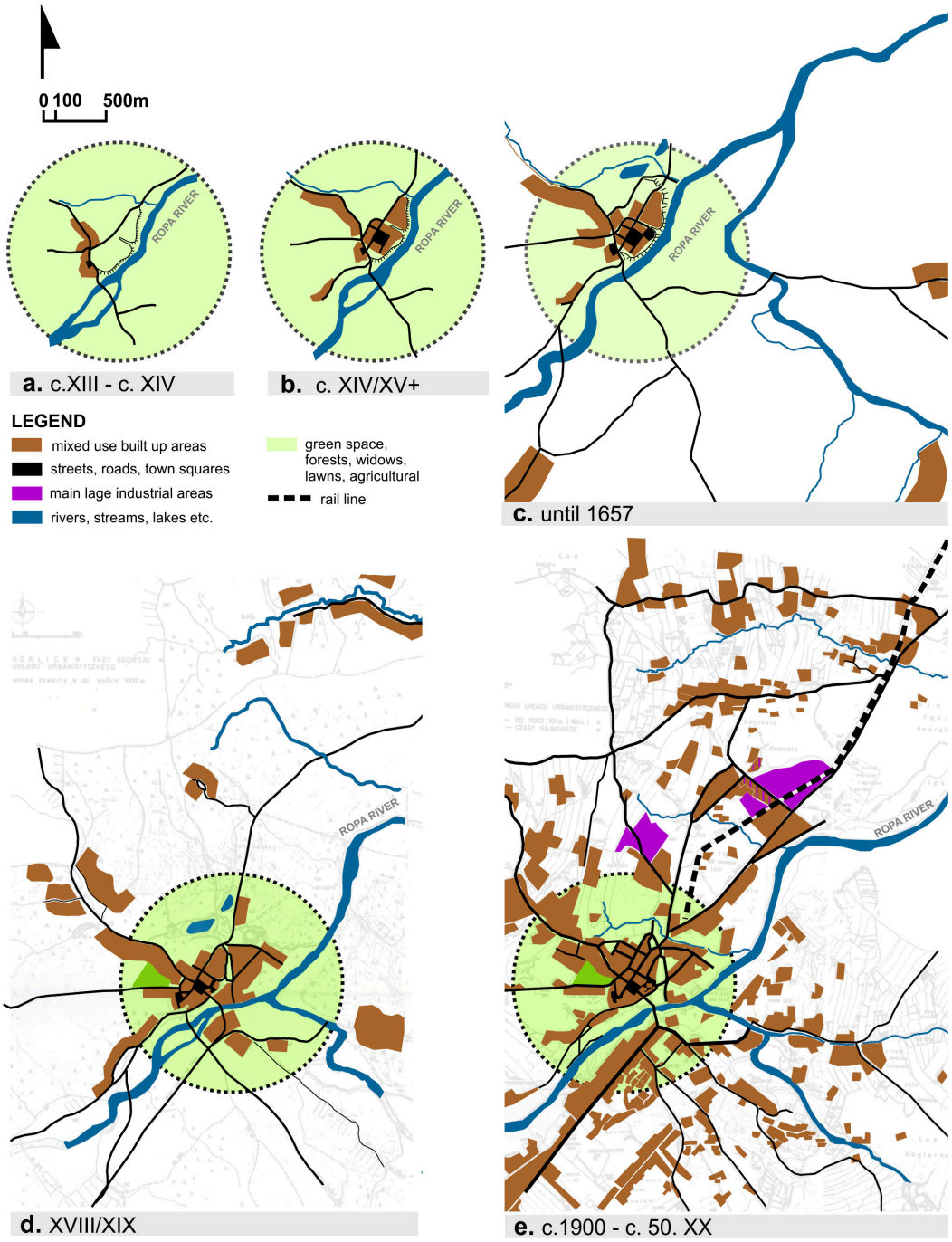

Figure 5. Urban development generalised schemes: (**a**) circa XIII–XIV, (**b**) XIV/XV+, (**c**) circa 1657, (**d**) circa XVIII/XIX, and (**e**) 1900–50.XX. Source: illustrations based on maps by Kazimierz Kusnierz derived from [95].

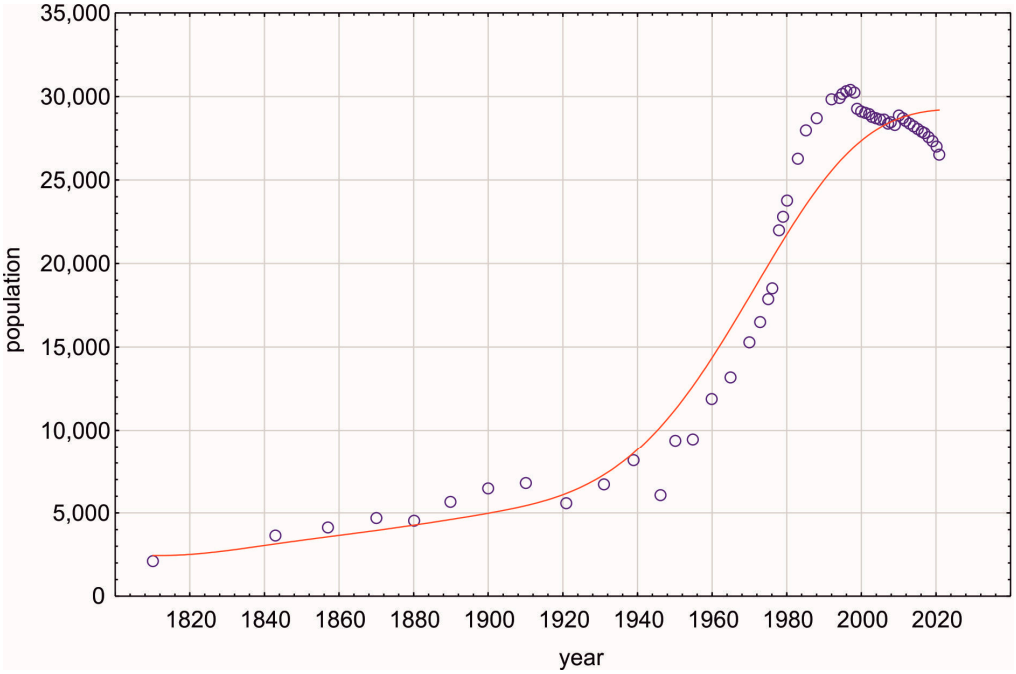

Figure 6. Population change in Gorlice between 1815 and 2022 with a trend line (original work).

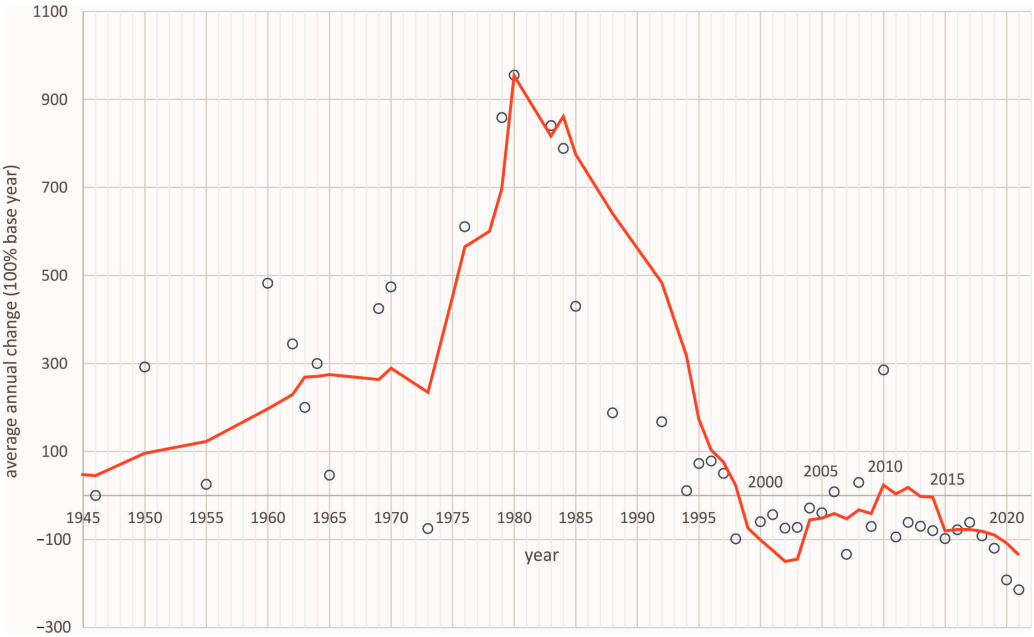

Figure 7. Average annual change in population of Gorlice between 1945 and 2022 (100% base year) (original work).

6. Spatial and Functional Transformation of Industrial Areas

While the turn of the 19th and 20th centuries was a period of prosperity for the oil and heavy industry in Gorlice, 100 years later, it was gradually replaced by smaller forms of enterprises and companies. In the 1990s, a subzone of Poland's first Special Economic Zone (SEZ) Euro-Park Mielec was established in Gorlice [113–115]. Steps were taken that led to the transformation of the industry, and foreign investors were attracted. However, Gorlice, as a result of economic transformations and its peripheral location in the Malopolska Region and competition from nearby cities of Nowy Sącz and Jasło, influenced the inhibition of its economic development [116,117]. Additionally, as a result of social changes, the Gorlice region started growing its tourist service sector. This effort resulted

in the change in the direction of the development strategy of the city and the region [118]. Also, the developing process of suburbanisation caused a significant migration of the city's inhabitants to neighbouring cities. Gorlice turned into a service centre for neighbouring regions and also an important trade centre for border cities in Slovakia.

In the first decade of the 21st century, two so-called Special Economic Activity Zones were set out in the vicinity of historic industrial areas. In the last two years, the creation of a third was also agreed. All of them are located in the north-eastern part of the city along the Ropa River and the DK28 national road from Zator to Przemyśl and coincide with, or are located in contact with, areas of former industry. In the areas of former factories and refineries, medium and small businesses are gradually emerging. The economic activity zones are dominated by small- and medium-sized production and service establishments. Furthermore, investment areas associated with the industrial zone on Biecka and Zakole Streets are developing. In Gorlice, apart from the manufacturer of drilling tools by the Glinik S.A. Capital Group, there are metalworking plants and enterprises, such as the Insulation Materials Company "Matizol" S.A., Severt Polska, Gór-Stal, TLC Architectural Metalwork, and the wood industry-related Forest Gorlice and Saint-Gobain Adfors Polska, a manufacturer of construction materials. Voyager, a transportation company, and Empol, the municipal services company, are the leading local employers. These establishments are mostly located in and around the economic zone located on the site of the former refinery. There are also new residential developments planned for the city, such as the Kasyno Park housing estate in Kardynała Stefan Wyszyńskiego Street and Szklane Tarasy—Gorlice in Kapuścińskiego Street. However, the measures taken are not reflected in the city's population growth, which is also linked to demographic processes, including Poland's ageing population. The built-up and urbanised areas of the urban municipality of Gorlice cover 44.9% of its area [119]. The former oil and refining industry hardly exists today.

7. Research Results

The research was aimed at identifying trends in the spatial and functional development of the city in different historical periods. It was assumed that the main factors in the changes were fluctuations in the development of Gorlice's industry, with a particular emphasis on the operation of the city's largest industrial zone, "Glinik", and its adjacent industrial areas. By attempting to estimate the quantitative changes in terms of built-up areas and biologically active areas, an attempt was made to assess the gravity of the impact and possible relationship between the condition of the industrial sector and the development of other major urban functions and changes in the city landscape. It was assumed that the aforementioned transformations should be particularly vividly observable in the statistical analysis of spatial data considering the scale of a city with a medium-sized structure. Gorlice qualifies as one because of its population [120] (according to the Central Statistical Office in Poland: small towns have a population of less than 20,000, medium-sized towns have a population of 20,000–100,000, while large towns have a population of 100,000 or more).

Reflection of a turbulent history in the spatial and functional structure of the city

In the analysis of land cover changes in the city of Gorlice in the period of more than half a century (Figure 8), it is possible to see momentous differences in the direction of its urban development, and these are linked to the socio-economic development of the city. The development of the city's population was used as a variable illustrating this socio-economic development.

At the beginning of the analysed period in 1966, four regions separated by watercourses could be distinguished in the city area: the Ropa River and its right tributary, the Sękówka River. On the left bank of the Ropa, compact urban developments, including the historic city centre, were clustered around the historic city centre. To the north-east of the centre, industrial areas developed, which occupied almost twice the area, with compact residential buildings included in the city centre. Industrial areas stretched along the Ropa

and its floodplain terraces. Further north of the Ropa stretched agricultural areas with scattered buildings.

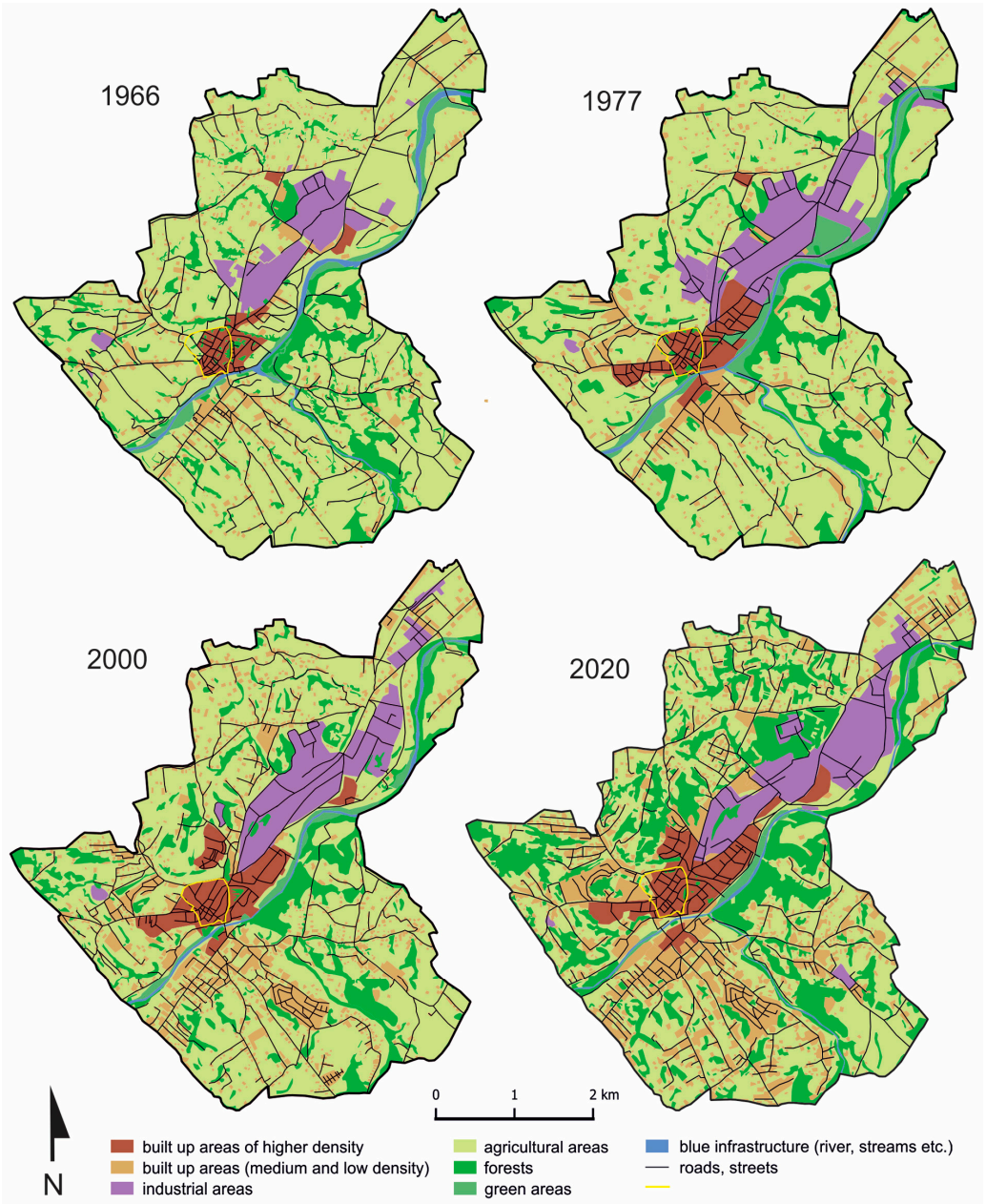

Figure 8. Land cover analysis based on aerial photographs taken in four selected years within the study period (original work).

South of the Ropa, on the left bank of the Sękówka, there were low-rise urban developments and scattered developments—single-family houses. These buildings gradually disappeared towards the south, giving way to agricultural areas with single farm buildings. Only along the Sękówka River, on its left bank, did dense housing develop. To the east of the watercourse, however, the land was mostly covered with forest, and buildings were limited to rural households located in agricultural areas. Note that the hydrological network was the main determinant of the historical settlement development [121].

The following period of the 1970s saw a rapid development of the city, with its population growth exceeding 100%. This was mainly the result of the development of industrial plants located in Gorlice, as well as the service functions of the developing

city. During this period, the city also expanded to include the areas of neighbouring municipalities, which also evidenced its spatial development.

As a result of the city's development, new residential areas were built to the south and north of the historic centre. Furthermore, compact developments crossed the Ropa River to the right bank in the vicinity of the bridge, which is the axis of the main traffic route. The development of the area close to the city centre on the right bank of the Ropa was also associated with major investments, including the construction of a hospital and a dairy.

Industrial areas also increased in this period, mainly in the north-east of the city, between the Ropa and the railway line from Gorlice to Zagórzany. The development of industrial and urbanised areas occurred at the expense of agricultural areas. In addition, the areas adjacent to the industrial areas could no longer be cultivated and were transformed into green areas. This is particularly evident in the strip between the industrial areas and the Ropa, which ceased to be used for agriculture. There was also a decline in the forested area during this period.

As shown by the variation index, the greatest changes in land cover structure were observed in urbanised and industrialised areas along the Ropa and the main transport route which is part of the Nowy Sącz–Jasło road (Figure 9).

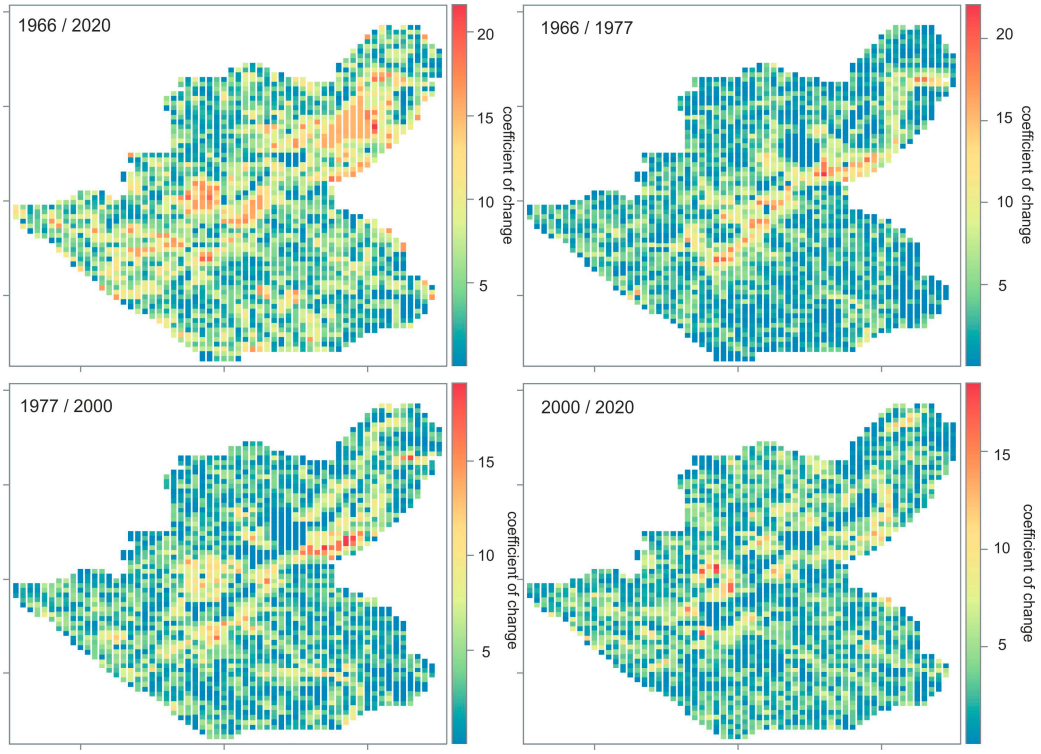

Figure 9. Index change in land cover structure of Gorlice (original work).

The 1990s brought economic and social changes associated with the transformation of Poland's economy. These changes resulted, among other things, in a decrease in the number of inhabitants of Gorlice. However, further development of urbanised areas can still be observed throughout the 1980s. This development took place at the expense of the industrial areas closest to the city centre. In contrast, industrial functions continued to be developed in the northern peripheral areas of the city.

The decline in green spaces was due to their conversion to industrial and residential functions. This took place on the basis of development spilling over into peripheral areas. An increase in forested areas at the expense of agricultural areas was also observed. The largest changes during this period according to changes in the land cover structure occurred in the northern region of the city, which was incorporated into the Special Economic Zone in 1995.

The beginning of the 21st century has seen the slow demise of the 'Glimar' plants associated with the oil refinery. This results in the development of wooded areas on abandoned brownfield sites. Growth of wooded areas is also occurring in agricultural areas. Industrial areas are moving further to the northern periphery of the city. During this period, the city bypass is built, gradually attracting investors towards the economic activity areas designated along its route. New housing estates have also been established. This includes compact single-family house developments on agricultural land in the south of the city. The western area of the city is developing intensively, which may be related to commuting to Nowy Sącz [122,123] (Figure 9). The proportion of green and agricultural land is also gradually declining. These areas to the south of the Ropa River are mainly used for residential development and, to the north, are occupied by woodland.

Summarising the results of the analysis carried out, there is a strong relationship between the city's urban structure and landscape and the turbulent changes in the industrial sector taking place since the 1970s, against the background of the political and socio-economic conditions. It can be observed that there has been a steady decline in the area of agricultural land, especially at the beginning of the 21st century (Figure 10). The expansion dynamics of the area of land classified as industrial have been decreasing significantly over the years despite the decline in the oil industry. No decrease in their area is observed, and more often there are small increases. During this period, there has also been an increase in the area of forests and land allocated for housing. This is a process that can be observed throughout Poland related to the processes of suburbanisation. As a result of these processes, at the beginning of the 21st century the greatest changes in the land cover structure of the city were observed to the west of the city centre characterised by the most intensive suburbanisation processes.

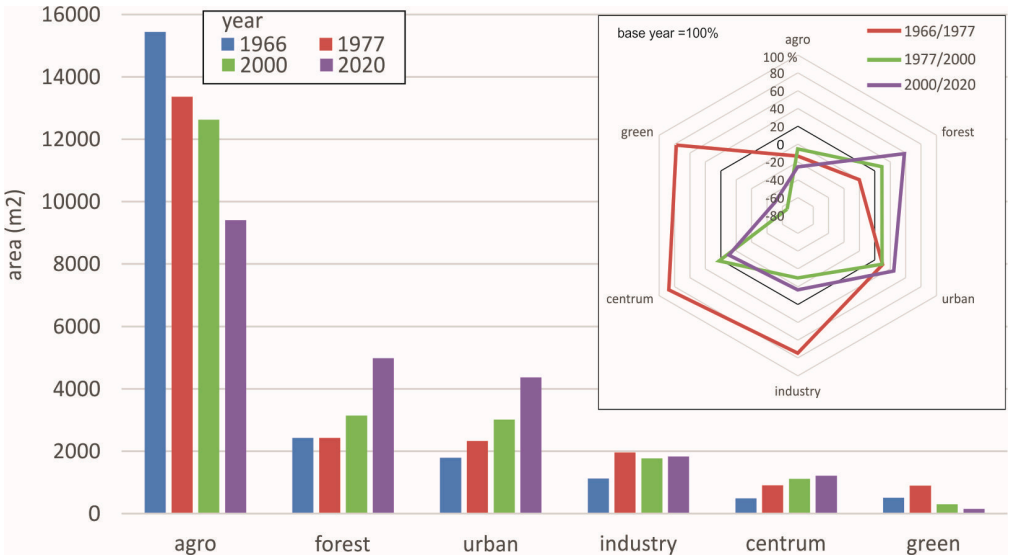

Figure 10. Graph of land cover categories and area changes within the study period (original work).

Post-industrial scar or processes of adaptation?

In recent years there has been an emerging developers' interest in former industrial areas. New developments are completely and irreversibly changing the area of the former residential complexes and factory facilities created back in the days of MacGarvey and the heyday of its refinery. The cultural heritage of this period has been included in the municipal register of monuments, but this has not saved some culturally valuable buildings and their surroundings from demolition [124] (Figure 11).

Figure 11. Photographs of the old MacGarvey's refinery in modern times: (**a**) Area with derelict buildings, (**b**) fenced-off inaccessible area of the former refinery, and (**c**) view of the refinery chimneys, in the nearer plan new blocks of flats built on the site of a demolished villa from the early 20th century. Photos: author's archives.

In the case of post-industrial areas, it is possible to see their peculiar permanence in the urban space. This is a result of the city's long-standing policy of maintaining them as areas for small production plants or commercial and service facilities. In this aspect, it can be assumed that although these areas are far from their former significance and specialisation in the region, here we are dealing with a kind of adaptation to contemporary market realities. In relation to the oldest parts of the industrial areas, connected with the former refinery, as well as the areas serving them (a complex of residential buildings and office and public buildings listed in the register of historic monuments), the lack of an overall idea for the revitalisation process is strongly visible. The lack of an active policy in this area, despite the vestigial declarations in the city's strategic documents [125], is gradually leading to the destruction of valuable industrial architecture and the complexes of buildings associated with it. Areas that could be seen as the cultural heritage of the history of the city lose their potential and are, rather, becoming a post-industrial scar, a kind of difficult, problematic heritage. The adaptation of deteriorating structures requires huge investment and a strong revitalisation concept. Despite some of the buildings being included in the municipal register of historical monuments, subsequent structures are being replaced by, for example, multi-storey multi-family block buildings that do not match their surroundings in terms of scale, urban composition, architecture, and volume (Figure 11). Also, they are obliterating traces of the former urban layout and functions (Figure 12). This is happening despite the fact that the Old Glinik post-industrial area has been designated as a so-called revitalisation area in the planning documents for 2017–2023 [125].

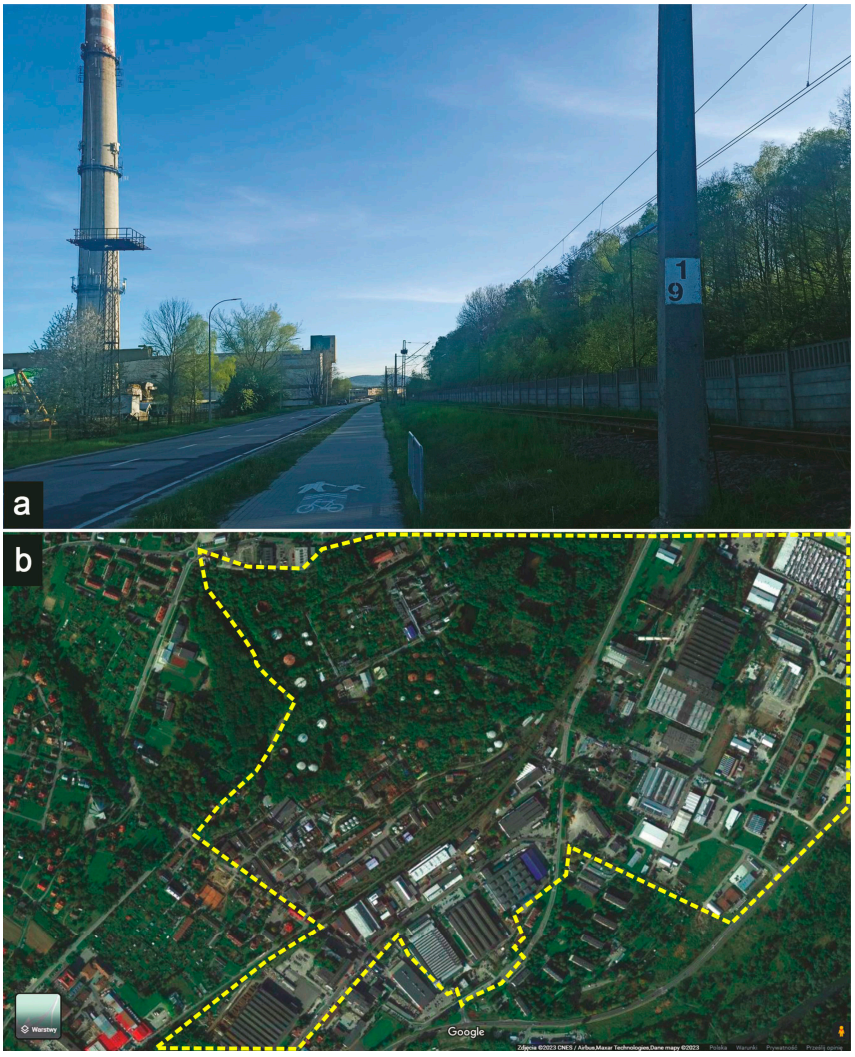

Figure 12. (**a**) View of the modern areas of the thermal power station, and to the left the tree-lined area of the former refinery and unused railroad (photo by authors). (**b**) Contemporary bird's eye view to the industrial and post-industrial areas (delineated with yellow dotted line). To the north side is a former refinery overgrown with wild greenery (Source: illustration based on Google Maps image).

In contrast, new industrial zones are also being built in the city area along with the development of transport infrastructure. Therefore, it seems to be easier for the city to develop investments in previously undeveloped areas than to revitalise brownfield sites.

8. Discussion

The research, run as planned, provided an insight into the process of functional, spatial, and landscape transformations in Gorlice over a period of 50 years at the turn of the 20th and 21st centuries. The research methods made it possible to clearly illustrate and present estimated calculations of changes occurring in the studied area. It must be admitted, however, that the method of analysing aerial photographs used by the authors is burdened with several basic shortcomings. Its application is dependent on the availability of aerial photographs, which can be particularly difficult when it comes to historical images from the remote past. For years, aerial photographs have been a resource created and archived for military and strategic purposes. Many of them are still not available, and if they are, it is not uncommon to have to cover the costs of purchase to obtain them.

Aerial photographs present a fragmented view of an area. It is sometimes the case that the format, scale, and extent of the images vary from one series of so-called air raids to another, presenting smaller or much more extensive sections of the photographed

space. The assembling of these photographs into all-encompassing images, taking into account minor shifts due to the changing position of the aircraft as well as the curvature of the globe, is fraught with the risk of certain inaccuracies, as pointed out by many other researchers [79,88,126]. Older photographs tend to be in black and white, with later photographs in colour. The different series of photographic images come from different seasons and are also taken at different times of the day. All this means that at a later stage of analysis, when the land cover image is developed, the process depends on the individual interpretation of the photographs. For example, winter and autumn photographs make judgements about wooded areas and land cover classification difficult. Long shadows in the photographs can also affect the inaccurate indication of individual areas. Support for this type of analysis in the case of contemporary photographs is, therefore, undoubtedly provided by field research and direct verification of the aerial image with reality.

Nowadays, an important source of information is the Geographic Information Systems (GIS) software available online, containing integrated vector and raster spatial data. Its use was intentionally omitted when trying to assess the relevance of the analyses carried out in this study. Currently, land cover information can be derived from the so-called database of topographic objects (BDOT10k). However, this is continuously updated vector data and, as such, could be compared mainly with aerial photographs taken between 2020 and 2021. Data for earlier periods could possibly be considered for comparison of high-resolution aerial photographs with analogue paper topographic maps of that period. However, here too the same problems of accuracy, scale, and frame range of the aerial images being compared arises. Idea for making this kind of comparison for the most recent aerial photographs compared to the available digital data could instead be explored in a separate study and article.

In the case of the research presented in this study, the conclusions of the calculation of the index of variation coincide with the conclusions of the analysis of the surface changes in land cover in individual periods. This is a kind of confirmation of the correctness of the calculations made and the spatial model created. However, this indicator does not correspond to what changes have taken place, but only provides information about the strength of their intensity. Therefore, in a full analysis of land cover structure changes, it is necessary to interpret the created land cover plans. Similar results can be obtained using geoprocessing tools in QGIS.

The study of the area differences in the different land cover categories over time allows for the illustration and calculation of some general trends of functional, spatial, and local landscape development. However, it does not take into account many aspects of the existence of urban functional areas. The fact that an area's function remains constant over time does not mean that its various attributes and character do not change. The industrial function, which is strong in Gorlice, has not reduced its area over the last 30 years, but its specific nature has changed significantly, and its socio-economic importance has been reduced. Some of the oldest areas are only partly adapted by smaller companies, and some are falling into disuse. Capturing this kind of transformation would require further in-depth research taking into account the sectoral structure of the businesses developing in the area and the directions in changing the functions of existing facilities.

It could also be interesting to precisely map the areas occupied by specific types of industrial functions and facilities. However, this may be a difficult study to carry out due to the limited availability of sites, some of which are enclosed and fenced areas. A wider methodological palette would also need to be used in this type of research. However, broadening the research field would provide an opportunity not only to ascertain changes in the spatial distribution of functions, but also to assess these phenomena in more depth.

At the same time, the authors are aware of the need to verify the analysis of aerial photographs in the field. However, this is impossible or very difficult with historical data, whose traces in space may have already disappeared.

In future research, it would be interesting to compare both the land cover changes in other post-industrial cities, but also to compare land cover changes in cities with functions

other than industry. The research could be also extended and carried out in the small cities and towns in other Central- and Eastern European countries.

9. Conclusions

Referring to the two research questions presented at the beginning of this article, it can be concluded that the results of the research carried out do indeed allow one to see clear transformations in the spatial-functional layout and landscape of the city of Gorlice. Thus, they confirm the suitability of the methods used for research in the above-mentioned area. On their basis, it is possible to draw conclusions on certain development trends, such as extensive development of single-family housing in the western and southern parts of the city, area domination of the industrial function (albeit of a changing nature) or, interesting for the quality of the local natural environment and climate, the phenomenon of an increasing area covered with forests and tall trees (which would be difficult to capture without recourse to remote sensing methods). But it is more difficult to answering the second question of the study—whether, on the basis of the research carried out, we are able to determine whether the industrial function that dominated the character of the city throughout the twentieth century has left a kind of "post-industrial scar" or whether it is adapting to the present day. The transformation of the land cover purely by calculation shows that this category of function is resilient to strong cyclical, systemic, economic, social, and demographic shocks. Nevertheless, with the decline in the importance of the oil and engineering industry in the region and the gradual replacement of former heavy industry areas by small-scale production and service facilities, it is difficult to speak of a situation of any status quo in the study area. However, it is possible to identify three paths that the industrial function and related areas seem to follow according to the study. The first, indicating the abovementioned persistence of the industrial areas observed in the study, concerns the city's policy of adapting the existing areas to the current needs of the industrial and commercial functions. The second is the path of unsuccessful attempts to adapt or revitalise the oldest areas of the former refinery and factory and the complexes of buildings associated with them. This is the scenario closest to the situation of a post-industrial scar. Unfortunately, because it concerns the most valuable tissue of post-industrial buildings. The third path is the development of new industrial and economic activity areas in brand new areas within the city. Therefore, in order to obtain a more complete and closer to reality answer to the second question, further in-depth research into the condition and structure of the local industrial sector would become a necessity.

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