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Research paper

Analysis of greenery coverage of the area of the City of Warsaw on the quality of life of residents on the basis of spatial and statistical data

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Abstract: Biologically active areas play an extremely important role in the structure of a city and increasing their coverage, especially in large urban centres, is an activity with a number of advantages. This article compares, in terms of green spaces, two European cities of similar size – Warsaw (517.2 km^2) and Oslo (454 km^2). Both cities are capitals of their respective countries but implement different spatial policies in the scope of the Green Deal. In Warsaw, many industrial and post-industrial areas still exist and simultaneously urban green areas are decreasing year by year. In Oslo, a strategy based on deindustrialisation of the city and possible maximum use of urban greenery and public spaces is implemented. The research described in this article involved analysing the coverage of the analysed cities and their districts with biologically active area and then checking the correlation with other indicators that can be affected by this coverage. These included data on the incidence of the most common diseases among residents, the attractiveness of living for the elderly and families with children, as well as air and soil pollution and the occurrence of negative effects of climate change. The correlation of urban space use in terms of the presence of industrial land in relation to currently existing green spaces in the districts concerned was subsequently determined.

Keywords: green areas, spatial development; sustainable development, spatial planning, NDVI analysis

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1. Introduction

Human activity has led to large-scale disturbances in nature while the phenomenon of anthropopressure has affected natural systems, which became vulnerable to all kinds of continuing impacts and permanent adverse changes [1]. In the face of increasing urbanisation and climate change, rational land use is becoming necessary. One of the basic ideas is the concept of sustainable development, which assumes that any action in space takes into account not only technical, but also social, natural or economic aspects. The origin of the idea can be traced back to 1992 and the Earth Summit held in Rio de Janeiro at that time.

Particularly challenging for spatial management are urban areas where the greatest variety of functions, environmental hazards and their intensity are concentrated, including those caused by industrial activity, intensive motorisation, low emissions from individual households and the reduction of green spaces at the expense of newly constructed buildings and concreted areas [2]. This phenomenon is referred to in the literature as "concreting" [*Polish "betonoza"*] [3]. It is in these areas that the greatest number of people are affected by environmental hazards, such as lack of ventilation, smog, natural disasters – floods and flooding, landslides, and groundwater contamination [4]. As a consequence, the effects of anthropogenic changes to the natural environment become apparent in the form of fragmentation of natural spaces, elimination of green areas and decline in natural biodiversity, introduction of alien species, disruption of ecological corridors, or catastrophic phenomena. This is coupled with global climate warming affecting changes in the hydrological regime, drying of habitats and negative health effects, resulting in increased human mortality [5].

Important areas in the urban tissue are the brownfield sites found in individual districts [6]. Although they do not constitute a direct source of adverse impact on the city climate, due to their historical use and the difficulty of changing their development, they remain unused in many cases, at the same time constituting a land reserve of the city with high potential for use in crisis situations [7]. The rational management of such areas is often difficult due to their challenging conditions – for example, these are often areas with unregulated ownership status, contaminated or flood-prone areas [8].

The radiation-thermal characteristics of cities mean that the conditions of the perceptible climate in the central parts of cities differ markedly from those in the suburbs [9], which translates, among others, into a temperature difference of about 5 degrees Celsius, a noticeable change in air quality, water quality, noise levels and the condition of the organised and uncultivated greenery [10]. Individual elements of the city climate can then exert a significant impact both on environmental crises, but also on the health of the inhabitants, causing diseases of the respiratory [11], nervous [12] and circulatory [13] systems. These diseases are sometimes collectively referred to as 'climate-dependent diseases' [4]. In Central and Northern Europe, cardiovascular diseases and cancer are particularly dangerous and cause a high proportion of deaths. Hospital admissions for acute cardiovascular conditions are significantly more frequent in warmer periods and locations [14]. On the other hand, the most dangerous cancers in the city are skin cancers, especially in areas with excessive solar radiation (mainly UV) [4]. Other risks observed in central urban areas include overheating and dehydration due to high air

temperatures and small areas of green space. An increase in the number of deaths reaching 18% has been recorded in Warsaw on hot and very hot days [15].

As a response to the increasing threats, "Poland's Strategic Adaptation Plan for Climate Vulnerable Sectors and Areas to 2020, with an outlook to 2030" was developed in 2013 [16]. Individual municipalities are also developing their own climate change adaptation plans. The first of the above-mentioned documents specifies the directions of action which mainly include adaptation of the water management sector, protection of biodiversity, health protection and, finally, effective urban spatial planning policies.

The ideological principles of sustainable urban development based on, among others, green areas include [17]:

- A city that takes into account the protection of its surroundings and makes rational use of the resources of its surroundings and their protection against excessive pollution.
- A medium-sized city, optimal for reducing emissions and organising a community enforcing the development goals.
- A compact, integrated city, diversified in terms of spatial structure – beneficial in terms of environmental impact and social relations.
- A cost-efficient city in terms of the use of natural resources for its functioning, inter alia by rationalising the use of energy, water and other resources.
- A functional city, taking into account the protection of the environment and nature as well as cultural heritage.
- A city friendly in terms of organisation of social life and provision of conditions for healthy and creative living of the inhabitants.
- A positive city in economic terms that can afford to implement, for example, a green infrastructure system.
- An effectively managed city with long-term development planning.
- A city with a vision – in terms of green future rather than the immediate needs of particular groups of citizens.

One of the main factors affecting the implementation of development in line with sustainable development are the biologically active areas which are referred to as "green infrastructure" in urban planning reports [15]. These include areas covered with greenery, but also with water, forming the so-called green and blue infrastructure network. Based on biologically active areas, among others, the idea of the European Green Deal was developed as a priority in the European Union political strategy for 2019–2024 [18].

This concept in Polish legislation is clarified by the Regulation of 14 November 2017 amending the Regulation on technical conditions to be met by buildings and their location [19]; a biologically active area is "an area with a surface arranged in such a way as to ensure natural vegetation of plants and retention of rainwater, as well as 50% of the surface of terraces and flat roofs with such a surface and other areas providing natural vegetation of plants, with an area of not less than 10 m^2 and surface water on this area". With regard to this study, the authors confine their discussion to the first interpretation of the concept, which primarily comprises landscaped and uncultivated green areas that form part of the city green infrastructure.

The essence of green infrastructure is the human use of the properties of biologically active areas to shape space, control processes and reduce adverse impacts and mitigate risks

associated with land use [20]. Thus, properly developed green spaces are expected to start providing ecosystem services, leading to both environmental but also social and economic benefits for urban space. Urban greenery plays an important role in the melioration of the city climate [15], contributing to increased oxygen production, reduced air pollution [21], or increased relative humidity [22].

The basic functions of urban greenery include regulating gas exchange and oxygen production, shaping the microclimate (humidity, air flow), maintaining biodiversity, limiting the spread of pollutants (filtering role), secreting phytoncides, ionising the air, regulating the water cycle and providing a habitat for animals.

The aim of this paper is the comparative analysis of urban green areas in individual districts of Warsaw and Oslo and the examination of the impact of the degree of green cover on mortality due to climate-related diseases, as well as on the attractiveness of living for the elderly and families with children and the use of urban space in the context of the presence of industrial areas.

2. Research area

The research covered in this paper was carried out in two European cities which are the main centres of the region. The first is the capital of Poland, Warsaw and the second is the capital of Norway, Oslo. Both cities are capitals of their respective countries, however, they implement different spatial policies in terms of the Green Deal and the application of green and blue infrastructure tools. In the territory of Warsaw, many industrial and brownfield areas still exist and urban green areas are decreasing year by year. In Oslo, a strategy based on de-industrialisation of the city and possible maximum use of urban greenery and public spaces is implemented.

Warsaw covers the area of 517.2 km^2 and is divided into 18 districts. Oslo covers the area of 454 km^2 and is divided into 15 districts (plus two areas which do not belong to any city district – Marka and Sentrum).

3. Research methodology

The research performed within this study consisted in analysing the coverage of the analysed cities and their districts by biologically active area and then checking the correlation with other indicators that may be affected by this coverage. These included data on the incidence of the diseases most commonly occurring among residents, the attractiveness of living for the elderly and families with children, as well as air and soil pollution and the incidence of adverse effects of climate change. The relationship of urban space use in terms of the presence of industrial land, abandoned land and priority areas for change of use was then determined in relation to the currently existing green spaces in the districts concerned.

Archival and current Landsat satellite images showing land use change, statistical data obtained from the resources of the Statistical Offices of Poland and Norway and the BDOT10k topographic database were used in the analysis. Strategic and planning documents in force in

both described urban centres were also analysed. GIS software was used for spatial analyses and the production of resultant maps. In the final part of the analysis, the results of both cities were compared with each other. Recommendations were also issued regarding the development of the greenery system and the possibility of managing abandoned areas.

The time span of the research conducted depended on the availability and timeliness of the statistical and spatial data used in the study. In the case of population death statistics, the data for both cities analysed came from 2016, due to the limited availability of more up-to-date reports broken down by district. Additionally, they were enriched with 2016 and 2021 data for the whole Warsaw and Oslo. The spatial data (distribution of industrial facilities and green areas in the city) dates to 2021. The Landsat 9 satellite images used in the study for both cities studied come from June and July 2022, the period of increased vegetation.

4. Research findings and case studies

4.1. Case study no. 1 – Warsaw

Analysing the percentage distribution of the most important causes of death in Warsaw between 2011 and 2021, the prevalence of cardiovascular diseases is clearly visible (45.01% in 2011, 31.72% in 2021), a value comparable to other cities in Poland. The next most popular causes in 2021 included, respectively (Fig. 1): Cancer – 27.18%, COVID-19 – 18.88%, Respiratory diseases – 8.09%, Digestive system diseases – 5.31%, External causes – 5.04%, Symptoms of disease – 1.85%, Other – 7.53% (Statistics Poland).

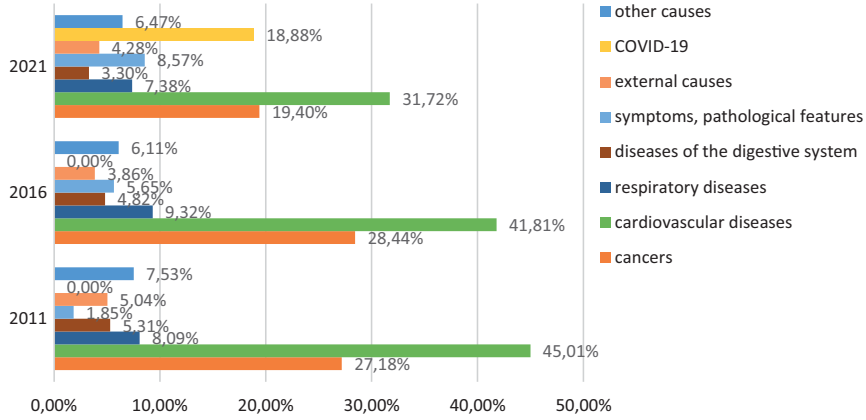


Fig. 1. Percentage distribution of mortality by main causes in Warsaw in 2011–2021 (Source: own study based on GUS data)

One of contemporary major threats for the population is the COVID-19 coronavirus pandemic covering the entire world. The latest figures show that several hundred million people have become ill due to the pandemic since the beginning of 2020. Mostly urban areas with high development density and limited access to health services and facilities are affected and

have recently struggled to serve patients of different health and age groups [6]. COVID-19 deaths proved to be such an important significant cause that they ranked third in the list in terms of contribution to the total number of deaths in Warsaw in 2021. The declines in the share of other causes (particularly cardiovascular disease and cancer) should therefore be interpreted as another factor posing threat to the health and lives of the population rather than as an improvement in the health status of Warsaw residents in this respect.

This is confirmed by the analysis of the number of deaths using absolute data of Statistics Poland. In 2011, a total of 17,586 deaths were recorded in Warsaw, in 2016 – 18,512 deaths, while in 2021 as many as 24,016. Due to cardiovascular diseases, the number of deaths reached, respectively 7,915 deaths in 2011, 7,739 deaths in 2016 and 7,618 deaths in 2021, and due to cancer, 4,780 deaths in 2011, 5,265 deaths in 2016, 4,660 deaths in 2021.

It was assumed that it was important to examine the distribution of mortality (per 100,000 inhabitants) from diseases contributing to the highest number of deaths in individual districts of the City of Warsaw. The last study of this type was conducted in Warsaw in 2016, so the first two categories – cardiovascular diseases and cancer – were adopted for analysis. In the case of circulatory diseases, the following districts clearly distinguish in negative terms (Fig. 2): Praga Północ – 131.2, Wola – 122.7, Ochota – 110.4, Śródmieście – 107.0, Bielany – 106.3. On the other hand, the districts least affected are: Wilanów – 65.7, Ursynów – 78.3, Białołęka – 88.8, Rembertów – 89.1, Wawer – 89.3.

For malignant tumours, a similar relationship is observed. The districts most affected by mortality from these diseases include (Fig. 3): Praga Północ – 120.8, Bielany – 109.6, Targówek – 109.4, Wola – 108.8, Ochota – 107.3.

In contrast, the lowest number of deaths from malignant tumours characterises the districts: Wilanów – 73.4, Wesoła – 75.5, Bemowo – 83.3, Włochy – 84.7, Ursynów – 91.6.

It is apparent, therefore, that in the case of the districts most at risk of death from the diseases mentioned, the same three districts are found in both cases – Praga Północ, Wola and Bielany, while in the case of the safest districts, they are also the same – Wilanów and Ursynów.

A rather obvious observation is that the districts at risk are those located in the city centre or associated with industrial activities (Fig. 4 and 5). Meanwhile, less exposed are neighbouring districts and districts not connected with industry, often covered to a greater extent with urban greenery (Fig. 6) – forests, parks, but also the greenery of city forts and allotment gardens, which unfortunately are and will be increasingly liquidated in favour of the creation of new construction projects, which is confirmed by the analysis of the planning documents of Warsaw and other Polish cities.

In addition to these factors, the results in terms of incidence and mortality of the diseases indicated can also be significantly affected by social factors, such as population structure, social status and social pathologies occurring in the analysed districts. People in the post-working age group are particularly exposed to risk. In Warsaw, according to the Statistics Poland data, the highest share of such people in 2021 has been recorded in the districts of Śródmieście (29% of the total number of district inhabitants) and Bielany (26%). The most problematic districts in terms of mortality – Wola and Praga-Północ – achieved results close to the city average (22% and 25%, respectively). The lowest share was recorded by peripheral districts – Wilanów

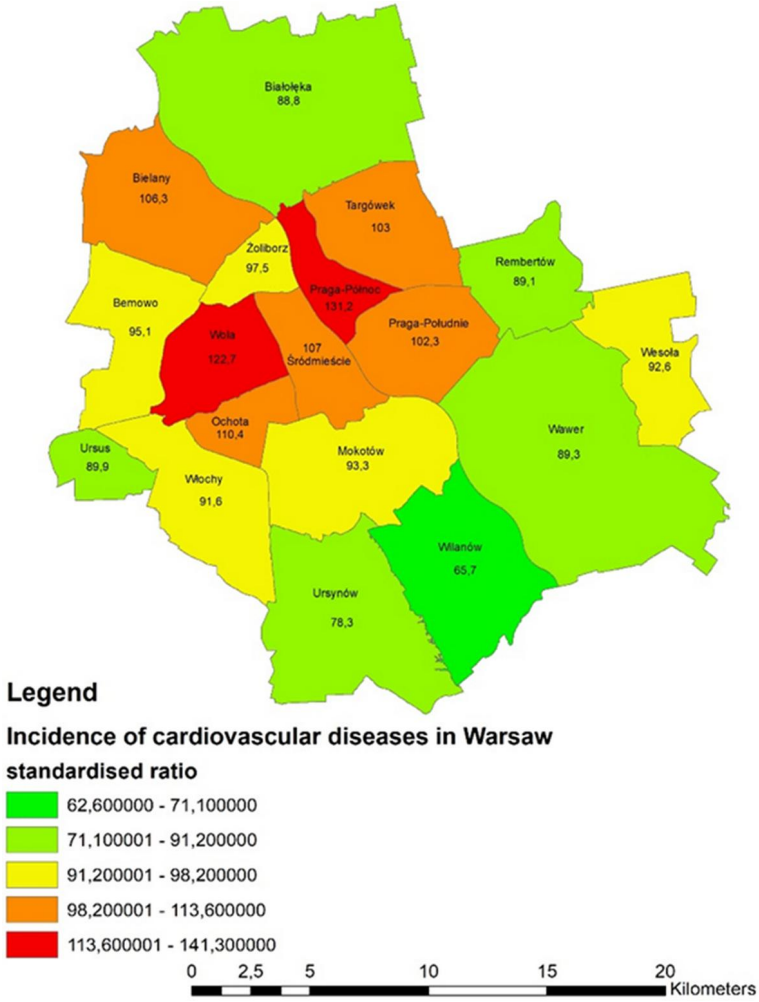


Fig. 2. Statistics on mortality from cardiovascular diseases in Warsaw in 2016
(Source: Own study based on data from the City Hall of the Capital City of Warsaw)

(12%), Białołęka (12%) and Ursus (16%). In the case of safety in individual districts and the number of recorded offences, the districts of Śródmieście and Praga-Południe dominated, while Rembertów and Wesoła proved the safest. It can be seen that population structure and the local community can also be important factors contributing to an increase or decrease in mortality from diseases, but this is not the only criterion showing a clear link.

The next summary prepared was the analysis of the distribution of industrial facilities in the districts of the capital city of Warsaw. For this purpose, the BDOT10k database of topographic objects available in vector format at the Regional Geodetic and Cartographic Centre (Fig. 4) was used.

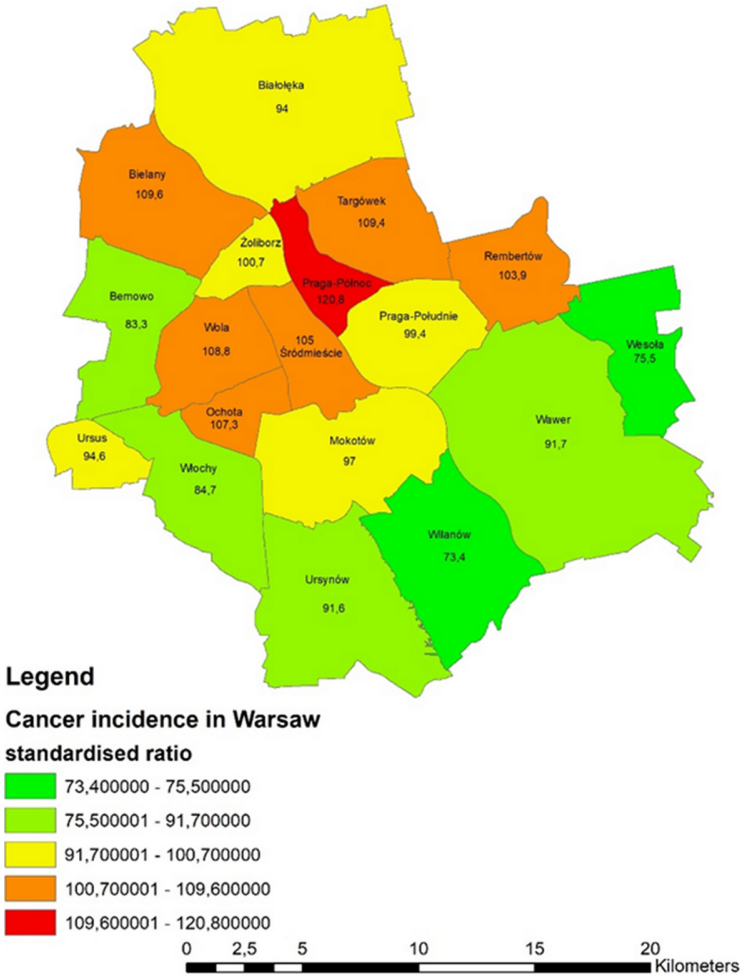


Fig. 3. Statistics on mortality from malignant tumours in Warsaw in 2016
(Source: Own study based on data from the City Hall of the Capital City of Warsaw)

Based on the analysis, the districts with the largest industrial areas included (Fig. 5): Białołęka – 579 ha, Bielany – 390 ha, Mokotów – 235 ha, Wola – 198 ha, Włochy – 175 ha. At the same time, the districts with the smallest area of industry-related facilities include: Wesoła – 8 ha, Żoliborz – 15 ha, Wawer – 51 ha, Ochota – 56 ha, Śródmieście – 56 ha.

Another indicator and factor related to the presence of green areas and the lack of industrial areas is the attractiveness of Warsaw districts for senior citizens (Fig. 7) as well as for families with children (Fig. 8). Such studies are conducted by the Statistical Office in Warsaw. Seniors are defined as women aged 60 and over and men aged 65 and over. Five indicators were used to construct the synthetic attractiveness index, including the number of people per outpatient

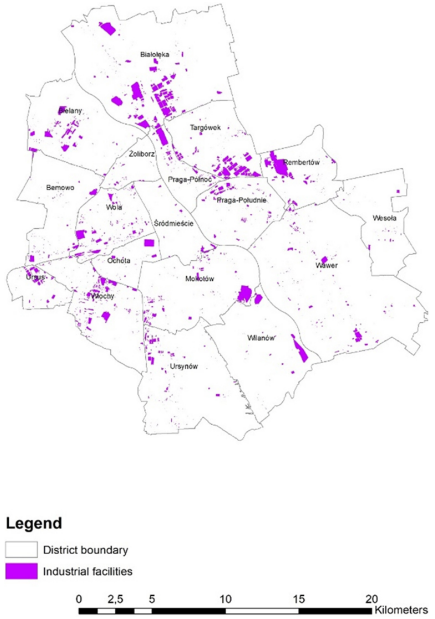


Fig. 4. Distribution of industrial facilities in Warsaw in 2021
(Source: Own study based on BDOT10k data)

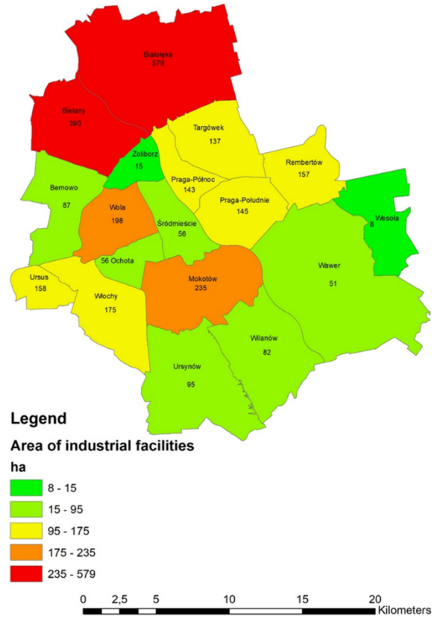


Fig. 5. Area of industrial facilities in Warsaw in 2021
(Source: Own study based on BDOT10k data)

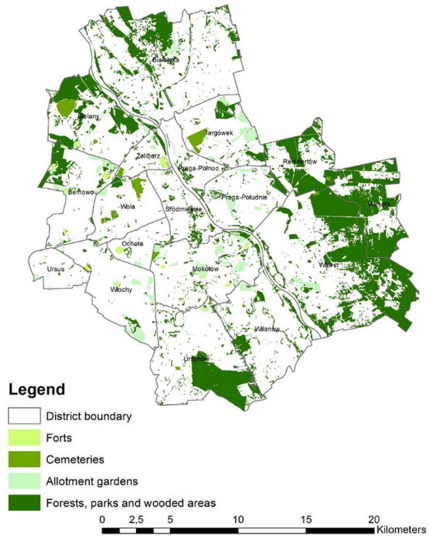


Fig. 6. Distribution of urban green areas in Warsaw in 2021
(Source: Own study based on BDOT10k data)

clinic, per shop, per pharmacy, per available library book collection and per area of parks, green spots and green areas per inhabitant. The total value was the arithmetic mean of the standardised values of the calculated sub-indices.

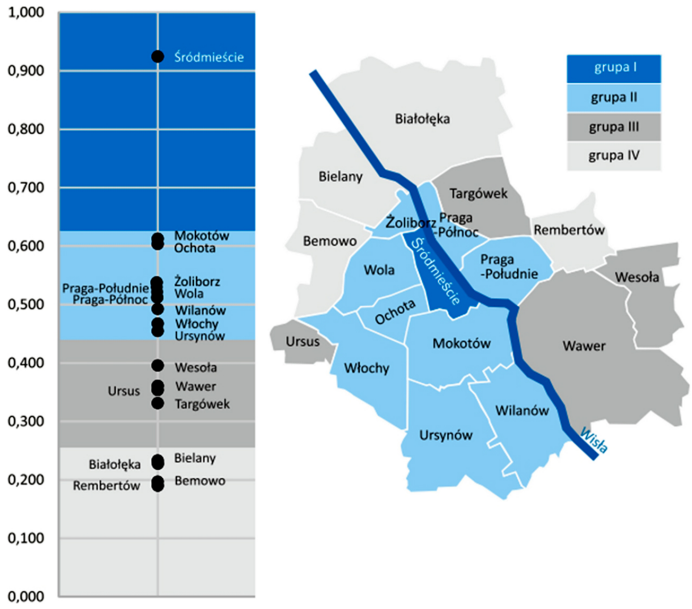


Fig. 7. Value and spatial distribution of the synthetic measure for seniors
(Source: Ranking of Warsaw districts in terms of attractiveness of living conditions) [23]

Due to their often limited mobility and health condition, accessibility to certain service points – outpatient clinics, pharmacies, libraries or neighbourhood shops – is of great importance to them. In the context of the subject-matter of the paper, it was significant to include the area of parks, green spots and green spaces in residential areas per inhabitant. As a consequence, districts were divided into four attractiveness groups, where group I indicates a very high attractiveness level and group IV a low level.

The Śródmieście [Downtown] district proved to be most attractive. It was the only one to be ranked as very attractive. This may result, among others, from the fact that there are many services located in the city centre but with its green areas and air pollution, it is not a comfortable place to live. On the other hand, it can be noted that the score of some of the lowest ranked districts – Bemowo and Rembertów is also mostly determined by the criteria of accessibility (or rather its absence) to essential services, as in terms of greenery coverage, they score significantly lower. On the other hand, it is confirmed that the most industrialised Bielany and Białołęka also score lowest in terms of attractiveness for the elderly.

The second group surveyed and significant in terms of the subject of this paper, are families with children. The construction of the synthetic attractiveness index was also based on five indicators including the area of parks, green areas and green spaces, the number of live births, the percentage of children at nursery school age, the number of children per place in

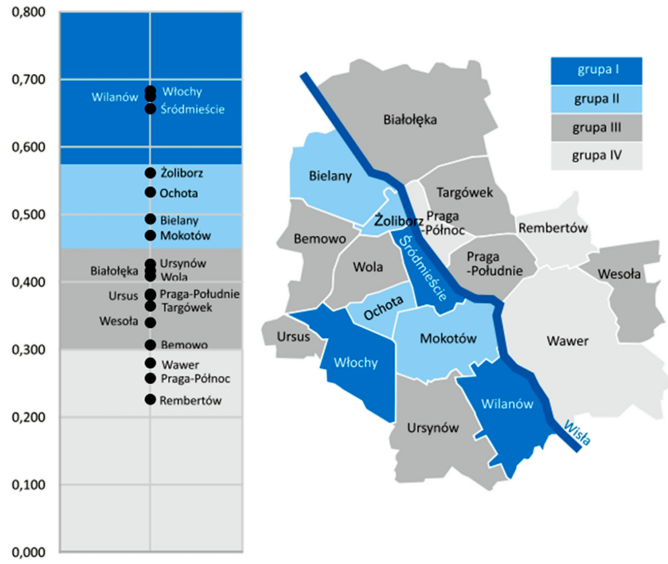


Fig. 8. Value and spatial distribution of the synthetic measure for families with children (Source: Ranking of Warsaw districts in terms of attractiveness of living conditions) [23]

kindergarten and the net enrolment rate for lower secondary schools. The total value was the arithmetic mean of the standardised values of the calculated sub-indices.

Here again, one of the important factors affecting the attractiveness of the neighbourhood was the area of parks, green spots and green areas in residential areas per resident. For children, it is necessary to find an educational facility close to where they live without having to commute at long distances. In addition, the school availability rate, the location and distribution of educational facilities or the number of live births were also taken into account.

As before, the districts were divided into four attractiveness groups. The following districts were considered very attractive (group I): Włochy – 0.683, Wilanów – 0.675, Śródmieście – 0.656. On the other hand, Group IV – not very attractive, included: Wawer – 0,280, Praga-Północ – 0,258, Rembertów – 0.226.

The most attractive districts, in the case of Śródmieście and Włochy, have been chosen mainly because of their high coverage by educational institutions, as well as good transport accessibility. They are also not overly industrialised areas. In the case of Wilanów, on the other hand, it was the coverage by green areas that proved decisive, as well as the low incidence of disease and the lack of industrial facilities.

When analysing the selection of the lowest ranked districts, the poor service facilities of Rembertów again play a rather significant role, coupled with limited transport accessibility (apart from the railway). It should also be borne in mind that the green areas of this district are mostly not used for public purposes, but for the use of the Academy of Military Arts and the military training ground. Also ranked low was Praga-Północ, which is quite heavily industrialised, affected by a significant percentage of disease and thus unattractive for families with children.

The analysis of district attractiveness indicators for different population groups shows the important influence of green coverage on inhabitants' well-being. Of course, the extremely important aspect of accessibility to services and communication should not be forgotten, as without their adequate development, such a district will not be an attractive place to live for groups characterised by limited mobility.

The last group of indicators discussed showing the important role of biologically active areas are those directly related to the city climate and plans for adapting to its changes. For example, the temperature in the city centre is higher than in the suburbs of Warsaw and the number of hot nights is up to four times higher. Hot nights, with minimum temperatures above 20°C, cause sleeping problems and additional fatigue.

The Urban Heat Island phenomenon and the occurrence of the highest temperature anomalies are recorded in the following districts, respectively: Śródmieście, Mokotów, Ursynów. However, this phenomenon is least disruptive to the residents of: Wesoła, Rembertów, Wawer.

Thus, a clear correlation can be seen between the impact of an increased share of green areas in favour of excessive urbanisation on the lower intensity of the Urban Heat Island and, consequently, lower temperatures on hot days and greater living comfort (Fig. 9).

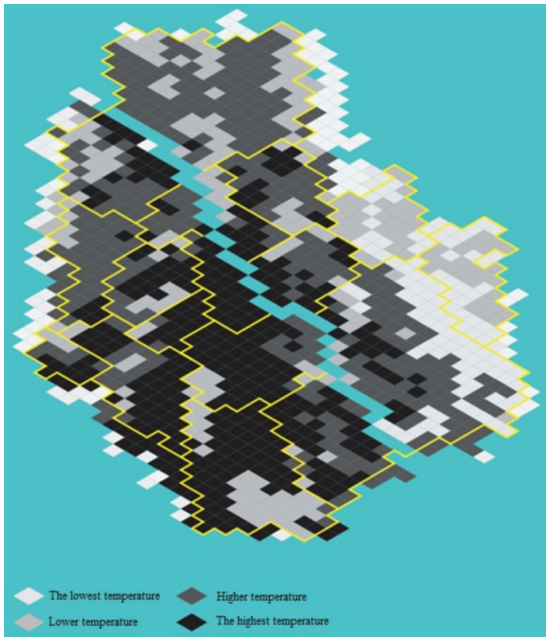


Fig. 9. Map of air temperature distribution in Warsaw
(Source: Warsaw Climate)

In addition, the number of days with heavy rainfall per year will increase and the maximum daily rainfall above 80 mm/m^2 will rise. In the absence of adequate coverage of biologically active areas and soil sealing, however, this water is not absorbed by the ground but stagnates on the surface or runs off, causing flooding [23].

These relationships are also confirmed by the analysis of the NDVI (Normalised Difference Vegetation Index), allowing for determining the development status and the condition of vegetation observed in the area of individual Warsaw districts (Fig. 10).

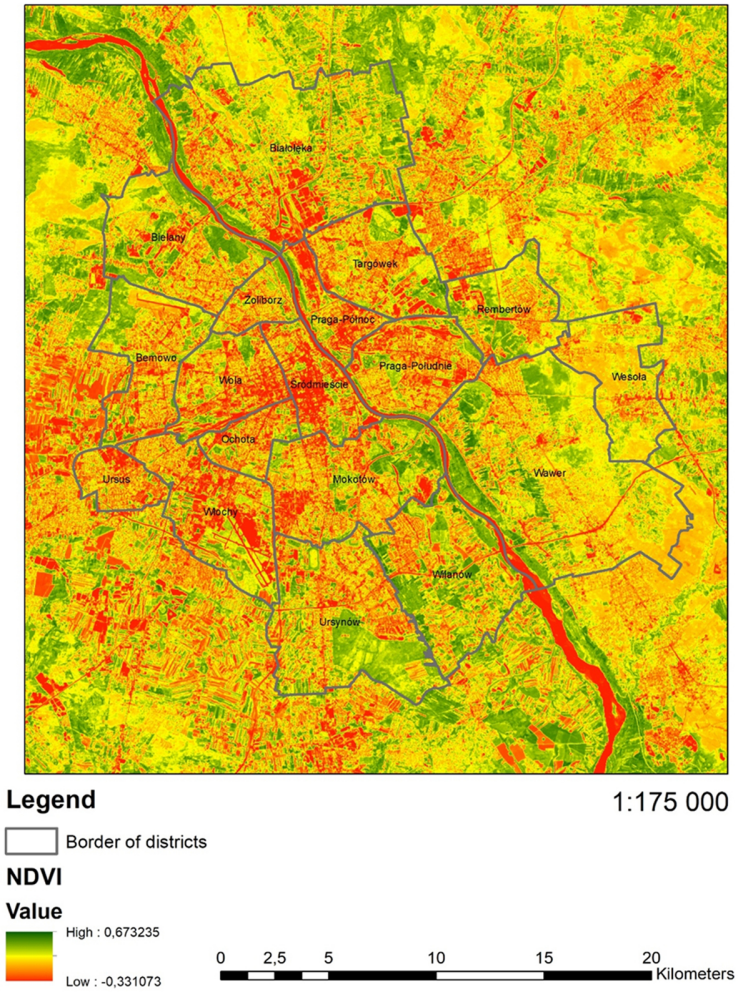
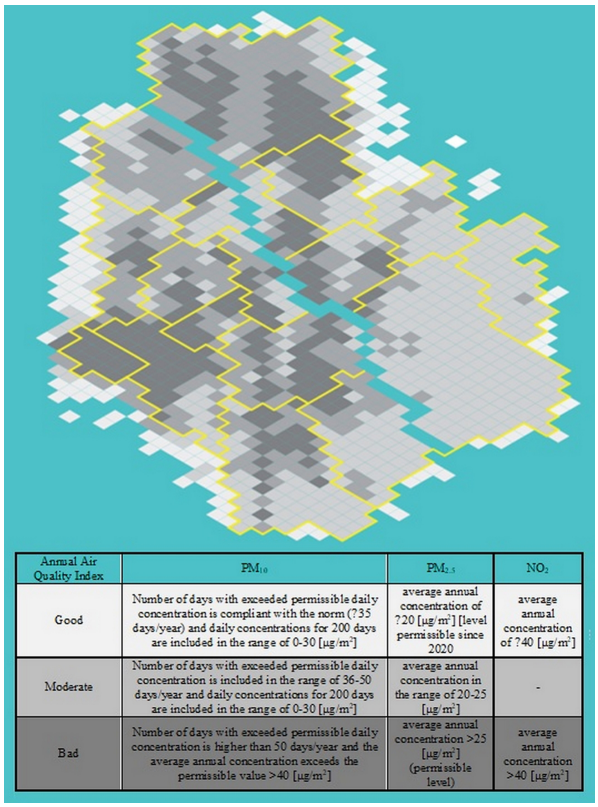


Fig. 10. NDVI in Warsaw (Source: Own study based on Landsat 9 data of 5 June 2022)

Another climatic indicator is the Annual Air Quality Index (Figure 11). The AAQI takes into account three pollutants whose permissible levels are exceeded in Warsaw: particulate matter PM10 and PM2.5 and nitrogen dioxide (NO2). The AAQI also distinguishes three categories of air quality: good, moderate and bad [24].

Four districts of Warsaw fell into the good category: Wesoła, Wawer, Rembertów, Wilanów, In contrast, bad AAQI is also recorded in 5 districts: Włochy, Mokotów, Praga-Północ, Białołęka, Praga-Południe. These are the same districts as the best and worst districts in



Annual Air Quality Index	PM_{10}	$PM_{2.5}$	NO_2
Good	Number of days with exceeded permissible daily concentration is compliant with the norm (?35 days/year) and daily concentrations for 200 days are included in the range of 0-30 [µg/m³]	average annual concentration of ?20 [µg/m³] [level permissible since 2020	average annual concentration of ?40 [µg/m³]
Moderate	Number of days with exceeded permissible daily concentration is included in the range of 36-50 days/year and daily concentrations for 200 days are included in the range of 0-30 [µg/m³]	average annual concentration in the range of 20-25 [µg/m³]	-
Bad	Number of days with exceeded permissible daily concentration is higher than 50 days/year and the average annual concentration exceeds the permissible value >40 [µg/m³]	average annual concentration >25 [µg/m³] (permissible level)	average annual concentration >40 [µg/m³]

Fig. 11. Annual Air Quality Index in Warsaw (Source: Warsaw Climate)

terms of green coverage, industrial areas and resident morbidity. When the ventilation aspect is added to the air quality index, the aero-sanitary comfort index is obtained. The districts with the highest share of areas with good comfort levels include: Wesoła – 100%, Wawer – 97%, Rembertów – 95%, Żoliborz – 88%. Districts with the highest share of areas of poor aero-sanitary comfort include: Praga-Południe – 50%, Śródmieście – 20%, Ochota – 18%, Mokotów – 10%, Wola – 10%.

4.2. Case study no. 2 – Oslo

Analysing the percentage distribution of the leading causes of mortality in Oslo, cancer can be identified as the prevailing cause (39.53% in 2021) Calculated per 100,000 inhabitants, 275.8 deaths were recorded in Oslo in 2016 and 261.8 deaths in 2021 (GUS). This value is significantly lower than for Warsaw. The leading causes highlighted in 2021 included: Cancer – 39.53%, Cardiovascular diseases – 17.23%, Violent deaths – 10.35%, Accidents – 5.65%, Suicides – 4.24%, Respiratory diseases – 4.01%, Others – 18.98% (including COVID-19).

As in the case of Warsaw, the distribution of the number of deaths (per 100,000 inhabitants) for the diseases contributing to the highest number of deaths in each Oslo district was examined. In order to obtain comparable results, the 2016 data were again derived and the first two categories – cancer and cardiovascular diseases – were adopted for analysis. The districts most affected by deaths from cardiovascular disease are (Fig. 12): Sagene – 90.7, Grünerløkka – 77.4, Grorud – 68.2, Gamle Oslo – 66.4, Alna – 63.2.

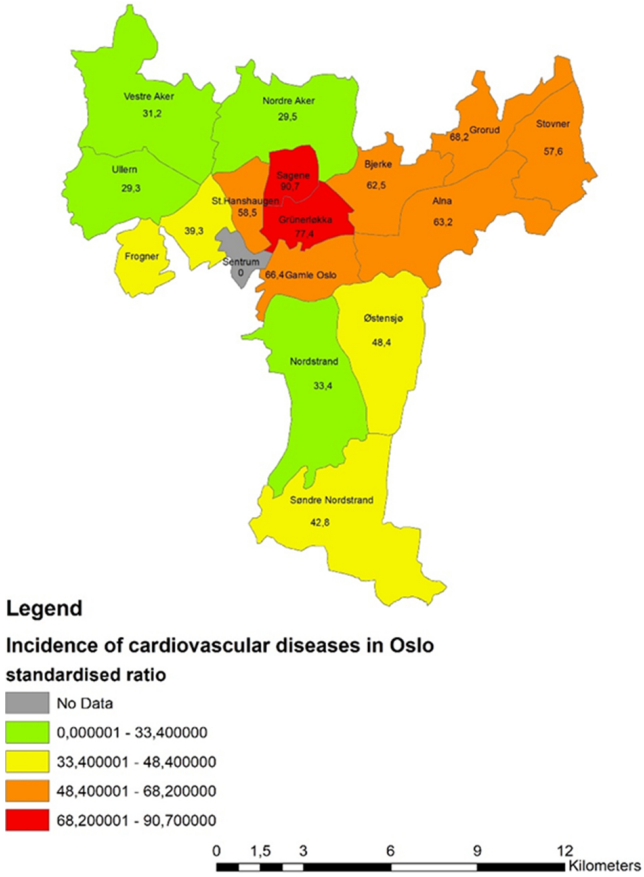


Fig. 12. Statistics on mortality from cardiovascular disease in Oslo in 2016
(Source: Own study based on data from Folkehelseinstituttet)

On the contrary, the lowest number of deaths from malignant tumours is characteristic for: Ullern – 29.3, Nordre Aker – 29.5, Vestre Aker – 31.2, Nordstrand – 33.4, Frogner – 39.3. For cardiovascular diseases, a similar spatial relationship is observed. For cancer diseases, the following districts distinguish clearly negatively (Fig. 13): Sagene – 154.9, Grünerløkka – 144.0, Gamle Oslo – 133.8, Grorud – 129.4, Bjerke – 125.3. On the contrary, the districts least affected by this problem include: Nordre Aker – 84.1, Vestre Aker – 85.4, Ullern – 88.1, Frogner – 96.6, Nordstrand – 99.0.

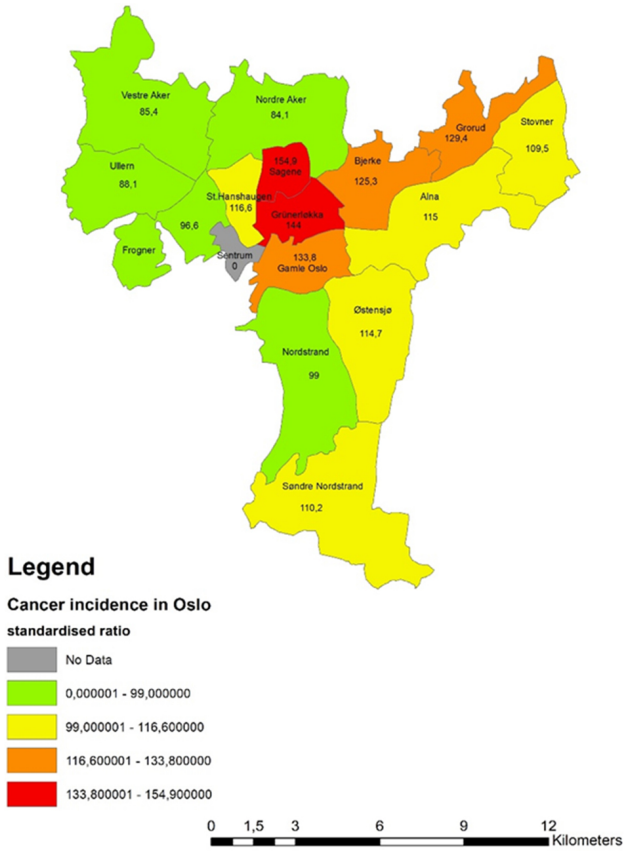


Fig. 13. Cancer mortality statistics in Oslo in 2016
(Source: Own study based on data from Folkehelseinstituttet)

As in the case of Warsaw, the same four most affected districts – Sagene, Grünerløkka, Gamle Oslo and Grorud – appear in both analyses of the districts at risk of death from the diseases listed above, while the safest districts are also the same – Nordre Aker, Vestre Aker, Ullern, Frogner and Nordstrand.

Again, the districts at risk are those located in the city centre. Less exposed are the neighbouring districts, which are often more covered by urban greenery (Fig. 14). In addition, the area of greenery is visibly larger than in Warsaw. Additionally, according to the statistics provided by the Oslo authorities, 98% of the city residents live at a distance of less than 300 metres to green areas from their residence.

A fundamental difference between Warsaw and Oslo can also be noted. In Oslo, the rate of deaths from cardiovascular diseases is significantly lower, which may confirm the results of studies according to which exposure to green areas can have an effect on cardiovascular health by reducing air pollution, urban heat and noise, encouraging exercise [25]. Oslo, on the other hand, had higher cancer mortality statistics than Warsaw.

Fig. 14. Distribution of urban green spaces in Oslo in 2021
(Source: https://magasin.oslo.kommune.no/byplan/kartlegger-gront-i-oslo)

It is worth noting that most of Oslo central industrial areas were transformed after 1985. The factories of many well-known companies disappeared from the urban space: Akers mek., Christiania Spigerverk, Kværner, STK, EB, Thune Eureka and NEBB. The brownfield sites have been converted into offices, flats, shops and recreation areas [26]. The relocation of industry outside the Oslo city boundary to new industrial areas in neighbouring municipalities was a part of the plan for the overall deindustrialisation of Oslo already implemented since the mid-1960s [27]. For this reason, the analysis of the distribution of industrial facilities in Oslo was not carried out.

In Oslo, the districts of Ullern (21% of the total district population) and Vestre Aker (19%) have the highest share of people in the post-working age group in 2021 according to the Folkehelseinstituttet data. The most challenging neighbourhoods in terms of mortality, Sagene and Grünerløkka, had some of the lowest results in the entire city (8.9% and 7.2%, respectively). The districts with the lowest share were Grünerløkka (7.2%), Gamle Oslo (8.5%) and Ursus (16%). In terms of neighbourhood safety, Alna and Gamle Oslo were identified as the neighbourhoods most affected by violence and crime, while Ullern and Hanshaugen were the safest. It can be seen that in the case of Oslo, no clear link was found between population structure and increased mortality.

The relationships described are also confirmed by the analysis of the NDVI index observed in the various Oslo districts (Fig. 15). The value of the index in the city only falls below 0 in some places, reaching a value of 0.68 in the vicinity of the urban green areas. This value is comparable to the green areas in Warsaw. However, Oslo does not have the large paved areas lacking greenery found in Warsaw, where the indicator often reaches negative values (up to –0.33).

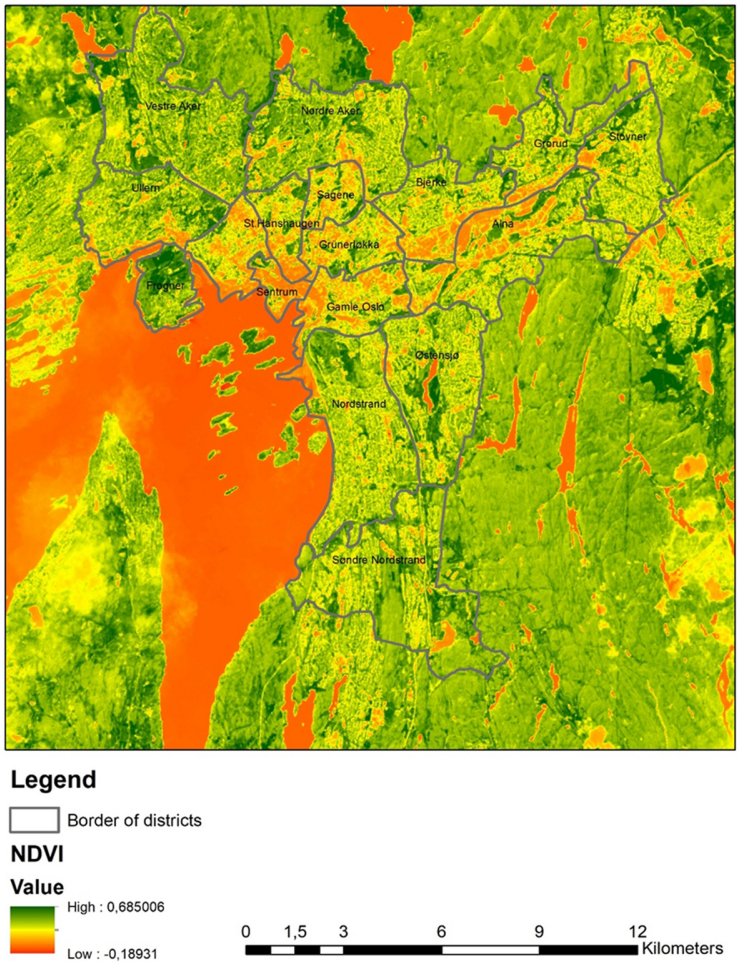


Fig. 15. NDVI value in Oslo (Source: Own study based on Landsat 9 data of 6 July 2022)

5. Conclusions

When comparing the results obtained for Warsaw and Oslo, clear differences can be seen. Oslo, as a city with a long-standing policy of deindustrialisation and planning of biologically active areas, records much lower death rates per 100 thousand inhabitants, including in particular a much lower number of deaths from cardiovascular diseases (Fig. 16). This is particularly evident in districts rich in green areas. Thanks to its planned system of urban greenery, Oslo also scores higher on the NDVI index, which is used to determine the state of development and condition of vegetation in the study area (Fig. 18). Clearly higher values are recorded in particular in the central areas, where the problem of ground cover is less pronounced (the minimum value of the indicator more favourable in Oslo than in Warsaw). A less clear indication is seen in the case of the cancer death rate, where the extreme values are higher in Oslo than in Warsaw (Fig. 17).

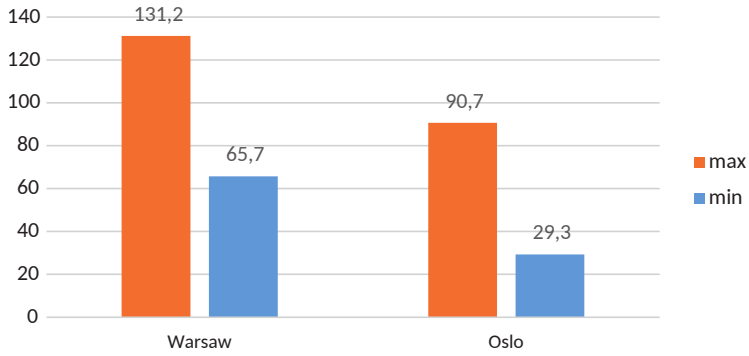


Fig. 16. Cardiovascular mortality statistics in Warsaw and in Oslo
(Source: Own study based on Statistics Poland and Folkehelseinstituttet data)

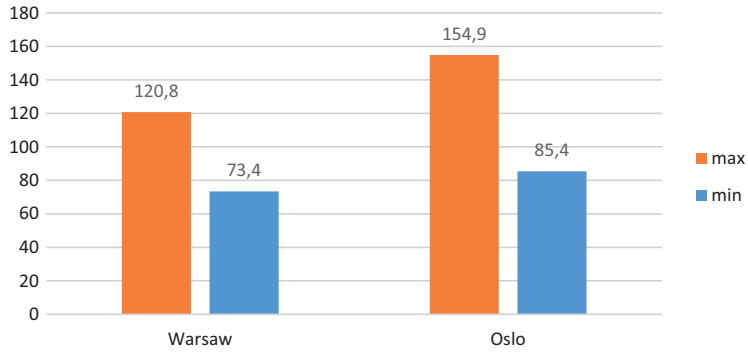


Fig. 17. Cancer mortality statistics for Warsaw and in Oslo
(Source: Own study based on Statistics Poland and Folkehelseinstituttet data)

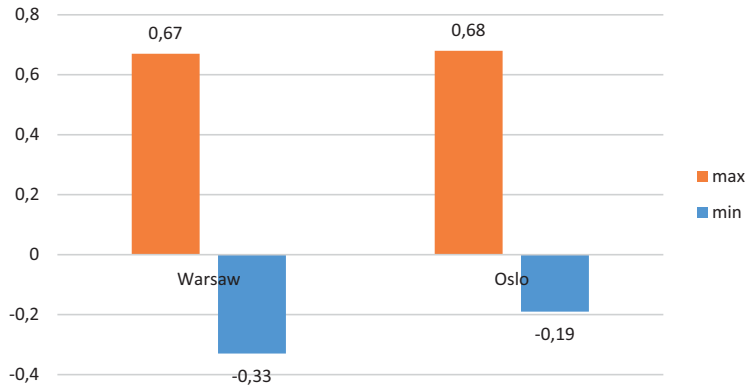


Fig. 18. NDVI values in Warsaw and in Oslo (Source: Own study based on Landsat 9 data)

After analysing the indicators of different nature – social (attractiveness and comfort of living, morbidity of inhabitants), economic (coverage of industrial areas) and environmental (air temperature, precipitation, air quality), it can be concluded that there is a visible correlation between the individual factors and the share of biologically active areas in the districts concerned [28].

In the case of social criteria, the greater the proportion of green areas, the greater the attractiveness of the district, especially for people with reduced mobility (the elderly, families with children), also the lower the incidence of civilisation diseases among the inhabitants;

In the case of economic criteria – the greater the proportion of green areas, the lower the negative impact of industrial/post-industrial areas, the development of these areas, at least in part as biologically active area, should be the current trend;

In the case of environmental criteria – the greater the proportion of green areas, the lower the average air temperature, the greater the outflow of water into the ground, and the better the air quality and aero-sanitary comfort.

In the absence of measures aimed at increasing the area of biologically active areas in the city, scenarios developed by experts assume a sharp increase in the number of skin cancers, cardiovascular diseases and heat stress-induced diseases [4]. Actions aimed at preserving undeveloped areas and areas of existing high greenery in the city space, as well as introducing green areas with tree planting in areas to be developed, the development of street trees [15] and other elements of green infrastructure (e.g. green roofs, green walls) are of key importance.

In conclusion, biologically active areas play an extremely important role in the structure of a city and increasing their coverage, especially in large urban centres, is a measure with a number of advantages presented above.

In view of the challenges facing modern societies and the emerging crisis situations, sustainable development is a key strategy for building a stable future for our planet. The rational management of space, with particular emphasis on the preservation of urban green spaces and the use of optimally available land reserves in this area, have a significant impact on achieving the objectives of sustainable development and, consequently, on improving living conditions today and in the future.

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Analiza wpływu pokrycia zielenią obszaru m. st. Warszawy na komfort życia mieszkańców na podstawie danych przestrzennych i statystycznych

Słowa kluczowe: tereny zieleni, rozwój przestrzenny; zrównoważony rozwój, planowanie przestrzenne, analiza NDVI.

Streszczenie:

Obszary biologicznie czynne odgrywają niezwykle istotną rolę w strukturze miasta, a zwiększanie ich pokrycia, szczególnie w dużych ośrodkach miejskich, jest działaniem mającym szereg zalet. Niniejszy artykułporównuje pod kątem przestrzeni zielonych, dwa europejskie miasta stanowiące główne ośrodki regionu o zbliżonej do siebie wielkości – Warszawę (517,2 km^2) i Oslo (454 km^2). Oba miasta są stolicami swoich krajów, realizują jednak inną politykę przestrzenną w zakresie Zielonego Ładu. W Warszawie cały czas obecnych jest wiele obszarów przemysłowych i poprzemysłowych, a obszary zieleni miejskiej z roku na rok zmniejszają swoją powierzchnię. W Oslo wdrożona jest strategia oparta na deindustrializacji miasta i możliwym maksymalnym wykorzystaniu zieleni miejskiej i przestrzeni publicznych. Badania opisane w niniejszym artykule polegały na analizie pokrycia analizowanych miast i ich dzielnic powierzchnią biologicznie czynną, a następnie sprawdzenie korelacji z innymi wskaźnikami, na które może mieć wpływ to pokrycie. Były to dane dotyczące zachorowalności mieszkańców na najczęściej spotykane choroby, atrakcyjnością zamieszkania dla osób starszych i rodzin z dziećmi, a także zanieczyszczeniami powietrza, gleby oraz występowania negatywnych skutków zmian klimatycznych. Następnie określona została zależność wykorzystania przestrzeni miejskiej w kontekście występowania obszarów przemysłowych w relacji do aktualnie istniejących obszarów zielonych danych dzielnic.

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