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Assessing the evolution of urban expansion density over a century, Konya, Türkiye

Kentsel yayılma yoğunluğunun yüzyıldaki gelişiminin değerlendirilmesi, Konya, Türkiye

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Abstract

The year 2023 represents a 100-year period of becoming a country for Türkiye. This study examines the urban expansion evolution of Konya in Turkey over a century of urbanization. The expansion process is assessed through the analysis of urban plans from 1923, 1945, 1967, 2000, and 2023 using (1) density calculation derived from the population divided by built-up cells and (2) density calculation utilizing Inverse S function based on land use data. Considering the calculated densities, the city's evolution over a hundred years is examined concerning evolving regulations land use decisions, and growth trajectories. The existing conditions, encompassing both the advantageous and disadvantageous facets of urban expansion, are examined using SWOT analysis, and spatial development strategies for the future are devised. As a result, it has been determined that Konya has undergone urban expansion in certain directions irregularly, attributed to transportation-focused planning decisions, deviating from human-scale and compact urban development.

Anahtar kelimeler: Urban expansion, Land density, Inverse S-shape Rule, GIS, SWOT

Öz

2023 yılı Türkiye için 100 yıllık bir devlet olma sürecini ifade etmektedir. Bu çalışmada, Türkiye'nin Konya kentinin 100 yıllık bir kentleşme deneyiminde yayılma süreci analiz edilmiştir. Yayılma süreci 1923, 1945, 1967, 2000 ve 2023 yıllarına ait planlar kapsamında; (1) yerleşik hücrelere bölünen ve bu hücrelerde yaşayan kişi sayısına bağlı yoğunluk ve (2) arazi kullanım verilerine dayalı Ters S ile yoğunluk hesaplaması yöntemleri kullanılarak elde edilen yayılma ölçütleri üzerinden değerlendirilmiştir. Elde edilen yoğunluk verileri kapsamında 100 yıllık süreçteki kent; değişen mevzuat, arazi kullanım kararları ve gelişme yönleri kapsamında tartışılmıştır. Kentsel yayılmanın olumlu ve olumsuz yönlerini içeren mevcut durum SWOT yardımıyla analiz edilerek gelecek için mekânsal gelişim politikaları oluşturulmuştur. Sonuç olarak, Konya kentinin ulaşıma yönelik plan kararları nedeniyle homojen olmayan nitelikte belirli yönlerde kentsel yayılma ve sıçramalar gösterdiği ve insan ölçeğinden ve kompakt kentleşmeden uzaklaştığı tespit edilmiştir.

Keywords: Kentsel yayılma, Arazi yoğunluğu, Ters S Kuralı, CBS, GZFT

1 Introduction

Urbanization is a process that refers to the movement of the population from rural areas to urban areas and the development of the transportation system and residential areas with the increase in construction [1, 2]. The industrialization movement initiated by the fordist system in the agricultural sector after World War II reduced the need for labor in the agricultural sector [1, 3, 4]. Accordingly, due to the decreasing employment in the agricultural sector, the society, seeking new sectors, left the rural areas and migrated to the cities to provide new employment opportunities [4, 5]. Therefore, urbanization also refers to a process that transforms from agricultural societies to industrial societies.

In Türkiye, migration from rural to urban areas increased after 1950. The society started to create industrial areas for employment purposes and housing around them for sheltering and the first urban expansion movements started [2, 6, 7]. These first urban expansion movements emerged due to the urbanization process caused by the economic transformation triggered by industrialization. In this process, the city's orientation towards rural areas and fertile agricultural lands, the planning approach that enables the city to expand towards the rural-urban fringe with low housing density, dependence on private vehicles and the formation of decentralized communities are defined as urban expansion [8-14].

Since urban expansion is a result of population and economic growth, it has positive aspects such as the development of urban business sectors and infrastructure. However, it has many negative consequences, such as environmental problems, traffic congestion, water scarcity, economies of scale, car dependency, fragmented land use and loss of agricultural and natural land, which reduce urban livability and accelerate climatic changes [13-16]. The negative consequences of urban expansion endanger the sustainability system and livability level of cities [17-19]. In order to find solutions for the negative effects of urban expansion, it is necessary to measure the change of spatial and temporal expansion and to understand the causes of expansion [18, 20-22].

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The variability of urban expansion across regions, its lack of a universal definition, and its relative nature have led to concerns regarding the measurement of expansion [18, 23-25] However, many indicators and statistics have been developed in the literature to measure urban expansion [18, 20, 26-29]. Urban form must first be characterized in order to measure urban expansion. The metrics defining urban form have been analyzed in three categories: density, diversity, and spatial structure pattern [21, 30].

In the literature, there are many studies based on density, diversity and spatial structure pattern metrics that categorize urban form to measure urban expansion. Jiao [31] analyzed urban expansion based on land use change using an inverse S-shaped mathematical function. In Steurer and Bayr [21], urban expansion is analyzed by considering all three characteristic categories of urban expansion (low density, low continuity of land use type and low compactness of the city shape) and using multiple urban expansion indicators. Although urban expansion has been analyzed with different indicators, it has been stated in many studies that density analyses are the basic and most important indicator to define urban expansion [20, 31-33].

In this study, the change of urban expansion in Konya, Türkiye is analyzed by examining plans and planning decisions from the years 1923, 1945, 1965, 2000, and 2023. Two different density metrics that categorize urban form are used for measuring urban expansion. Firstly, the density change of urban expansion is calculated using the inverse S-shaped mathematical function of Jiao [31] based on land use intensity. Then urban expansion is calculated using the number of people divided by built-up cells in study district based on population [21]. The expansion pattern was analyzed by comparing the results of both density metrics by years. The urban expansion process is discussed within the scope of changing legislation, land use decisions and urban development directions in 100 years within the scope of density changing over the years. Then, the current situation, including the positive and negative aspects of urban expansion, is analyzed with the help of SWOT method and spatial development policies for the future are formed. Unlike the literature, the change of urban expansion is compared by analyzing the population and land use intensity together in a long period covering 100 years. This study provides important contributions to science in determining the areas expected to experience rapid urbanization in the future for Konya city, quantitatively characterizing and evaluating regional or global urban expansion in a century-long period.

2 Materials

Konya province is located between 36° 41' and 39° 16' north latitudes and 31° 14' and 34° 26' east longitudes with a surface area of 38.873 km2 in the Central Anatolia region of Türkiye (Figure 1). The city of Konya, which was selected as the study area, is a settlement that has traces of the Roman city dating back to ancient times and has developed as the capital of the Seljuks civilization. Being a Seljuks capital was effective in the development of urbanization and trade. The city, which shows sectoralization in agricultural production, is also an important religious tourism center.

Figure 1. General view of Konya city

The studies in the literature supporting the existence of the spread regarding the urban expansion process in Konya city have been examined. Akseki and Meşhur [34] analyzed the expansioning process in Konya city through different city plans after 1950 within the scope of fertile agricultural lands opened to construction. As a result, they determined that although the agricultural areas were tried to be protected with the zoning plans prepared after 1960, especially the 1st and 2nd class agricultural lands in the southern and western parts of the city were opened to construction due to the inadequacy of economic solutions and the plans were not successful. Karabacak [16] examined the urban expansion processes including Konya at the metropolitan scale and determined that urban expansion was intense in cities where the establishments were old and the population size increased. In the study conducted by Öncel and Meşhur [35] on the causes of urban expansion in Konya, it was determined that liberal policies and the increase in public and private sector capital investments in Turkey after 1980 caused expansion specific to Konya in planning control. These studies conducted for the city of Konya provide important evidence that urban expansion is directly related to population growth and capital growth based on planning studies

2.1 Dataset

In order to analyze the change in urban expansion in Konya city center between 1923-2023, maps and inventories for the past years were collected from institutions. The ways of obtaining the collected maps, their characteristics and the spatial analyses performed are summarized in Table 1 by years.

The problem encountered in all the maps obtained is the lack of a common georeference system. In order to solve this problem and to ensure that the maps overlap, the land use patterns that have survived in the city from 1923 to 2023 and have not changed have been investigated (Figure 2). First of all, the historical urban fabric was examined and some landmarks (cemetery, mosque, monuments, etc.) that still exist on the city were identified.

By using these landmarks in both physical and digital maps, common georeferencing was performed and digital format of all maps was obtained on GIS (Figure 3).

Table 1. The Maps characteristics and the spatial analysis

Year	Resulting Institution	Spatial Analysis
1923	Obtained from the archive of Konya Chamber of Architects.	The base map obtained was converted from Ottoman to Turkish and land use features were digitized.
1945	The zoning infrastructure of the city was determined from the archives in physical environment.	Physical sheet format map was digitized and a land use pattern was created.
1967	City zoning plan as a raster image from Konya Meram Municipality has been obtained.	The land use pattern was digitized by performing georeferencing on the resulting image.
2000	The map of the city's zoning status was obtained from Meram Municipality in digital format.	The resulting map was converted into GIS format and all land use features were digitized.
2023	The land use pattern expressing the current situation of the city was obtained from Google Earth and Konya City Information System.	It was digitized over the database using GIS software.

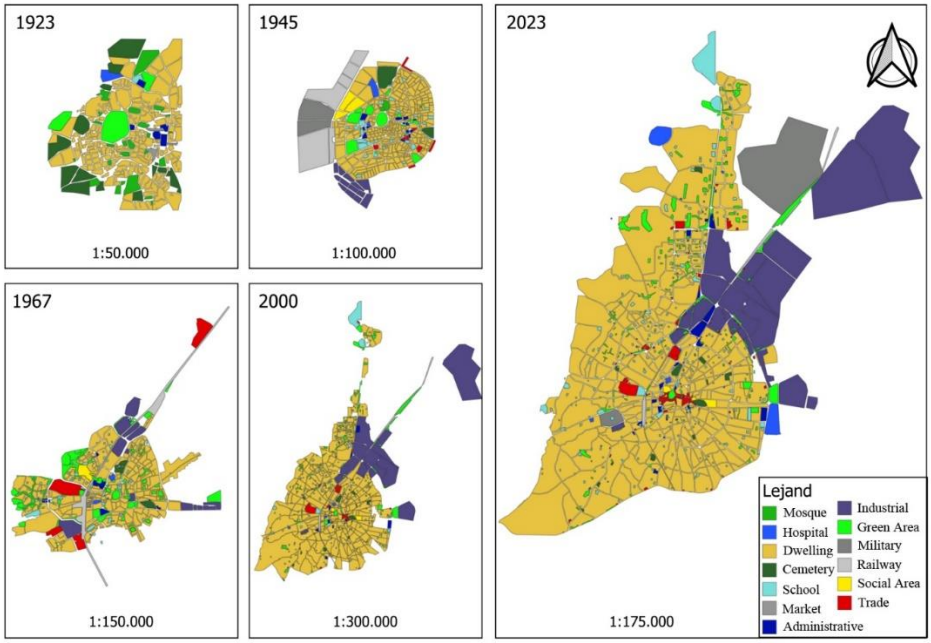

Figure 2. City maps of Konya for the years 1923-2023

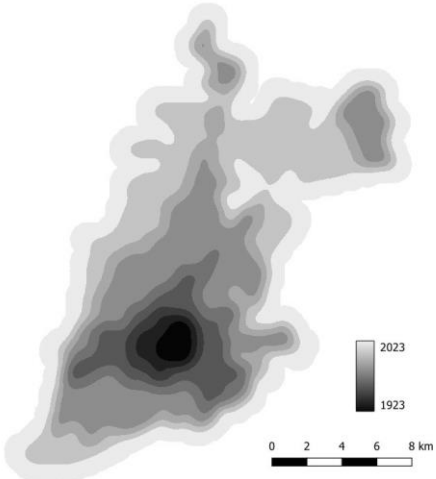

Figure 3. Representation of Konya city in the common georeference system in the years 1923, 1945, 1967, 2000, 2023

3 Method

The quantitative description of urban expansion and growth is one of the main activities of urban research. In particular, the analysis of density change is at the center of studies on measuring urban expansion [31, 35-37]. In this study, two different density metrics were used to measure urban expansion. The following calculation methods were used for these metrics:

- The mathematical formulation (Inverted S-shape Rule) that shows the general trend of the change of urban "land density" from the city center outwards.
- The number of people divided by built-up cells in the districts/municipalities where uninhabited areas are excluded.

The study compares the results of the analyses by testing two different methodologies, one of which is land density and the other is population density, on the same city over a

period of one hundred years between 1923, 1945, 1967, 2000 and 2023 and urban expansion will be examined within the scope of legislation, land use change and direction of the city. According to the analyses, spatial policies regarding the expansion process of Konya city have been formed by using SWOT analysis.

3.1 *Density metric I for measuring urban expansion: Inverse S-shape Rule*

Jiao [31] proposed the "Inverted S-shape Rule" for the variation of urban land density to quantitatively measure urban expansion. The inverted S-shape is a method to characterize urban form based on urban land density function and measure urban expansion. In this method, an inverse S-shaped sigmoid function is proposed to express the spatial variation of urban land density shown in Equation 1.

$$f(r) = \frac{1-c}{1+e^{\propto((2r/D)-1)}} + c \quad (1)$$

where f is the urban land density, r is the distance from the city center, e is the Euler's constant number, c is a constant number indicating the background value of the built-up land density in the city's hinterland, and D is the estimated radius of the main urban area of a city.

The resulting urban land density function is continuous, monotonically decreasing and differentiable [31]. Figure 4 shows the graph of the function created with the constants α = 4, c = 0.05 and D = 30, which gives the inverted S-shape.

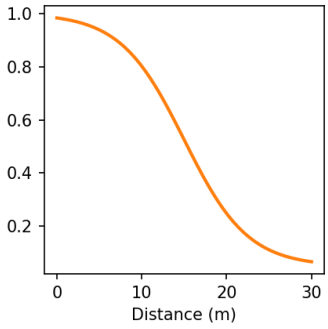

Figure 4. Inverse S-shape graph

3.2 *Density metric II for measuring urban expansion: the number of people divided by built-up cells*

More than half of the world's population now live in urban areas [19, 38]. The fact that population density is an increasing variable in urban areas has made it one of the most popular methods for measuring urban expansion [20, 33, 39]. However, urban expansion analysis with a land-independent population density change is a relative measurement method. [18, 28, 40].

Steurer and Bayr [21] measured urban expansion using land use data based on population density. They proposed a measure of urban expansion that takes into account population density in built-up areas, excluding areas where no one can live (e.g. streams, rivers, lakes, high mountains) or where no one is allowed to live (e.g. forests, parks or other areas outside zoning restrictions). This measure first determines the hinterland of the city, divides the city into cells of a certain size and calculates the density by taking into account the types of land use in the cell. The formula for this density measure is shown in Equation 2.

$$D_2 = \frac{\Sigma_i \Sigma_j pop_{ij}}{\Sigma_i \Sigma_j \Sigma_k x_{ijk}} \quad (2)$$

where i is cell, j is the region and k is the land use types counted as housing.

3.3 *SWOT analysis*

SWOT, which is a strategic planning tool, creates a perspective on the subject with the titles of Strengths (Strengths) and Weaknesses (Weaknesses), Opportunities (Opportunities) and Threats (Threats) [41]. SWOT analysis technique is an easy-to-use and practical method that defines the positive and negative aspects and areas of importance for the subject, and offers a clear perspective. SWOT analysis represents an important feature for creating action strategies and strategic spatial plans especially for urban areas [42]. SWOT analysis can identify the strengths and weaknesses, opportunities and threats of a particular region, such as urban expansion.

In the literature, SWOT analysis is used to development of strategic urban planning [43], management of urban environment [44], development of urban agriculture [45], planning urban mobility [46], demonstrate to the role of stakeholder engagement [47] and determine of urban regeneration intervention [48].

In this study, SWOT analysis criteria were established by considering urban expansion metric I, which examines land density, and urban expansion metric II, which examines population density. Ferrell and Hartline [49] and Wheelen and Hunger [50] were used as an example for matching the SWOT criteria (Figure 5).

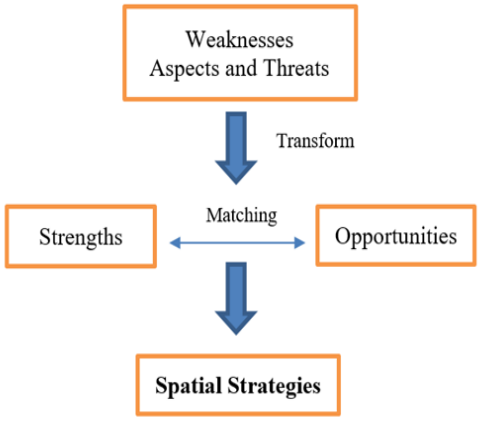

Figure 5. Matching of SWOT criteria [50-52]

The matching given in Figure 5 enables the transformation of the threats and weaknesses of the region and the development of appropriate spatial strategies for expansion by utilizing the strengths and opportunities of the region. SWOT criteria are associated with each other according to this matching technique and spatial policies are formed with expert opinions.

4 Result and discussion

4.1 Density metric I

Within the scope of the inverse S-shape rule, urban expansion processes of Konya city for the years 1923, 1945, 1975, 2000, 2023 were analyzed in the common georeference system. According to this density metric, the land density of each year was calculated and compared by years. In these calculated values, the urban hinterland, the estimated radius of the main urban area, the distance to the city center and the open and green areas representing the background value of the built land density were taken into account and urban land densities were determined (Table 2).

Table 2. Land densities in 1923, 1945, 1967, 2000, 2023 according to Inverse S

Year	α	r	D	C	f(r)
1923	4	1599	865	0.036098398	**0.0362**
1945	4	2849	1521	0.035983558	**0.036**
1967	4	7267	4581	0.039029272	**0.03921**
2000	4	18567	9601	0.04420525	**0.04421**
2023	4	18689	10738	0.06680814	**0.06681**

Inverted S-shape graphs representing the change in land density for each year and its comparison with each other are given in Figure 6. Here, the change of urban expansion density between 1923 and 2023 is expressed in terms of distance. It is seen that the spread intensity between 1923 and 1945 and between 2000 and 2023 are close to each other. However, the spread of 1967 compared to 1945 and 2000 compared to 1967 is noticeably higher.

4.2 Density metric II

Land use data is used to measure urban expansion according to the number of people divided by built-up cell. For this calculation, the hinterland of the city is first determined. In the studies analyzed, the hinterland of the city varies according to the city's agricultural and geographical characteristics and urban macroform [52-54].

In the study, the hinterland of the city was determined for each year by taking the area where the built-up area of the city ends as the boundary. After determining the hinterland of the city, the land use map was divided into built-up cells for each year. WorldPop states that gridded population datasets with spatial resolution equal to 100 m by 100 m are a reliable representation of population distributions based on census data [55-58]. In this context, the land use map for each year in the study area was divided into 100 m grids (Figure 7). Within these grids, the areas that remain in the land use pattern and where no one will live are eliminated and the expansion criterion based on the population density in the built-up area is calculated. An important criterion affecting this calculation is the floor rate in buildings. The floor rates have been determined by taking an average value within the framework of plan decisions and legislation over the years. Accordingly, urban land density is calculated based on the number of people per built-up cell over the years (Table 3)

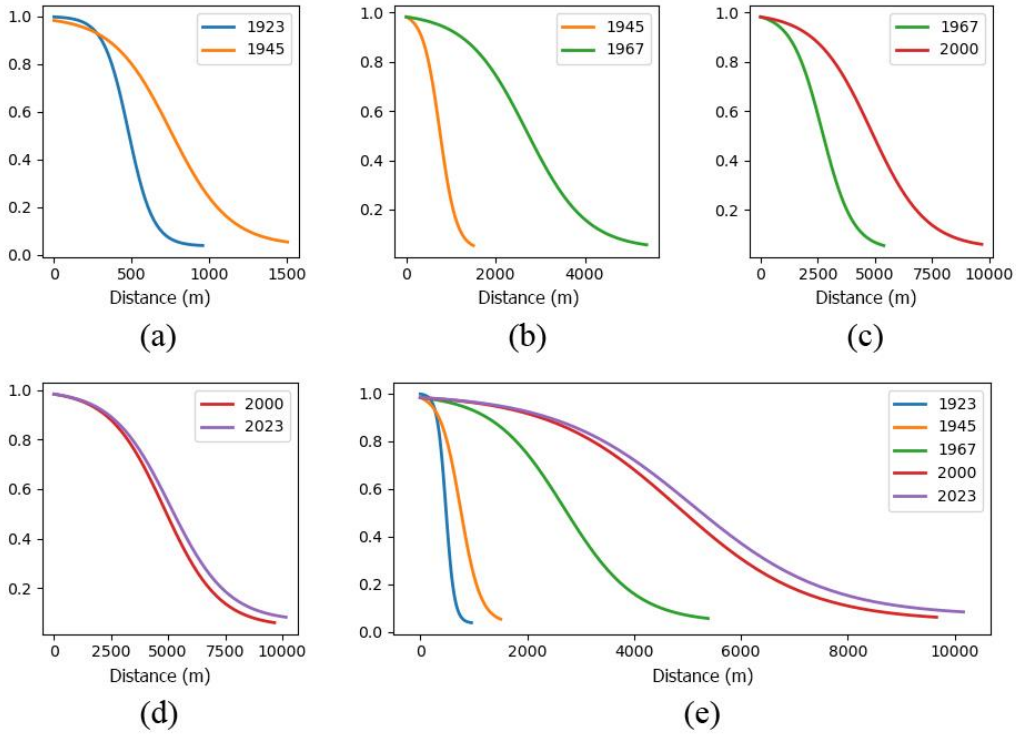

Figure 6. Urban expansion results according to the inverted S-shape rule

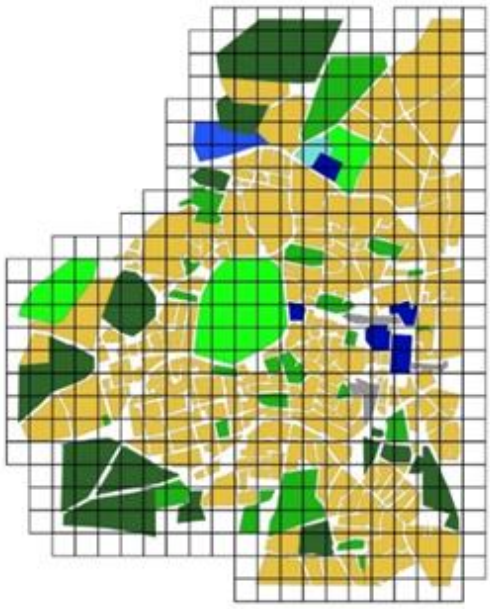

Figure 7. Example of the year 1923 for the generated built-up cells

Table 3. Land densities according to the number of people per built-up cell

Years	Average number of floors	Land densities
1923	3	0.0358
1945	3	0.02965
1967	4	0.03043
2000	5	0.05546
2023	6	0.0651

4.3 Discussion of urban expansion results according to density metrics

We compared the expansion pattern according to density metrics based on land use data for urban expansion and population data in the built-up area (Table 4).

Table 4. Comparison of the density metrics used

Years	Density Metric I based on land use	Density Metric II based on resident population
1923	0.0362	0.0358
1945	0.036	0.02965
1967	0.03921	0.03043
2000	0.04421	0.05546
2023	0.06681	0.0651

Both density prediction metrics obtained very close results on urban expansion in 1923 and 2023. In 1945, 1967 and 2000, the estimation results are close to each other, but the difference between them is mainly due to the changing legislation and land use decisions over the years. In this context, the effects of urban expansion over the years are analyzed according to legislation and land use decisions.

4.3.1 Examination of urban expansion according to legislation

An analysis was made according to the legislative framework that influenced the change of the city in 100 years:

- 1923-1945 was the period of post-war reconstruction of the country after the proclamation of the Republic. There were laws enacted in good faith between 1923 and 1945. The Law No. 1580 on Municipalities in 1930 and the Law No. 2290 on Municipal Building and Roads in 1933 contain provisions for the regulation of urban areas within this framework. However, these legislations could not be implemented due to the lack of technical and qualified manpower, and therefore there were no major differences between 1923 and 1945 in terms of land density metric. The difference in 1945 in terms of both expansion metrics is thought to be due to the lack of statistically significant post-war population data.
- The years 1945-1967 correspond to a period in which slum settlement started in urban areas with the increasing industrialization and migration from rural to urban areas after World War II. Especially the Zoning Law No. 6785 enacted in 1957 is important for the orderly development of urban areas and the prevention of urban expansion. However, it is determined that the economic depression caused by World War II, industrialization and increased migration for employment purposes increased urban density. Periodic unreliability of population data leads to differences in both expansion metrics [59, 60].
- The years 1967-2000 were a period of political turmoil and at the same time, special laws such as the Zoning Law No. 3194, which is still being revised and used today, the Zoning Amnesty Law No. 2981 in 1984, and the Law No. 2983 in 1983 on the Protection of Cultural and Natural Assets laws were enacted. With the laws enacted in this period, cities entered a rapid development process and the population density also increased [61-62]. In this period, practices based on the Condominium Law No. 634, enacted in 1965, caused the results obtained with the density metric II based on resident population to differ from the results obtained with density metric I.
- The years 2000-2023 were a period in which urban transformation activities started and transformation activities were increased with the Law No. 6306 on Urban Transformation in Areas of Disaster Risk in 2012.

As a result, according to both density metrics, it is observed that urban expansion has increased for Konya city after 1967 in terms of both population and land use.

4.3.2 Examination of urban expansion according to land use decisions and urban development directions

Land use changes (public, green, residential and industrial areas) over the years and the urban development directions of these areas were analyzed (Figure 8a, 8b, 8c, 8d and Figure 9a, 9b, 9c, 9d).

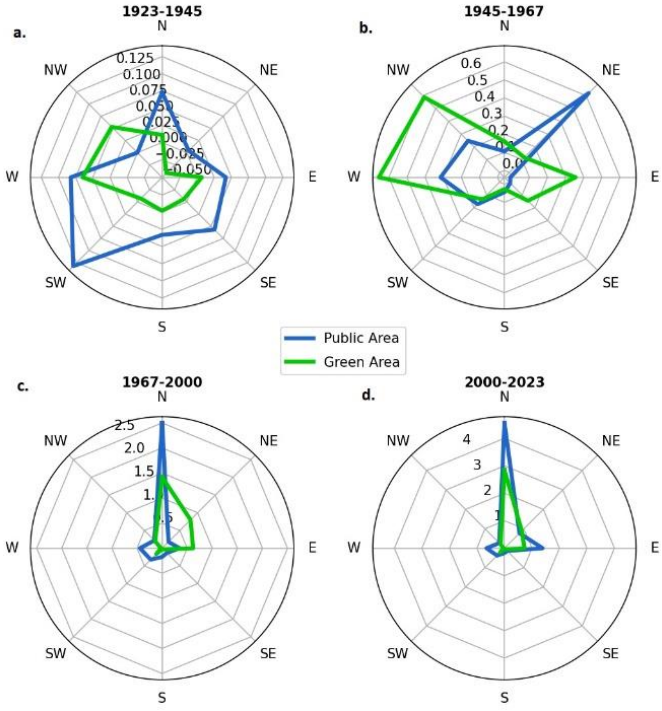

Figure 8a, 8b, 8c, 8d. Public and green space utilization and urban development directions by years

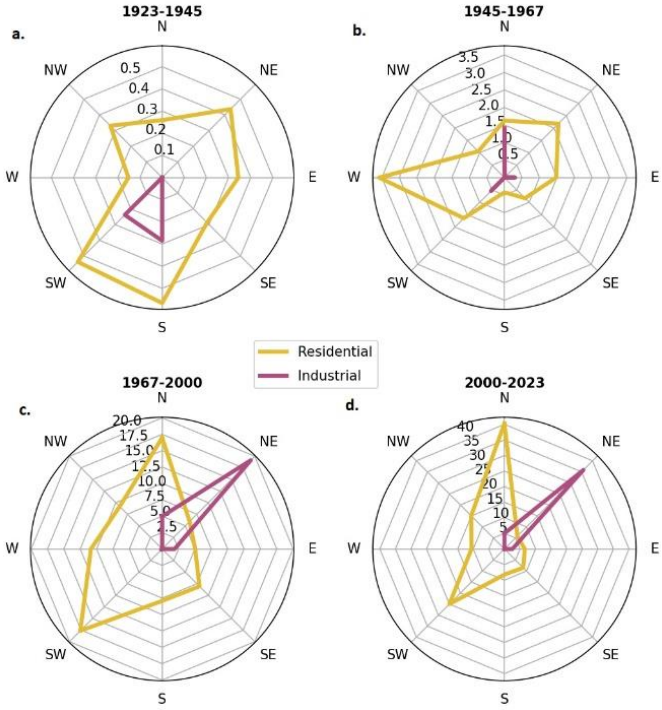

Figure 9a, 9b, 9c, 9d. Residential and industrial land uses and urban development directions by years

It has been determined that the use of public and green areas has developed in the north direction of the city after 1967. It is observed that the residential land use of the city was more homogeneous until 2000, but after 2000, it intensified in the north and south-west directions. In this period, it can be said that the city has developed rapidly in the north direction because of the university campus built in the north of the city and the light rail system developed in the north direction between the city and the campus. In addition, after 2000, the high-density construction process in the northern part of the city accelerated with the light rail system created in the previous period. After 2000, urban transformation activities increased in the west and south west of the city. It is observed that industrial areas developed in the north-east direction of the city after 1967.

4.3.3 Creating spatial policies with SWOT analysis to combat with urban expansion l in Konya

By means of SWOT analysis, the strengths and development opportunities of the city in the development process as well as the negative effects of urban expansion on the land use structure of the city and the threats to the sustainable development of the city are expressed. SWOT analysis criteria are as in Table 5.

Table 5. SWOT analysis criteria

STRONG ASPECTS
(S1) Increase in public areas (educational and health facilities) in the southern direction of the city
(S2) Development of public transport services in the eastern part of the city
(S3) Increasing urban regeneration activities in the west and south of the city
(S4) Existence of light rail system
WEAK ASPECTS
(W1) Development of the city's residential, industrial and green area utilization in a certain direction
(W2) Moving away from a human-scale settlement
(W3) Transformation of the city from a spider web urban form to a form with a linear spread in the north direction
(W4) Clustering of public transport services in certain directions within the hinterland
OPPORTUNITIES
(O1) No geographical obstacle in the planning of the city
(O2) The city is developed in terms of university and religious tourism
(O3) Dense green areas in the southern region
(O4) The city had a compact urban form in the past
THREATS
(T1) Clustering of public areas (educational, health and administrative facilities) in a certain direction of the city
(T2) Clustering of public transport mostly in the north and east of the city
(T3) Tendency of the city towards high-rise expansion in the north direction and opening up more car and development areas
(T4) Increase in carbon emission caused by the traffic density of the city spreading in linear form

The identified SWOT criteria were associated with each other according to the matching technique expressed in Figure 5 and spatial policies were determined to prevent urban expansion:

- Public, residential, industry and green space uses are concentrated in a certain direction within the city and cause regional inequality. The land use distribution should be integrated with green areas by being organized in accordance with the urban transformation activities starting in the west and south directions of the city (W1T1-S3O3). Thus, a homogeneous distribution of the urban expansion effect developing in a certain direction can be ensured in the city.
- Within the hinterland of the city, light rail public transportation services are concentrated in certain directions. In the planning of the city, the existing light rail systems should be developed by utilizing the geographical suitability of the area (W4T2- S2O1). By increasing the accessibility of transportation services to the entire city, the light rail systems concentrated in the north of the city can be concentrated in the south and southwest directions.
- There is an increase of high-rise development areas in linear form in the northern direction of the city. Transformation in the west and south directions for a compact development of the city urban density should be re-planned with the applications (W3T3-S3O4). The western and southern parts of the city should be redeveloped through urban transformation due to the worn-out urban fabric. Thus, urban density can be balanced with a homogeneous distribution throughout the city without urban expansion.
- Increasing development areas in the city in a linear form in the north direction leads to increased traffic density and more carbon emissions. For this reason, the city's existing light rail system should be integrated with green areas and expanded in the east and south directions (W3T4-S4O3). Thus, an urban fabric that is sensitive to climate change and has increased accessibility to green areas can be created.
- The city is becoming densely populated with high-rise buildings and is moving towards a settlement that is far from human scale. Opportunities to transform the city into compact and human-scaled settlements with increasing urban regeneration activities in the west and south should be seized (W2T3- S3O4). By increasing the transformation processes in the west and south of the city, the spreading effect can be reduced and the homogeneous distribution of the city can be ensured.
- The development trend of the city in the north direction has led to the concentration of public spaces in this direction. The city's development in the south direction should be planned by using the newly developing universities and tourism potential (W3T1-S1O2)

5 Conclusion

Measuring urban expansion provides an important framework for determining the effects of the urbanization process on rural areas, environmental characteristics and a sustainable development process. In this study, the 100-year urbanization experience and expansion process of Konya, which was the capital of the Seljuk civilization in Türkiye and is today at the forefront of faith tourism, is examined.

Density change criterion, which is frequently used in urban expansion processes, has been analyzed and compared based on land use and population data and legislative framework. In a 100-year period, the strengths and development opportunities in the development of the urban area and the positive and negative aspects affecting the expansion were analyzed by SWOT analysis and spatial policies for the future were formed. There is a need to organize urban policies for Konya city as stated below:

- Re-planning the direction of urban development through transformation and reconstruction activities to prevent regional inequalities,
- The realization of a human-scale and compact settlement form from high-rise residential use and
- Establishing the use of public transportation to arrangement the city in the form of a spider web, rather than in a certain direction of the city.
- Creation of reserve areas for homogeneous distribution of residential areas and public spaces
- Development of green areas integrated with public transportation in the south and west directions

Based on the city of Konya, it can be said that the correct reading of urban expansion processes for each city is very important for the sustainable and livable development of cities.

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Conflict of interest

The authors affirm that none of their known financial conflicts of interest or personal connections could have appeared to impact the research presented in this study.

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