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Demographic Structure and Center-Periphery Gradient in Greater Sfax: A Spatial Analysis

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Abstract

Greater Sfax has experienced strong urban expansion and population growth in recent decades, with differences between the center and the periphery in population, age structure and built-up area. This study examines these differences across the 44 administrative sectors of Greater Sfax. Demographic data come from the National Institute of Statistics for 2024, while built-up data come from GHSL 2018. The analysis considers population density, age structure, dependency ratio, distance to the center and share of built-up area. Thematic mapping, Spearman correlation and K-means classification were used. The results show that the share of under-15s increases from 19.61% within 5 km of the center to 24.05% beyond 15 km. Pooled population density decreases from 4604 to 123 inhabitants/km^2, while the pooled built-up share decreases from 34.77% to 2.66%. Population density and built-up share are strongly correlated ($\rho = 0.806$). However, the gradient is not regular: the dependency ratio does not follow the same trend, and local exceptions appear. K-means classification distinguishes four types. Central sectors are generally denser and more built-up, while peripheral sectors are younger and less dense. Distance to the center is important, but it does not explain all the differences in Greater Sfax.

Keywords

Greater Sfax, Demographic Structure, Center-Periphery Gradient, Built-Up Area, Spatial Analysis

1. Introduction

Greater Sfax is experiencing sustained urban growth. This growth concerns both its morphology and the distribution of its population. In 2024, it has 645,532

inhabitants on an area of about 551.4 km^2. The population is divided into six delegations and 44 administrative sectors (**Figure 1**). This distribution is very uneven. The differences also relate to demographic structure, in particular age and aging.

These inequalities can be linked to several factors. In Greater Sfax, the distance to the center varies greatly. It is less than 2 km in several central sectors and reaches nearly 18 km in the most remote areas. Built-up areas also show strong contrasts between sectors.

These differences show a center-periphery gradient. The areas near the center are generally denser and more built-up. Less than 5 km from the center, the pooled population density reaches 4,604 inhabitants/km^2 and the share of built-up area 34.8%. Between 10 and 15 km, they decrease respectively to 382 inhabitants/km^2 and 4.8%. The decrease becomes very clear beyond 10 km.

But this gradient is neither regular nor perfectly concentric. There are exceptions. El Ons, located 10.32 km from the center, has a high density of 5252 inhabitants/km^2. Conversely, Bab El Bhar, only 1.41 km away, has only 979 inhabitants/km^2. The gaps can also be significant between sectors located almost at the same distance. Cite El Bahri reaches 11,576 inhabitants/km^2 at 4.85 km from the center, against 3962 inhabitants/km^2 in Merkez Bouassida, located 5.06 km away. Distance therefore plays an important role, but it does not explain everything.

The form of urbanization can explain some of these differences. In Sfax, the urban extension has not been carried out uniformly around the center. It also followed the main roads. Towards the periphery, the built fabric becomes more dispersed and less continuous. This organization has promoted urban sprawl and a form that is not strictly concentric (Fakhfakh, 1985; Dlala, 1996; Bennasr, 2003; Belarem, 2024).

This situation is not unique to Sfax. Suburbanization changes the distribution of population between the center and the peripheries. It can also modify the structure by age. Aging is therefore not of equal importance in all parts of a city. These differences may also be linked to the history of urbanization and residential mobility (Kennedy & De Jong, 1977; Burgalassi & Matsumoto, 2024; Zhang et al., 2025).

The case of Greater Sfax allows us to study these relationships on a fine scale. The distance to the center, population density, built-up area and demographic structure can be compared across all 44 sectors. This study aims to determine to what extent the demographic structure of Greater Sfax follows a center-periphery gradient and how it relates to population density and built-up intensity. Three questions are asked: how does the demographic structure vary with the distance to the center? Do population density and built-up intensity follow the same gradient? Is this gradient regular or does it present breaks and exceptions?

A typology of sectors is also proposed to identify the main demographic and urban profiles and to see to what extent they are organized according to the center-periphery gradient.

2. Study Area, Data and Methods

2.1. Study Area and Data

Greater Sfax is part of the governorate of Sfax. It occupies a coastal position on the Mediterranean. It constitutes the main urban area of the governorate and concentrates a significant part of industrial activities and services. Its urban extension developed from the center, but also along the main roads. This organization partly explains the dispersed form of the current agglomeration (Fakhfakh, 1985; Dlala, 1996; Bennasr, 2003). The morphology of the city is semi-radial and concentric (Belarem, 2022; Belarem, 2024; Khebour Allouche & Belarem, 2017).

The governorate of Sfax has 16 delegations. Greater Sfax comprises six: Sfax Ville, Sfax Ouest, Sfax Sud, Thyna, Sakiet Ezzit and Sakiet Eddaïr. Their total population reached 645,532 inhabitants in 2024. This represents about 61.6% of the population of the governorate of Sfax, which has 1,047,468 inhabitants (INS, 2025). The area studied is about 551.4 km^2.

These six delegations include 44 administrative sectors (**Figure 1**). Their main characteristics are summarized in **Table 1**. They are not distributed in the same way. Sfax Ville has 12 sectors and Sakiet Eddaïr 8. Sfax Ouest, Sakiet Ezzit and Sfax Sud have 7 each, compared to only 3 in Thyna. The discrepancies are not just in number. The areas and populations are also very different. This diversity is already apparent among delegations. Sfax Sud, for example, has 142,716 inhabitants over 196.14 km^2, while Sfax Ville has 97,712 inhabitants over only 28.98 km^2.

In this study, the sector is the main unit of analysis. The choice of this scale makes it possible to work on 44 units, instead of limiting the analysis to the six delegations. Working on this fine scale makes it possible to better highlight local differences in age, population density, and built-up area.

The demographic data used correspond to 2024 and come from the General Census of Population and Housing of the National Institute of Statistics (INS, 2025). The database provides information on the total population of each sector, population by sex and age groups.

Table 1. Population, demographic and built-up characteristics of greater Sfax by delegation, 2024.

Delegation	Sectors	Population	Area km²	Density inh./km²	Aged 0% - 14%	Aged 65+ %	Aging index	Dependency ratio	Built-up area km²	Built-up share %
Sfax Ville	12	97,712	28.98	3372.18	18.45	13.52	73.28	47.01	9.17	31.65
Sfax Ouest	7	105,238	16.19	6498.87	20.18	12.48	61.85	48.51	6.67	41.21
Sakiet Ezzit	7	96,648	92.87	1040.73	20.67	12.24	59.24	49.05	11.27	12.14
Sakiet Eddaïr	8	123,457	114.89	1074.58	21.1	11.53	54.62	48.44	13.77	11.98
Sfax Sud	7	142,716	196.14	727.62	21.56	11.61	53.83	49.64	17.7	9.02
Thyna	3	79,761	102.32	779.52	24.54	8.03	32.73	48.31	8.3	8.12
Greater Sfax	44	645,532	551.38	1170.75	21.01	11.68	55.57	48.57	66.88	12.13

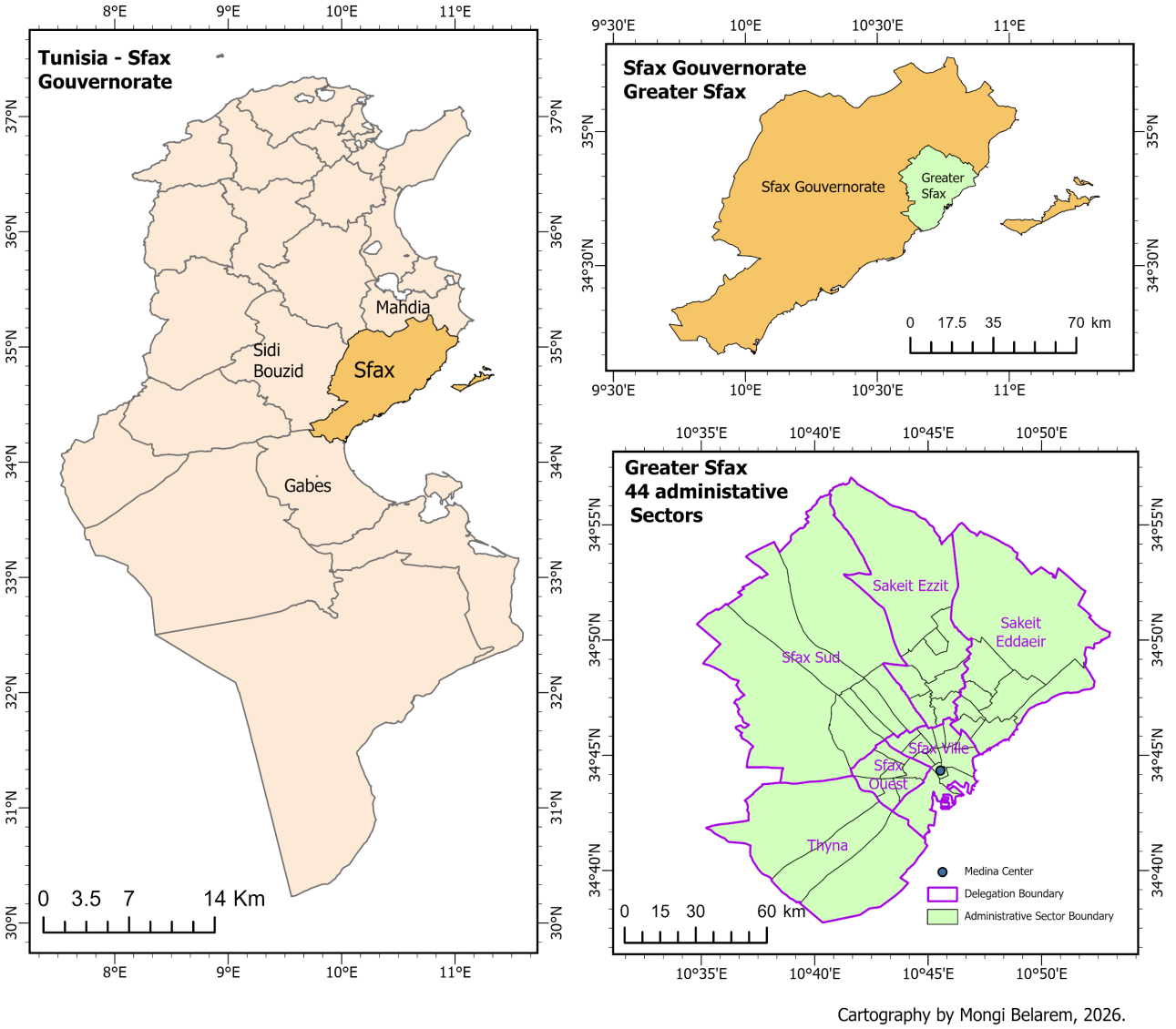

Figure 1. Location and administrative structure of greater Sfax by delegation and administrative sector.

The administrative boundaries of the sectors were also obtained from the National Institute of Statistics. Population records were linked to the sector boundaries using the administrative code assigned to each sector.

From these data, we calculated the population density, the share of the population aged 0 - 14 years, the share of those aged 65 and over, the aging index, and the demographic dependency ratio.

For built-up areas, the available data do not correspond to the same year. We used the Global Human Settlement Layer (GHSL) for 2018, with the product GHS-BUILT-S at a resolution of 10 m (Pesaresi & Politis, 2023). It makes it possible to estimate the built-up area in each sector. Two measures were selected: the built-up area in km^2 and its share within the sector. Contrasts are important. In Er-Rbadh, built-up areas account for 49.83% of the sector, compared to only 1.98% in Sidi Salah.

These demographic and urban data are also used to establish a typology of the 44 sectors. It is based on five variables: population density, the share of the population aged 0 - 14 years, the share of those aged 65 and over, distance from the center, and the share of built-up area. The classification method is presented in the next section.

2.2. Demographic, Built Environment, and Center-Periphery Gradient Indicators

The spatial distribution of the population is presented in Figure 2. Several indicators were used to compare the 44 sectors of Greater Sfax. Population density is the first. We mainly want to know if this density decreases with the distance from the city center. The gaps between sectors are very large. The density reaches 14,661 inhabitants/km^2 in Er-Rbadh, compared to only 71 inhabitants/km^2 in Sidi Salah (Figure 3; Table 2).

Table 2. Descriptive statistics of the main demographic and urban variables across the 44 sectors of greater Sfax.

Variable	Unit	Minimum	Maximum	Mean	Standard deviation
Population	inhabitants	2653	30,163	14671.18	7608.34
Population density	inhabitants/km^2	71.17	14660.94	3957.81	3006.32
Population aged 0 - 14	%	16.71	25.61	20.4	2.31
Population aged 65+	%	6.3	18.23	12.1	2.98
Aging index	per 100 children	28.76	109.1	61.11	19.55
Demographic dependency ratio	%	36.13	57.11	48.29	4.54
Distance from urban center	km	0	17.85	6.25	4.31
Built-up surface	km^2	0.35	3.71	1.52	0.92
Built-up surface share	%	1.98	49.83	32.21	14.65

The age structure is studied first by the young population. The share of the population aged 0 - 14 years shows the weight of young people in the population of each sector. It ranges from 16.7% in Merkez Kaddour to 25.6% in Ayoun El Mayel (Figure 4; Table 2). This indicator shows whether the presence of young people changes between the center and the periphery.

The share of those aged 65 and over gives another picture of age structure. It shows the weight of elderly people in the sector's population. The lowest value is recorded in El Ons with 6.3%. It reaches 18.2% in Merkez Kaddour (Figure 5; Table 2). The comparison with the 0 - 14-year-olds shows whether young and older sectors occupy the same areas.

The aging index directly compares these two age groups. It reports the number of people aged 65 and over to that of young people from 0 to 14 years. A value of 100 means that there are 100 elderly people for every 100 young people (Statistical

Office of the Slovak Republic, 2024). In Greater Sfax, this index ranges from 28.8 in Ayoun El Mayel to 109.1 in Merkez Kaddour (**Figure 6**; **Table 2**). In Merkez Kaddour, the number of elderly people therefore slightly exceeds that of young people. In Ayoun El Mayel, the situation is very different. Young people are much more numerous.

The demographic dependency ratio completes this analysis. It relates people under 15 and those aged 65 or older to the population aged 15 to 64 (World Bank, 2026). A value of 50 means, for example, 50 people in these two groups per 100 people aged 15 - 64.

The dependency ratio also varies from one sector to another. Its average value for the 44 sectors is 48.29, with a standard deviation of 4.54 (**Table 2**). The values range from 36.1 at El Ons to 57.1 at Merkez El Pacha (**Figure 7**; **Table 2**).

The built-up area is studied using GHS-BUILT-S 2018. This product gives the built-up area at a spatial resolution of 10 m (Pesaresi & Politis, 2023; Pesaresi et al., 2024). The raster was first limited to the area of Greater Sfax. The built area was then calculated for each of the 44 sectors. We mainly used the share of built-up area (%) as an indicator. It represents the share of the area occupied by buildings. It therefore makes it possible to compare sectors with very different areas. The gaps are also significant. Built-up areas represent 49.83% of the area of Er-Rbadh, compared to only 1.98% in Sidi Salah.

The distance to the center is used to study the center-periphery gradient. The center of the Medina of Sfax was chosen as a reference point. For each sector, we calculated the distance between its centroid and this point. Calculations were made in kilometers in the WGS 1984 UTM Zone 32N system (EPSG:32632). The distance used is planar.

The gaps are significant. The distance is 0 km for La Medina and reaches 17.85 km in El Aouabed. Er-Rbadh is 1.26 km from the city center. Gremda is 6.62 km, Khazanet 12.26 km and Sidi Salah 16.97 km (**Figure 8**). This distance does not correspond to a road trip. It simply gives the position of each sector relative to the center. It thus makes it possible to follow the passage from the center towards the periphery.

To facilitate this reading, four distance bands were selected: 0 - 5 km, >5 - 10 km, >10 - 15 km, and > 15 km. They group respectively 21, 15, 6, and 2 sectors. This division makes it possible to compare demographic characteristics and built-up area at different distances from the center. It also makes it possible to identify a possible break in the gradient. However, the exact distance in kilometers is maintained for each sector. It will be used as a continuous variable in statistical analysis.

For each distance band, population density was calculated as the total population of all sectors in the band divided by their total area. Similarly, the built-up share was calculated as the total built-up area divided by the total area of the sectors in the band. These pooled values therefore differ from the arithmetic means of sector-level values reported in **Table 2**. The demographic indicators were calculated from the aggregated population counts within each distance band.

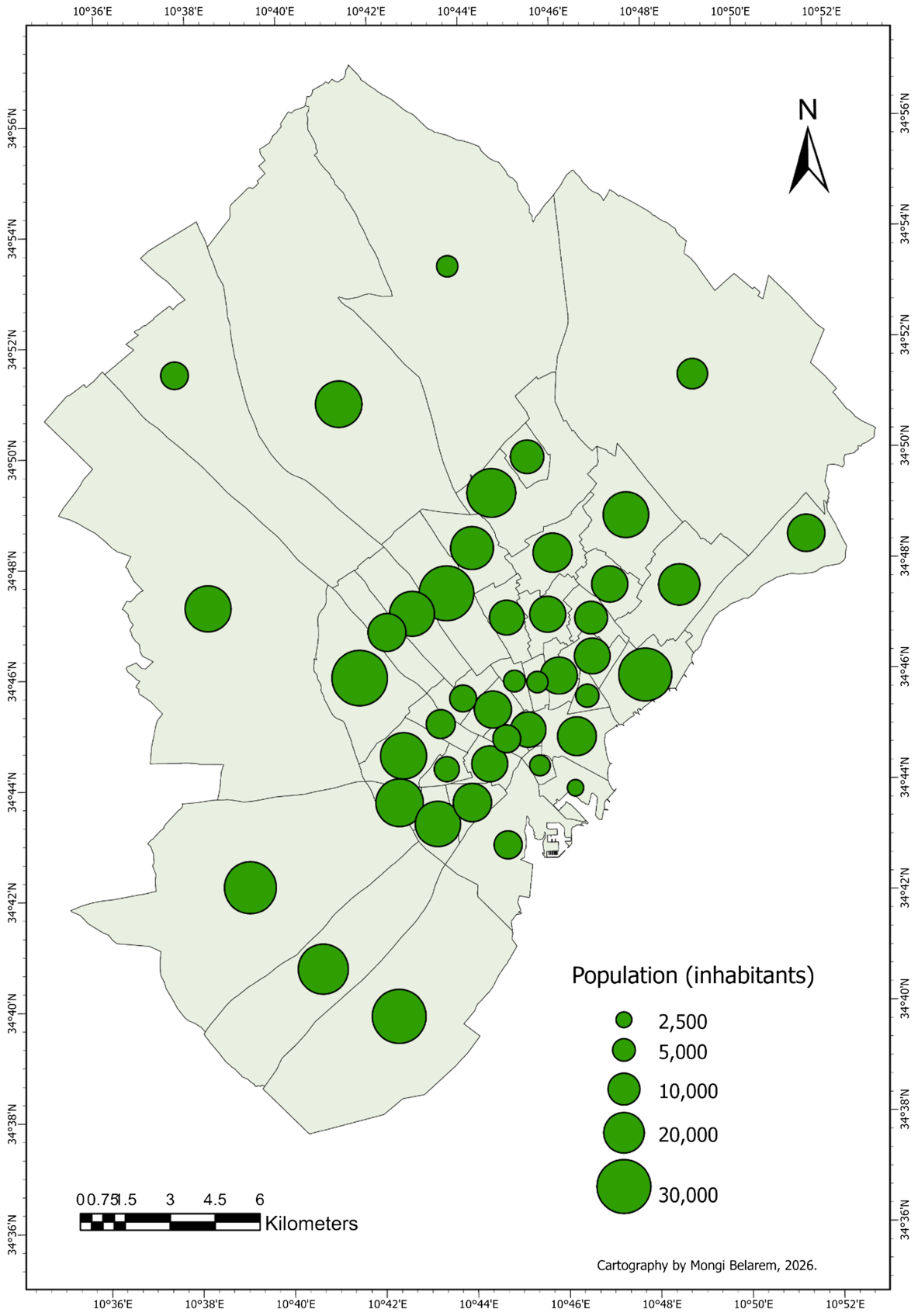

Figure 2. Spatial distribution of population by sector in greater Sfax, 2024.

2.3. Cartographic and Statistical Methods

The analysis is based on two approaches: statistical and cartographic. The statistical analysis starts with some descriptive statistics: minimum, maximum, average and standard deviation. They allow us to see the differences between the 44 sectors. These differences are sometimes important. The population density varies, for example, from 71 to 14,661 inhabitants/km^2. The share of built-up area ranges from 1.98% to 49.83% (Table 2).

The Spearman rank correlation coefficient is then used. It allows us to see whether two variables move in the same direction or in an opposite direction. It also makes it possible to measure the intensity of this relationship. The calculation is based on 44 sectors, with a significance threshold of 5% ($p < 0.05$). The main relationships tested concern the distance to the center with population density, the share of the population aged 0 - 14 years, the share of those aged 65 and over, the aging index, and the share of built-up area. The relationship between population density and the share of built-up area is also studied (Table 3).

A partial Spearman correlation was also calculated between population density and built-up share while controlling for distance to the urban center. This makes it possible to assess whether their relationship remains after accounting for the shared center-periphery gradient.

Spatial autocorrelation was also tested using Global Moran's I with contiguity edges-corners spatial weights and row standardization. This test was applied to population density and built-up share to assess whether neighboring sectors show similar values.

Table 3. Spearman correlation matrix between demographic, spatial and built-up variables in greater Sfax.

Variable	Pop. density	Aged 0 - 14	Aged 65+	Aging index	Dependency ratio	Distance to center	Built-up share
Population density	1	−0.498***	0.446**	0.487***	0.012	−0.663***	0.806***
Aged 0 - 14		1	−0.627***	−0.816***	0.154	0.779***	−0.660***
Aged 65+			1	0.950***	0.615***	−0.524***	0.739***
Aging index				1	0.390**	−0.673***	0.768***
Dependency ratio					1	0.090	0.244
Distance to center						1	−0.706***
Built-up share							1

Note: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. n = 44.

Cartographic analysis is based on several types of maps. Proportional symbols represent the total population. The size of the circles varies according to the number of inhabitants in each sector (Figure 2). The choropleth maps concern popu-

lation density, the share of the population aged 0 - 14 years, the share of those aged 65 and over, the aging index, the demographic dependency ratio, and distance to center (**Figures 3-8**). The values are divided into six classes according to Jenks' method of natural breaks. This method groups the close values and better reveals the differences between classes (Jenks & Caspall, 1971).

Built-up areas are represented in two ways. The first map directly shows the distribution of built-up area in Greater Sfax in 2018 (**Figure 9**). The second shows the share of each sector's area occupied by buildings (**Figure 10**). The latter mainly facilitates comparison between sectors with very different areas.

The built-up data date from 2018, while the demographic data are from 2024. This six-year lag must be considered. The GHS-BUILT-S 2018 product was selected because it covers the entire study area homogeneously, with a resolution of 10 m (Pesaresi & Politis, 2023). It also gives a good image of the general built-up structure of Greater Sfax.

New constructions were certainly carried out between 2018 and 2024. But our goal is not to measure this evolution. The 2018 data show strong contrasts in built-up area between the 44 sectors. They make it possible to distinguish between strongly built sectors and those that are less so. The 2018 built-up data are therefore used as a reference for urban structure. They do not represent exactly the situation in 2024.

This difference in dates, however, calls for caution. The comparison between the 2024 population and the 2018 built-up data mainly shows their spatial relationship. It does not allow us to say that the buildings of 2018 directly explain the population observed in 2024. Nor is it an analysis of the evolution between the two dates.

Two bivariate maps complete the analysis. The first one compares population density in 2024 and the share of built-up area in 2018. It allows us to see if the densest sectors are also the most built-up. It also makes it possible to identify different situations, for example with a high density and a lower share of built-up area, or the reverse (**Figure 11**).

The second bivariate map compares the share of the population aged 0-14 years with the aging index. It allows us to better see the differences in demographic structure between sectors. It also helps to track their organization from the center to the periphery (**Figure 12**). For both maps, each variable is divided into three levels: low, medium and high. The quantile method is used.

A classification of the 44 sectors completes the analysis. It allows the grouping of sectors with similar demographic and urban characteristics. Five variables are used: population density, the share of the population aged 0-14 years, the share of those aged 65 and over, distance to the center, and the share of built-up area. The aging index is not included in this classification, as it is already calculated from young and elderly populations.

The five variables are first standardized so that they can be compared despite their different units of measurement. The classification by K-means concerns the

44 sectors of Greater Sfax. Several solutions, from two to six groups, are tested. The two-group solution had the highest silhouette score (0.493), but it produced a very general classification. Four groups were retained to provide a finer and more interpretable spatial differentiation of the sectors. This choice allows us to distinguish the main differences between sectors without multiplying the groups. It also offers a clear reading of their organization in space.

Four profiles appear. The first corresponds to the central high-density sectors. The second group includes central and intermediate sectors with an older age structure. The third brings together intermediate urban sectors. The fourth corresponds to the peripheral areas, which are young and of low density. The characteristics and spatial distribution of these four groups are presented in the results.

The analysis combines cartographic and statistical methods. The statistics show the differences between the 44 sectors. The distance to the center allows us to study the center-periphery gradient. Spearman correlations measure the relationships between variables. The maps show their distribution in space. They also help to identify areas that deviate from the overall trend. Finally, the classification includes sectors with similar characteristics. It allows us to see if these groups follow the center-periphery gradient or if they have a more complex spatial organization.

3. Results and Discussion

3.1. Population Distribution and Demographic Structure

3.1.1. Population Density

The differences in density between the sectors are very significant. The highest value is recorded in Er-Rbadh with 14,661 inhabitants/km^2. By contrast, Sidi Salah has only 71 inhabitants/km^2 (**Figure 3**; **Table 2**).

High densities appear mainly in the central part and in some areas close to the center. La Medina reaches 5106 inhabitants/km^2. Er-Rbadh records 14,661 inhabitants/km^2, Cité El Bahri 11,576 inhabitants/km^2, 15 November 8278 inhabitants/km^2 and Mohamed Ali 7792 inhabitants/km^2. In several peripheral sectors, the values are much lower. Khazanet has only 286 inhabitants/km^2, Sidi Salah 71 inhabitants/km^2 and El Aouabed 224 inhabitants/km^2 (**Figure 3**; **Table 2**).

The size of the sectors explains some of these differences. Er-Rbadh covers less than 1 km^2. The Medina is also small in size. In the periphery, several sectors are much larger. El Hajeb thus has 26,412 inhabitants, but its density is only 568 inhabitants/km^2. Its area reaches 46.47 km^2. Thyna has 28,648 inhabitants on nearly 34.95 km^2, for a density of 820 inhabitants/km^2. In Ayoun El Mayel, 21,167 inhabitants are spread over more than 61 km^2. The density drops to about 345 inhabitants/km^2. A large population does not always mean high density.

The distribution is not regular. Bab El Bhar, close to the center, does not exceed 979 inhabitants/km^2. Cité El Khiari also has a low density, around 785 inhabitants/km^2. The opposite situation also exists. El Ons reaches 5252 inhabitants/km^2 despite its farther position. Khiria still reaches 4715 inhabitants/km^2 and Sakiet Eddaïr exceeds 4300 inhabitants/km^2.

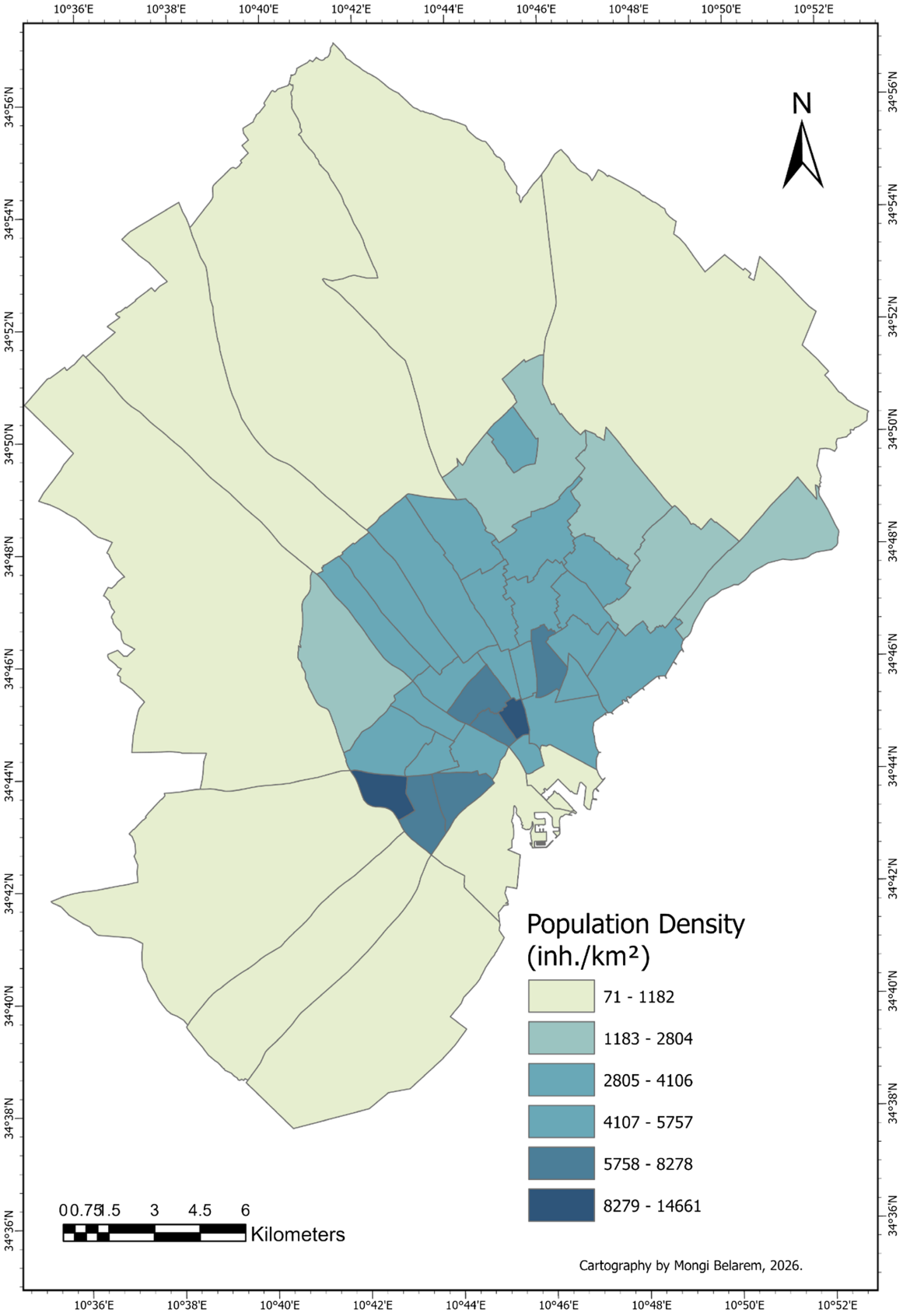

Figure 3. Population density by sector in greater Sfax, 2024.

These discrepancies partly correspond to the form of urbanization in Sfax. The city did not develop only around the central core. Its extension also followed the main roads (Fakhfakh, 1985; Dlala, 1996; Bennasr, 2003). This may explain the presence of relatively dense areas outside the center. Activities, businesses and facilities may also be involved, but they are not measured in this study.

3.1.2. Population Aged 0 - 14 Years

The share of the population aged 0 - 14 years varies greatly between sectors. It reaches its maximum in Ayoun El Mayel with 25.6%. The lowest value is recorded in Merkez Kaddour with 16.7% (**Figure 4**; **Table 2**).

Low proportions appear mainly in several central sectors. Merkez Kaddour recorded 16.7%, La Medina 17.2%, Mohamed Ali 18%, 15 November 18% and Er-Rbadh 18.7%. Several sectors close to the center thus remain below 20%.

Values are generally higher in the peripheral sectors. El Aouabed reaches 24.1%, Sidi Salah 24%, El Hajeb 24.1%, Sidi Abid 24.4% and Thyna 25.1%. Ayoun El Mayel reaches 25.6%. These areas therefore have a relatively younger population.

There are exceptions, however. El Ons has only 20.2% young people. El Afrane Nord remains at 18.5%. Conversely, El Houda has already reached 22%. The distribution of young people therefore does not follow a simple separation between the center and the periphery.

Population density and the share of young people do not follow the same pattern either. Ayoun El Mayel has the highest proportion of young people, 25.6%, but its density is only 345 inhabitants/km^2. Sidi Salah combines 24% of young people and only 71 inhabitants/km^2. In Er-Rbadh, the situation is reversed: the density reaches 14,661 inhabitants/km^2, while young people represent only 18.7% of the population. High density is therefore not necessarily associated with the strong presence of young people.

The greater presence of young people in several peripheral areas may be linked to urban extensions and the establishment of families with children. However, the data used do not make it possible to verify this. They provide information on the age of the population in 2024, but not on residential mobility or the date of establishment of households. We therefore retain here the spatial observation. The population is generally younger in several peripheral areas.

3.1.3. Population Aged 65 and Over

The distribution of people aged 65 and over also shows significant discrepancies. Merkez Kaddour recorded the highest proportion, with 18.2%. In contrast, it is only 6.3% in El Ons (**Figure 5**; **Table 2**).

The high values appear mainly in the central part and in some sectors close to the center. Merkez El Pacha reaches 17.7%, Ain Chaikh Rouhou 16.1% and Sidi Abbes 16%. High proportions also appear a little further on. El Alia reaches 17.1%, Chihia 16.1% and Merkez Bouassida 15.6%.

In several peripheral sectors, the proportions are lower. Khazanet has 8.8% of elderly people. Ayoun El Mayel drops to 7.4%. Thyna and El Hajeb record 7.8%. Sidi Salah reaches 8.3% and El Aouabed 9%.

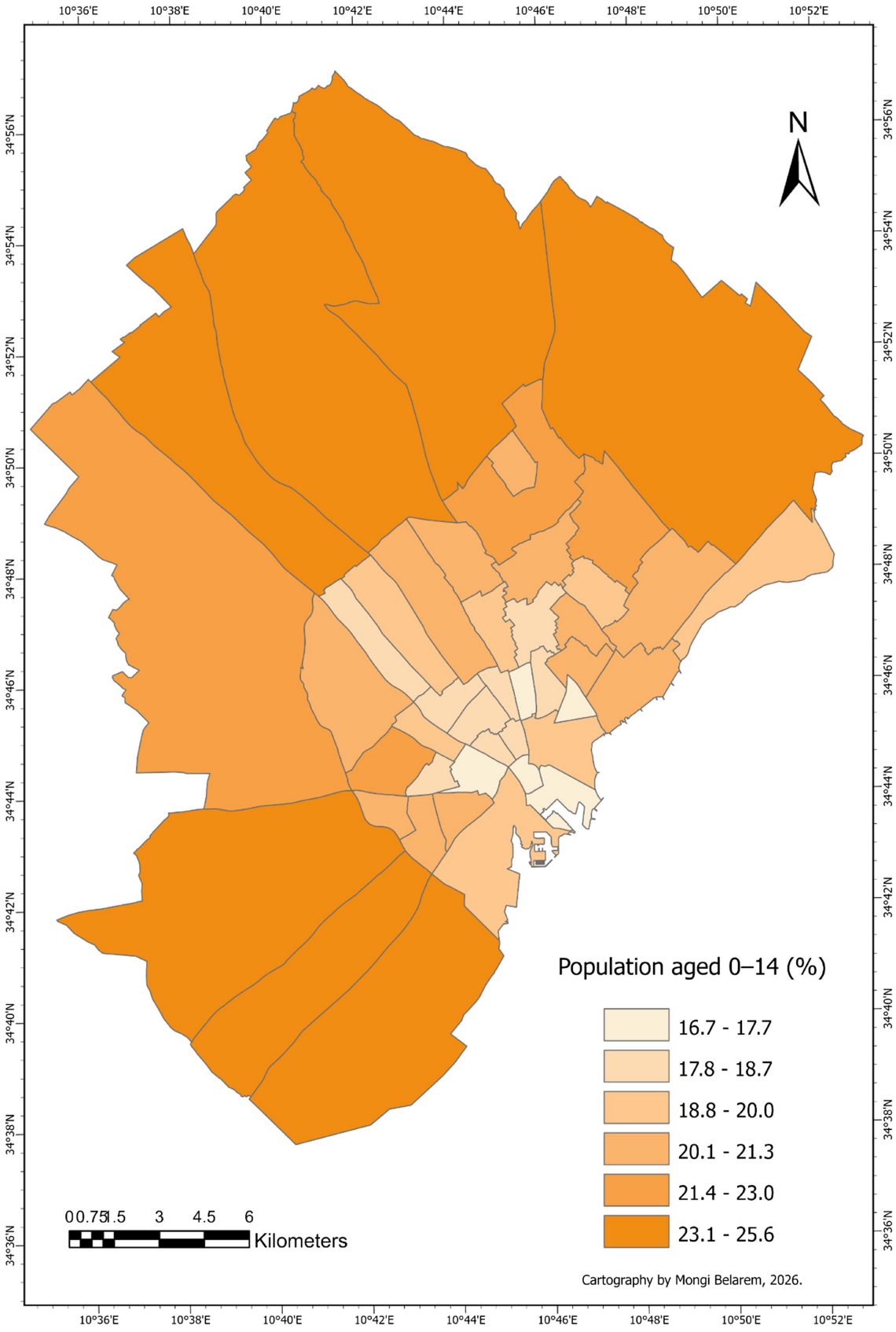

Figure 4. Population aged 0 - 14 years by administrative sector in greater Sfax, 2024.

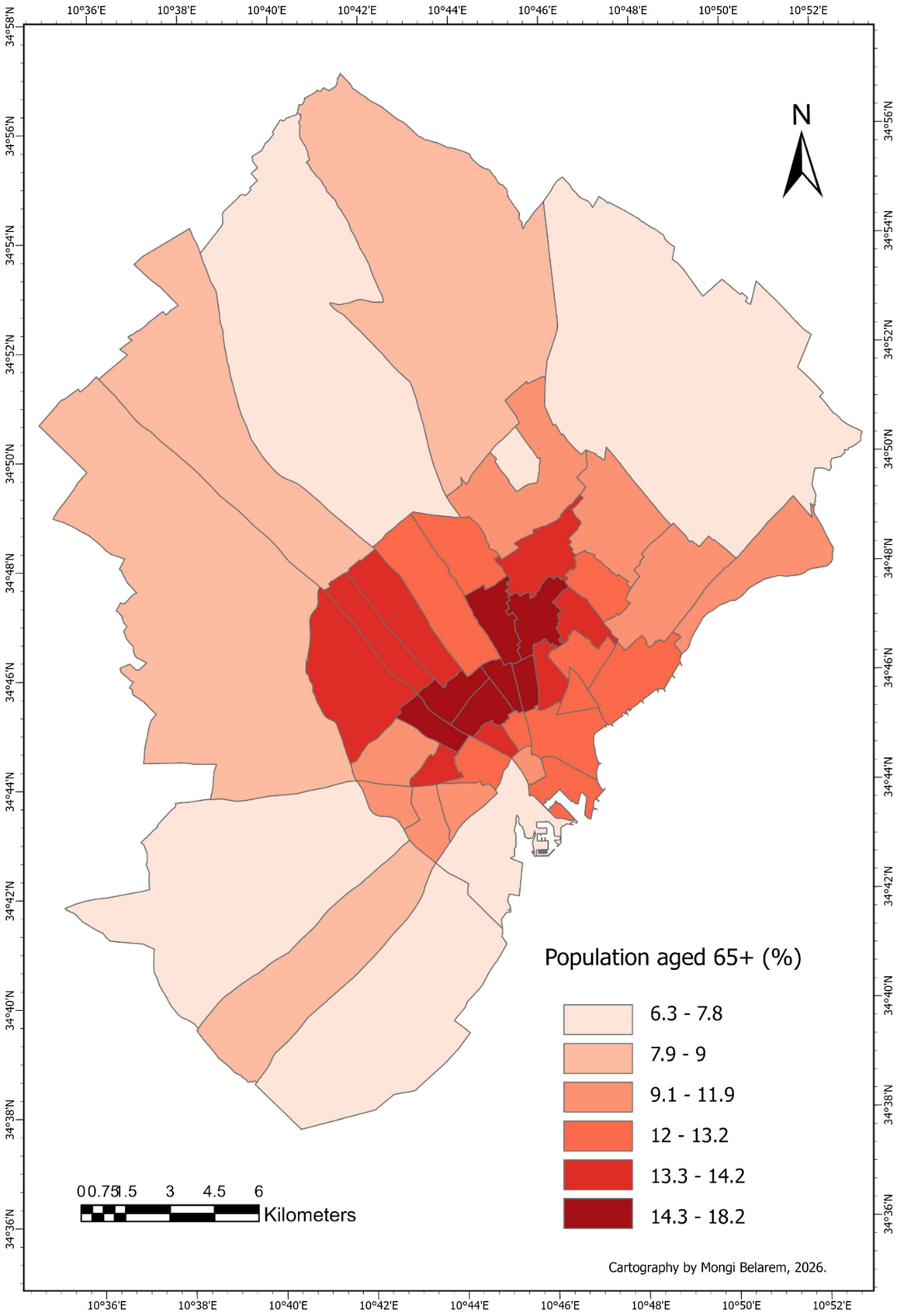

Figure 5. Spatial distribution of the population aged 65 years and over by sector in greater Sfax, 2024.

The comparison with young people shows these differences better. Ayoun El Mayel has 25.6% of young people compared to only 7.4% of elderly people. In Thyna, the proportions are 25.1% and 7.8%. In Sidi Salah, they are 24.0% and 8.3%. Merkez Kaddour presents almost the opposite situation: 16.7% of young people and 18.2% of elderly people.

But the exceptions remain important. The Medina has 11.2% of elderly people. Cité El Khiari drops to only 6.8%. Conversely, Gremda still reaches 14.2% and El Afrane Nord 13.6%. The distribution of elderly people therefore shows a spatial trend, but with several local variations.

3.1.4. Aging Index

The aging index directly compares the two previous groups. It expresses the number of people aged 65 and over per 100 young people under 15 (Kinsella & Velkoff, 2001).

In Greater Sfax, it ranges from 28.8 at Ayoun El Mayel to 109.1 at Merkez Kaddour (**Figure 6**; **Table 2**). In Ayoun El Mayel, there are about 29 elderly people for every 100 young people. In Merkez Kaddour, there are about 109. The elderly are slightly more numerous than the young.

Several high values appear in the central or intermediate sectors. Merkez El Pacha reaches 95, El Alia 89.3, Ain Chaikh Rouhou 86.2 and Sidi Abbes 85.9. Chihia still reaches 84.1 and Merkez Bouassida 84.

The values are lower in several peripheral sectors. The index is 38.3 in Khazanet, 35.4 in Sidi Abid, 34.7 in Sidi Salah and 32.2 in El Hajeb. It drops to 31 in Thyna and 28.8 in Ayoun El Mayel.

This organization still has exceptions. Cité El Khiari has an index of only 34 despite its proximity to the center. Soukra records 57. Conversely, El Afrane Nord reaches 73.6 and Gremda 71.9. Sidi Mansour still retains an index of 54.7.

The aging index therefore confirms what is shown in **Figure 4** and **Figure 5**. Sectors where young people are strongly represented generally have a lower index. Merkez Kaddour and Ayoun El Mayel clearly show the two opposite situations: 109.1 for the first and 28.8 for the second.

3.1.5. Demographic Dependency Ratio

As mapped in **Figure 7**, the demographic dependency ratio expresses the number of people under 15 and 65 or over per 100 people aged 15 to 64 (World Bank, 2026). In Greater Sfax, it varies from 36.1 in El Ons to 57.1 in Merkez El Pacha. The average of the 44 sectors is 48.29, with a standard deviation of 4.54 (**Table 2**).

A high ratio does not necessarily mean that there is a large presence of elderly people. It can also result from a significant proportion of young people. Ayoun El Mayel gives an example. Young people account for 25.6% of the population and the elderly only 7.4%. Yet its dependency ratio reaches 49.2. In Merkez Kaddour, young people account for 16.7% and elderly people 18.2%. The ratio reaches 53.7. The composition of the dependency is therefore different.

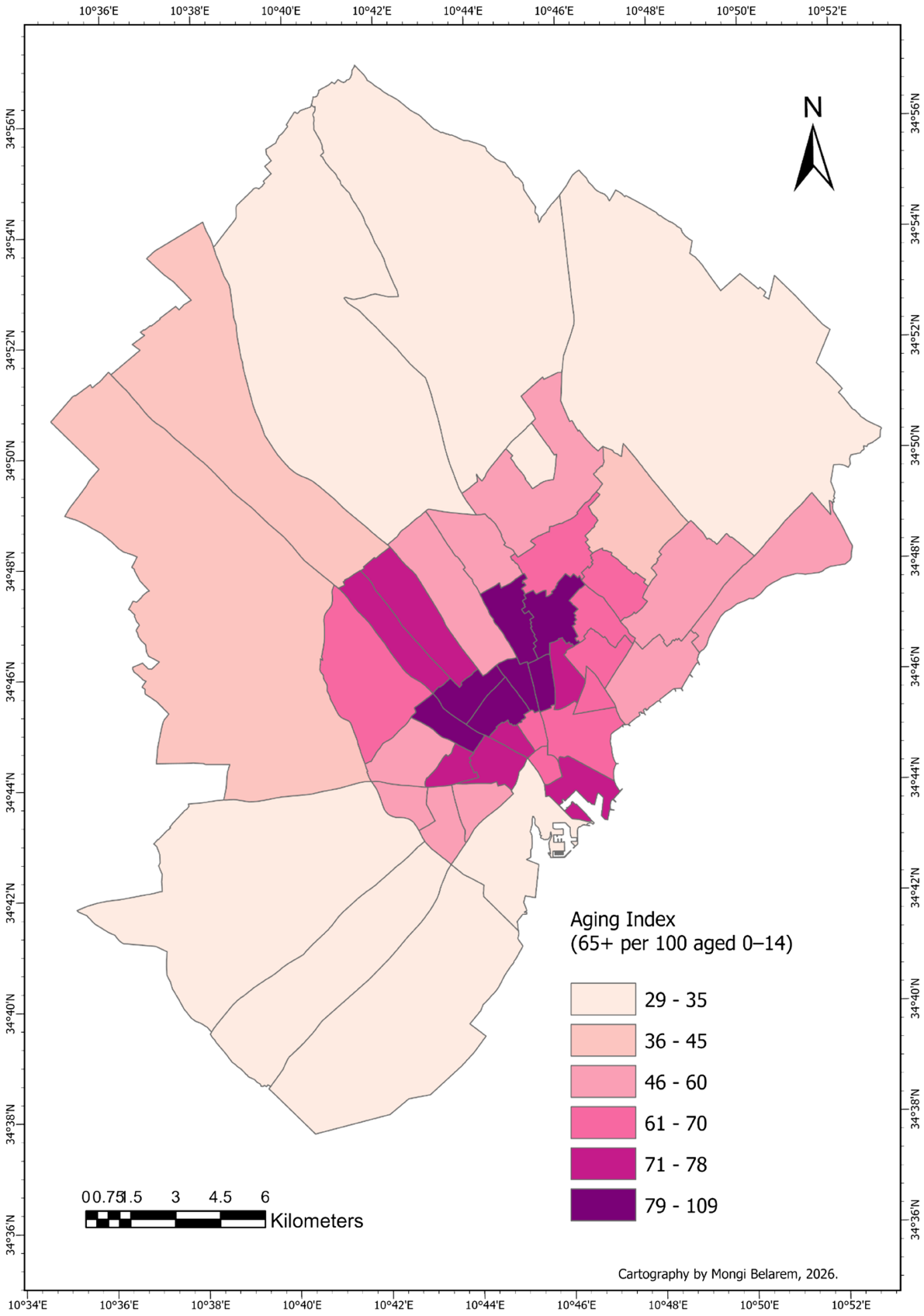

Figure 6. Aging index by sector in greater Sfax, 2024.

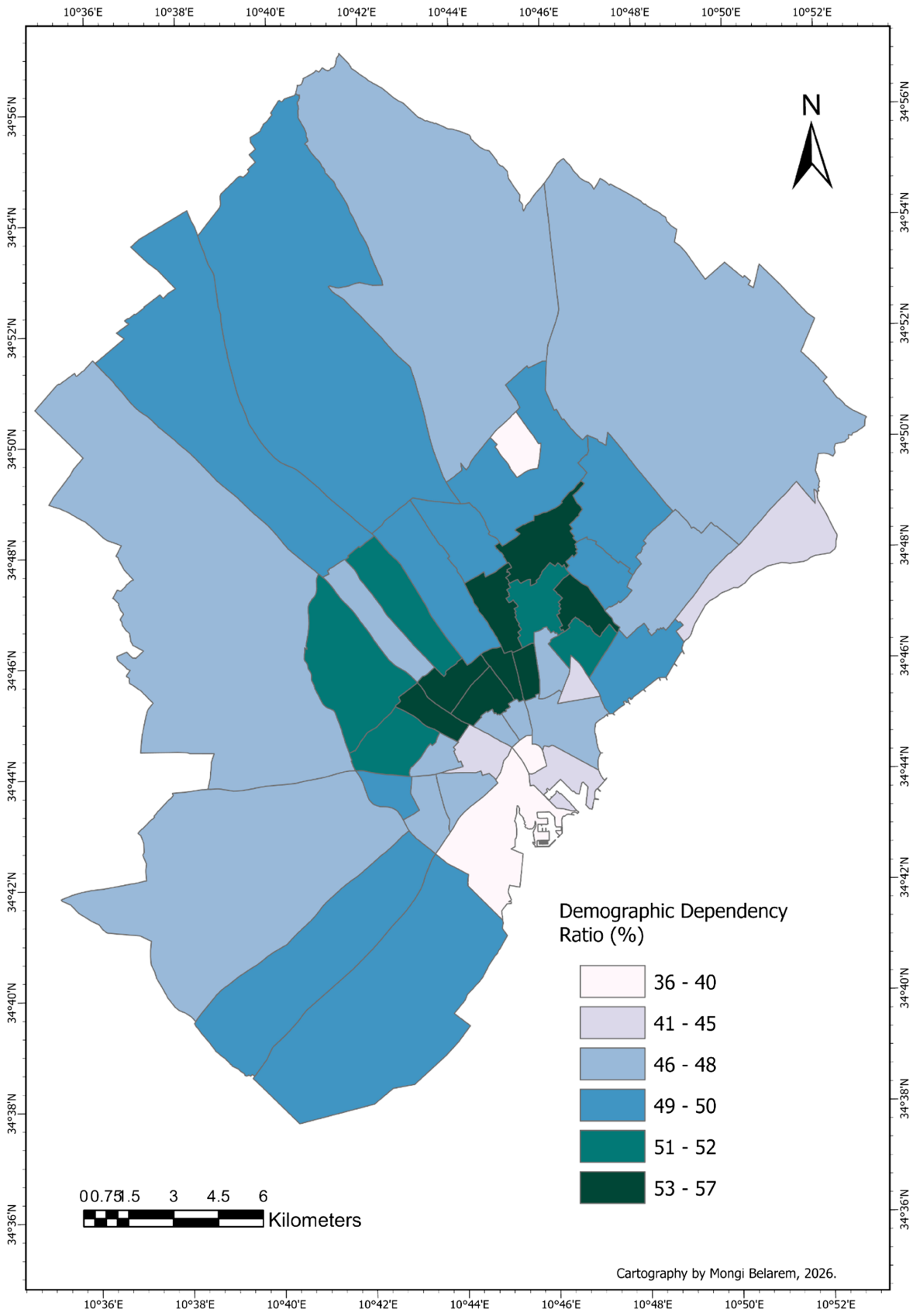

Figure 7. Demographic dependency ratio by sector in greater Sfax, 2024.

High values appear in several central and intermediate sectors. Merkez El Pacha reaches 57.1, El Alia 56.9, Merkez Kaddour 53.7, Ain Chaikh Rouhou 53.3 and Sidi Abbes 53. Chihia reaches 54.5, Khiria 53.4 and Sakiet Ezzit 53.4.

But the center is not homogeneous. La Medina registers only 39.8. Bab El Bhar reaches 41.6 and Cité Ettaouidhi 42.8. Cité El Khiari drops to 36.7. The latter is located almost at the same distance from the center as Merkez El Pacha, but the difference between their dependency ratios exceeds 20 points.

In more distant sectors, the values are often intermediate. Khazanet records 46.6, El Hajeb 46.8 and Sidi Salah 47.9. Ayoun El Mayel reaches 49.2 and El Aouabed 49.3. El Ons is an exception with only 36.1, the lowest value of Greater Sfax.

The map of dependency is therefore less simple than those of youth and aging. Two sectors may have similar dependency ratios but different age structures. This question will be taken up with the distance in the next section.

3.2. Center-Periphery Demographic Gradient

The distance to the center varies from 0 km in La Medina to 17.85 km in El Aouabed (**Figure 8**). The four distance bands allow us to see how the main indicators change between the center and the periphery.

The share of young people has the most regular gradient. It increases from 19.61% between 0 and 5 km to 21.30% between 5 and 10 km. It then reaches 23.20% between 10 and 15 km and 24.05% beyond 15 km (**Table 4**). The gap between the first and last band thus reaches about 4.4 points. The demographic structure is becoming globally younger towards the periphery.

The population aged 65 and over follows the opposite trend. The share of people aged 65 and over decreases from 12.91% in the first distance band to 12.04% in the second, then to 8.07% between 10 and 15 km. It rises slightly to 8.73% beyond 15 km. However, this last value should be considered with caution, because the outermost distance band includes only two sectors.

The aging index confirms this trend more clearly. It goes from 65.83 in the first distance band to 56.53 in the second, then to 34.77 between 10 and 15 km. It reaches 36.29 beyond 15 km. The slight change in the last distance band therefore does not call into question the overall trend. The small number of sectors in this class also explains why too much weight should not be given to it.

The dependency ratio gives another picture. It goes from 48.18 to 50.02, then drops to 45.48 before rising to 48.75. There is therefore no steady progression with distance. This is partly due to the composition of the indicator. Young people are increasing towards the periphery, while older people generally decrease.

Ayoun El Mayel and Teniour clearly show this difference. The dependency ratio is almost identical: 49.2 in Ayoun El Mayel and 49.3 in Teniour. Yet, Ayoun El Mayel has 25.6% young people and 7.4% elderly people. In Teniour, the proportions are 20.9% and 12.1%. The level of dependency is almost the same, but its demographic composition is different. The gradient therefore appears more in the age structure than in the dependency ratio itself.

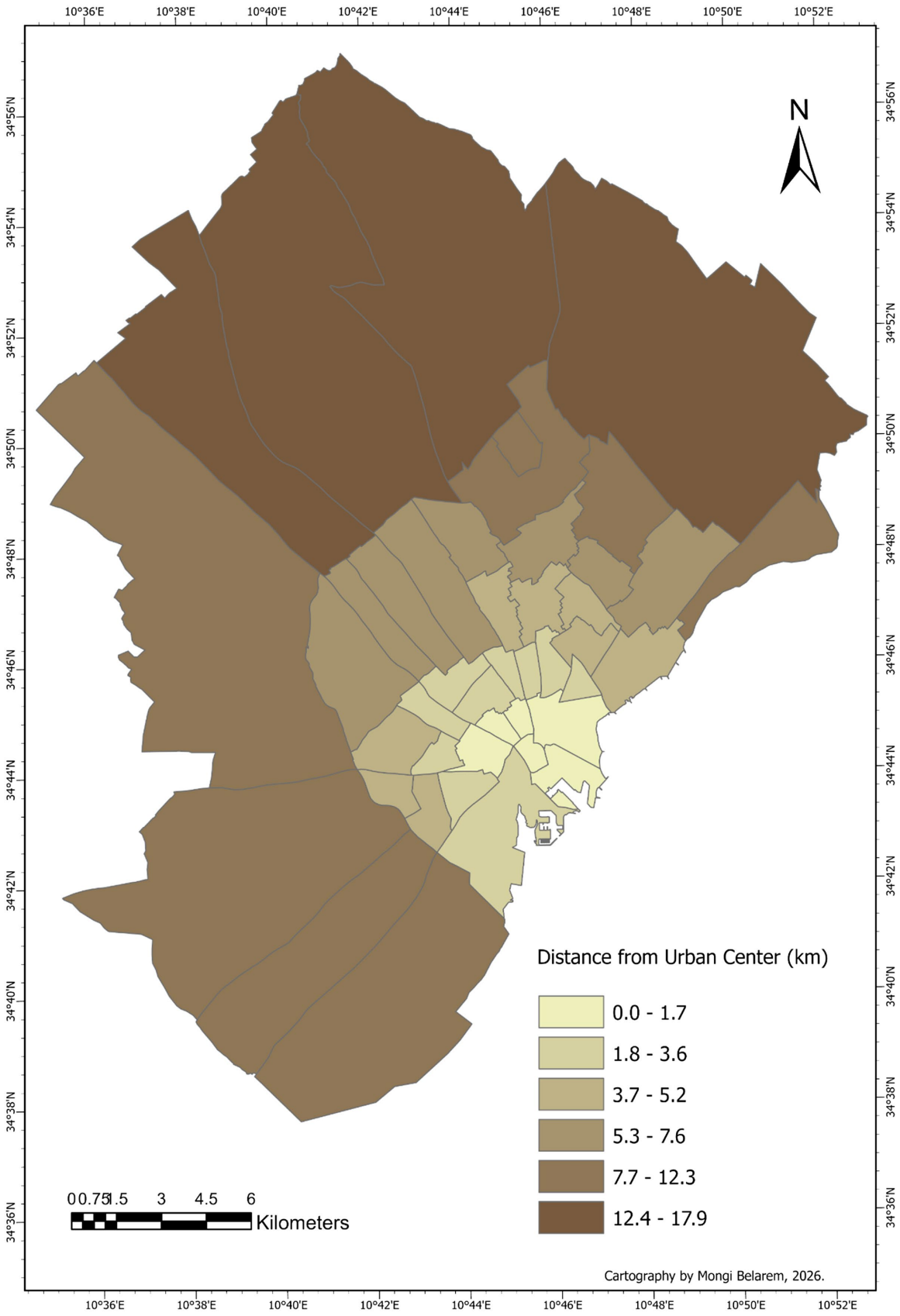

Figure 8. Distance from the urban center by sector in greater Sfax, 2024.

Table 4. Demographic and built-up characteristics along the center-periphery gradient in greater Sfax.

Distance from center	No. of sectors	Population	Population density inh./km²	Aged 0% - 14%	Aged 65+ %	Aging index	Dependency ratio %	Built-up share %
0 - 5 km	21	243,070	4604.19	19.61	12.91	65.83	48.18	34.77
>5 - 10 km	15	288,461	2139.64	21.3	12.04	56.53	50.02	24.5
>10 - 15 km	6	102,083	382.1	23.2	8.07	34.77	45.48	4.84
>15 km	2	11,918	123.36	24.05	8.73	36.29	48.75	2.66

Population density also follows the gradient. It goes from 4,604 inhabitants/km² between 0 and 5 km to 2140 inhabitants/km² between 5 and 10 km. It then drops to 382 inhabitants/km² between 10 and 15 km and then to only 123 inhabitants/km² beyond 15 km. The strongest difference appears after 10 km. We then go from a still relatively dense area to much less dense sectors.

The share of built-up area follows a similar pattern. It goes from 34.77% in the first distance band to 24.50% in the second. It then drops to 4.84% between 10 and 15 km and to 2.66% beyond 15 km. Here, too, the rupture becomes very clear after 10 km. This trend will be studied more precisely in the next section.

Spearman's correlations confirm these results. The strongest relationship with distance concerns the share of the population aged 0 - 14 years ($\rho = 0.779$). This relationship is positive. The share of young people therefore increases with the distance from the center. The aging index has a negative relationship ($\rho = -0.673$). The same is true for population density ($\rho = -0.663$) and for the share of people aged 65 and over ($\rho = -0.524$). The share of built-up area is also negatively related to distance ($\rho = -0.706$). The dependency ratio differs markedly from other indicators. Its relation to distance is very small ($\rho = 0.090$).

Table 5. Demographic and urban characteristics of the four spatial types identified in Greater Sfax.

Type	n	Population density (inhab./km²)	Population aged 0 - 14 (%)	Population aged 65+ (%)	Distance to center (km)	Built-up area (%)	Spatial profile
1	6	9533	19.33	12.49	2.85	44.5	High-density central
2	18	4196	18.68	14.47	3.61	40.81	Aging central/intermediate
3	12	3150	20.89	11.02	7.33	31.05	Intermediate urban
4	8	452	24.34	8.09	13.13	5.38	Young low-density peripheral

Note: Values represent the mean characteristics of the administrative sectors belonging to each type.

However, differences exist between areas located at almost similar distances from the center. Merkez Kaddour is 2.8 km from the city center and Cité El Khiari is 2.9 km away, but their demographic structure is different. In Merkez Kaddour, young people account for 16.7% of the population and older people 18.2%. In Cité

El Khiari, these proportions are respectively 20% and 6.8%. The distance to the center cannot therefore explain all the differences between the sectors. The gradient remains clear for youth, aging and population density. It is much less regular for the dependency ratio.

3.3. Built-Up Area and Population Density

This section examines the relationship between built-up area and population density. Are the most built-up areas also the most densely populated? And where does this relationship become less clear?

Figure 9 shows a high concentration of buildings in the central part. Figure 10 maps the corresponding built-up share for each administrative sector. The built fabric becomes less continuous towards the periphery. Er-Rbadh has a built share of 49.83%. It is only 1.26 km from the center. In Gremda, at 6.62 km, this share remains high with 40.45%. It drops to 4.16% in Khazanet, located at 12.26 km. In Sidi Salah, at 16.97 km, it is only 1.98%.

However, the gradient is not regular in all directions. The built-up area extends farther in some sectors. It is more discontinuous in others. This organization corresponds to the radial form of Sfax. It shows that the distance to the center is not enough to explain the entire distribution of built-up area.

Built-up area and population density are strongly linked. The Spearman coefficient reaches $\rho = 0.806$. Er-Rbadh associates 49.83% of built area with a density of 14,661 inhabitants/km^2. In Sidi Salah, both values are low. The built area is 1.98% and the density of 71 inhabitants/km^2. Khazanet also has low values: 4.16% and 286 inhabitants/km^2.

Both variables also show significant positive spatial autocorrelation. Global Moran's I is 0.210 for population density ($z = 2.771$, $p = 0.006$) and 0.408 for built-up share ($z = 4.924$, $p < 0.001$). The significance levels of the Spearman correlations should therefore be interpreted with caution because the sectors are not fully independent in space.

After controlling for distance to the urban center, the relationship between population density and built-up share remains positive (partial Spearman $\rho = 0.638$). Their association therefore cannot be explained only by their common center-periphery gradient.

But this relationship is not always so clear. El Ons has a density of 5252 inhabitants/km^2 and a built area of 26.94%. In Bab El Bhar, the built area is almost identical, with 25.94%. However, the density is only 979 inhabitants/km^2. The same share of built-up area can therefore correspond to very different densities.

Here, the nature of the data must be considered. The share of built-up area measures the area occupied on the ground. It does not measure the height of buildings. It does not consider the number of floors. It also does not give the number of occupied dwellings. Administrative, commercial and service buildings are also included in the built environment. These elements may contribute to the differences observed.

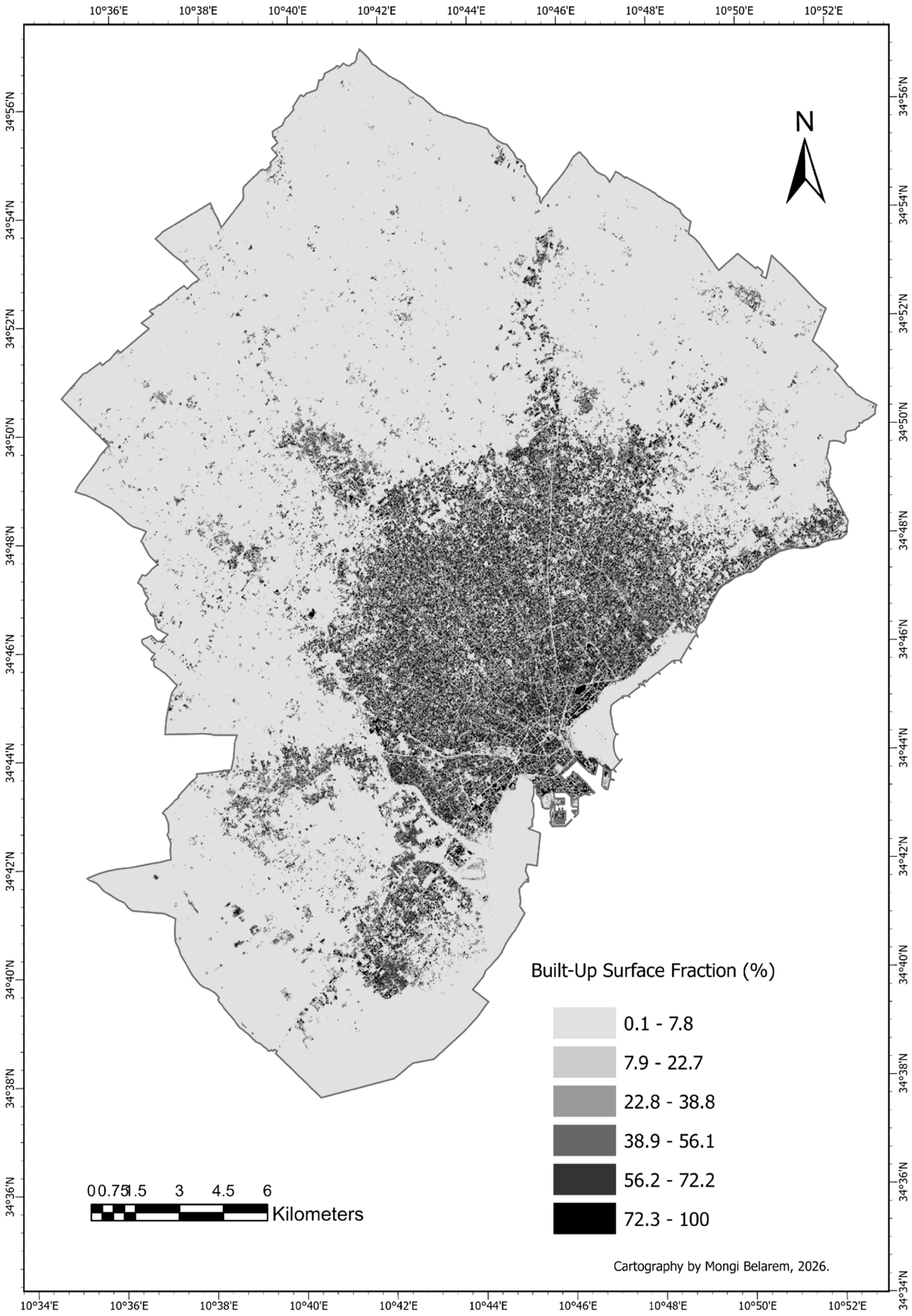

Figure 9. Spatial distribution of built-up area in greater Sfax, 2018.

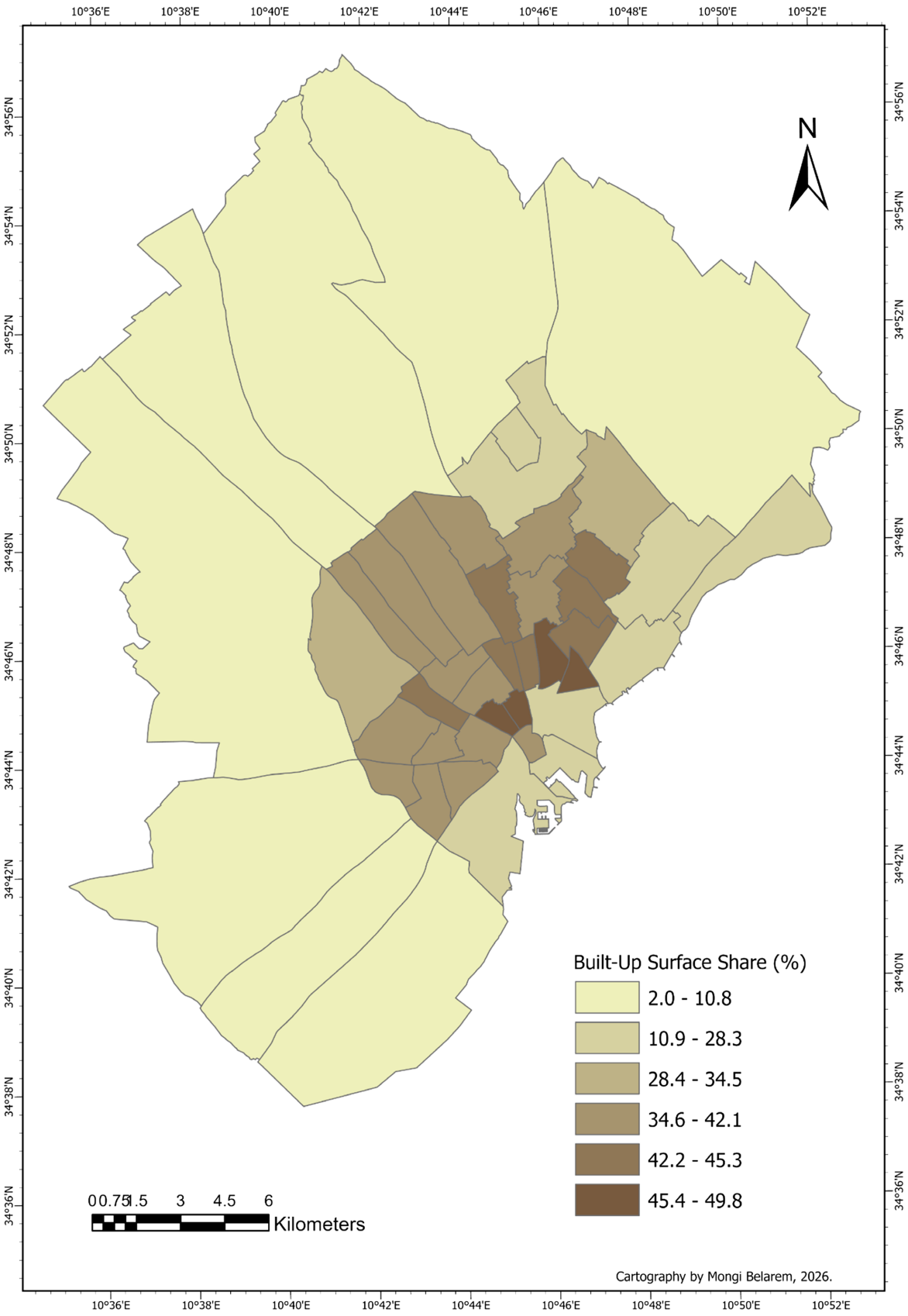

Figure 10. Share of built-up area by sector in greater Sfax, 2018.

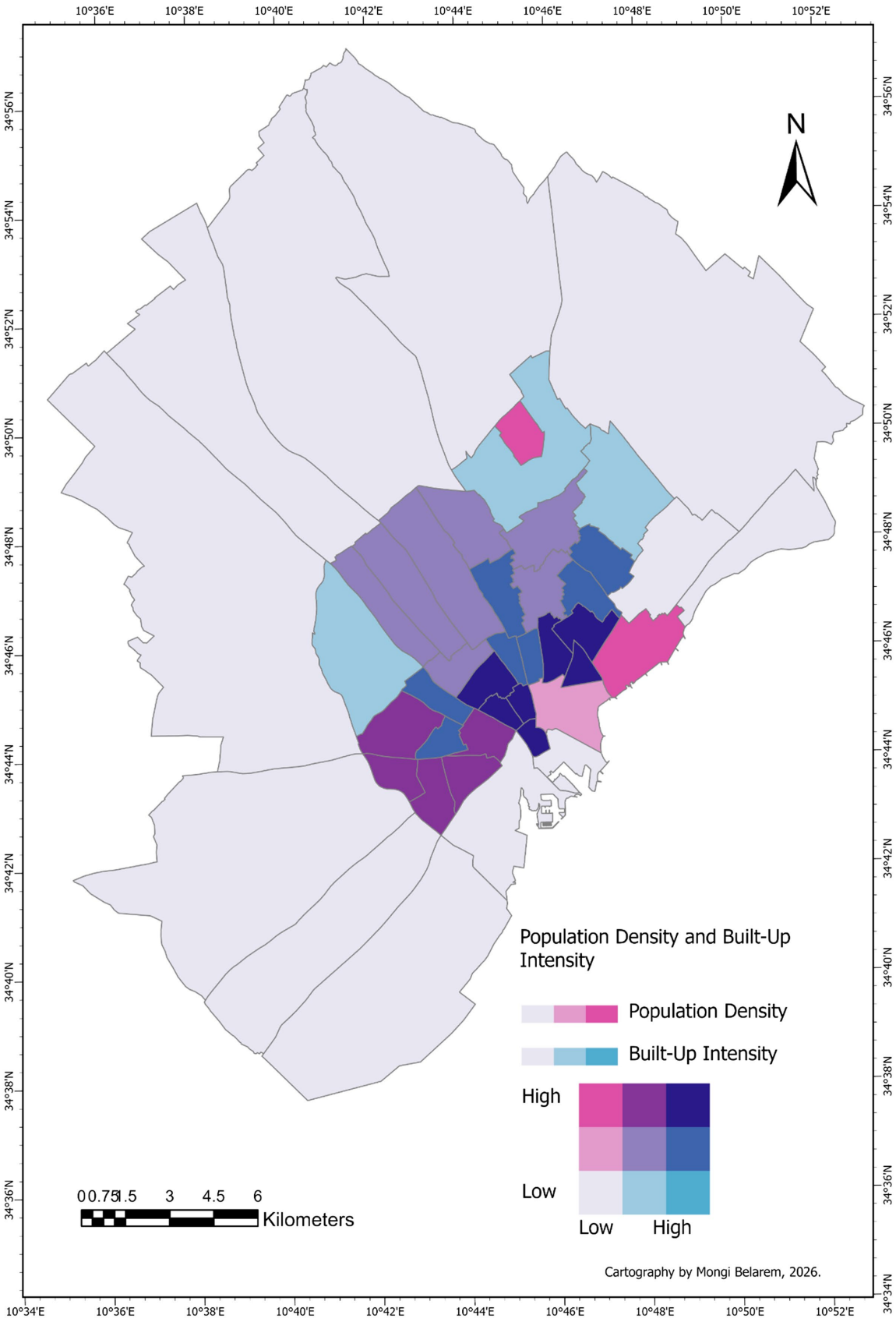

Figure 11. Population density and built-up intensity by sector in greater Sfax.

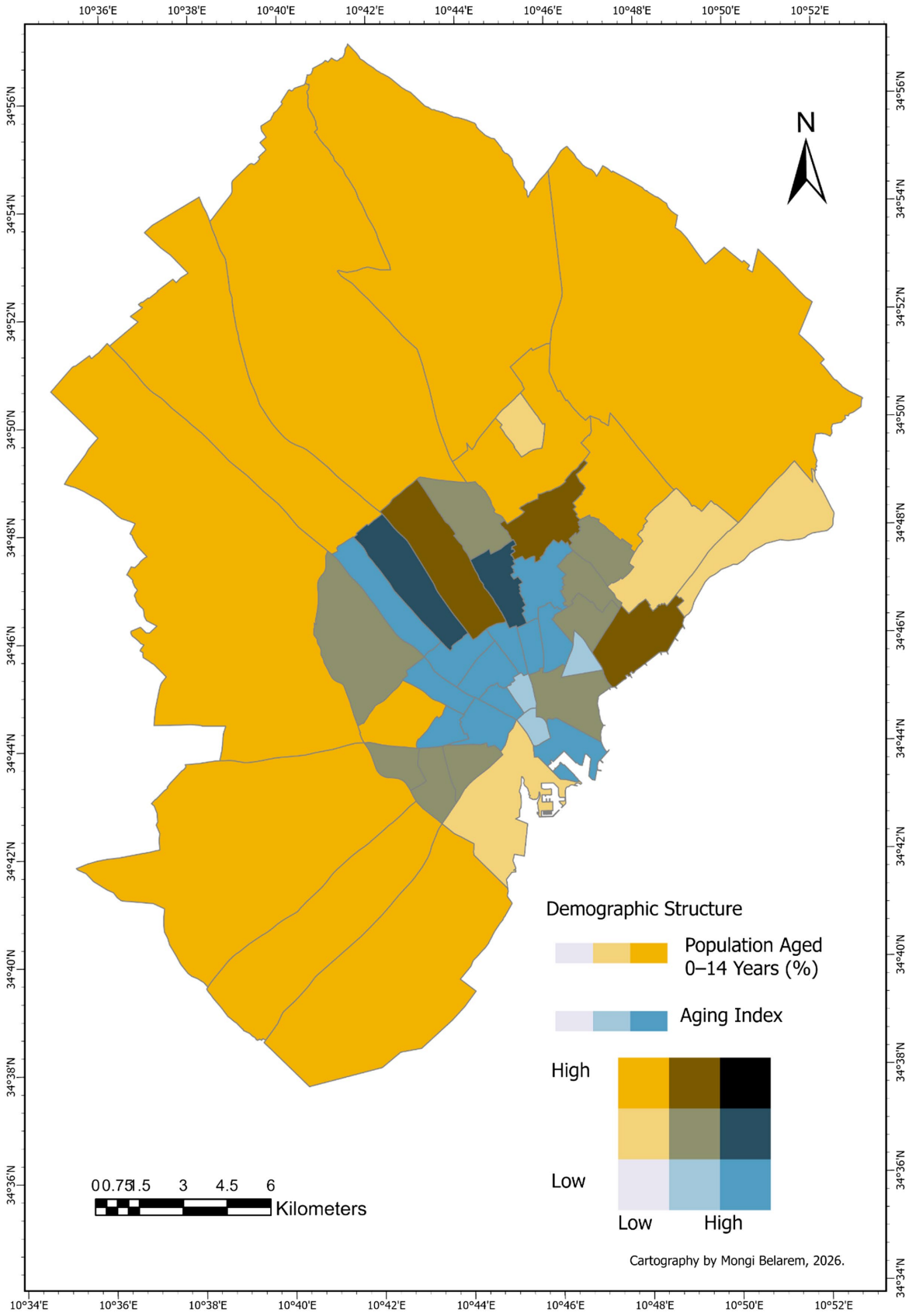

Figure 12. Demographic structure along the center-periphery gradient in greater Sfax, 2024.

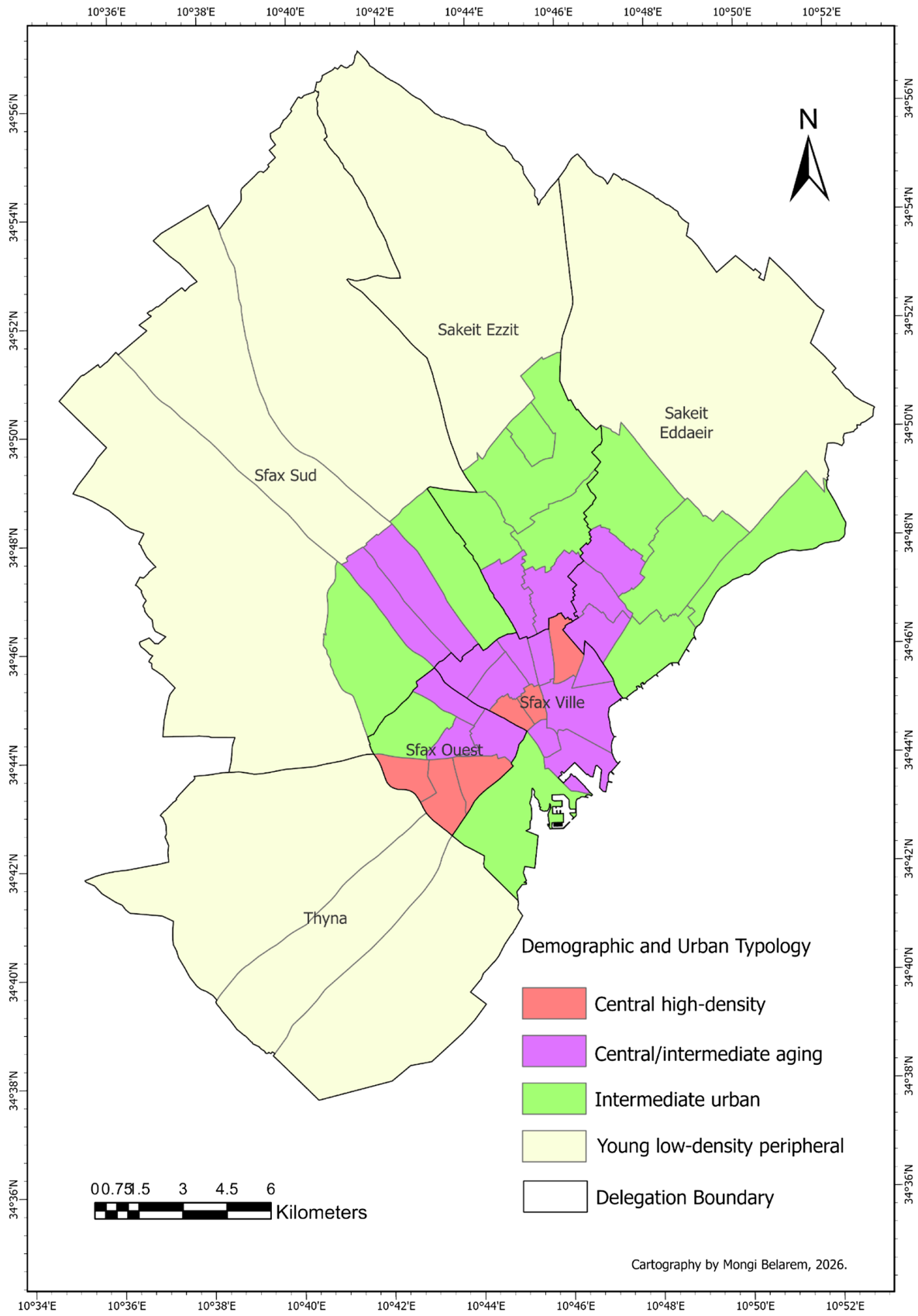

Figure 13. Demographic and urban typology of administrative sectors in greater Sfax.

Figure 11 confirms this relationship in space. High densities generally correspond to highly built-up areas. But El Ons and Bab El Bhar show that this relationship is not systematic. Density therefore also depends on how the built space is occupied. The complementary demographic bivariate map contrasts the share of children aged 0 - 14 with the aging index, highlighting the demographic differences discussed in Section 3.2.

3.4. Demographic and Urban Typology of the Sectors

In order to synthesize the previous results, a classification by K-means was carried out from the five variables selected. It distinguishes four types of sectors (Figure 13 and Table 5).

The first type includes 6 central sectors close to the center. It is characterized by the highest density, with an average of 9533 inhabitants/km^2. The share of built-up area reaches 44.5%. The average distance to the center is 2.85 km. The population aged 0 - 14 years represents 19.33%, compared to 12.49% for people aged 65 and over.

The second type is the largest with 18 sectors. It mainly includes central and intermediate sectors. Their average distance to the center is 3.61 km. The average density reaches 4196 inhabitants/km^2 and the share of built-up area 40.81%. This group is distinguished mainly by the highest share of people aged 65 and over, with 14.47%. Those under 15 account for 18.68%.

The third type comprises 12 sectors. It corresponds to an intermediate situation. The average distance to the center reaches 7.33 km. The density is 3150 inhabitants/km^2 and the share of built-up area is 31.05%. People under 15 years old represent 20.89% and those aged 65 and over 11.02%.

The fourth type includes 8 peripheral sectors. Their average distance reaches 13.13 km. The density drops to 452 inhabitants/km^2 and the share of built-up area to 5.38%. This group is also the youngest. People under 15 account for 24.34%, compared to only 8.09% of those aged 65 and over.

The classification therefore confirms the observed gradient. The central sectors are denser and more built-up. The peripheral sectors are less dense and younger. But this gradient is not regular. The four types do not form circles around the center (Figure 13).

4. Conclusion

This study aimed to determine the extent to which the demographic structure of Greater Sfax is organized according to a center-periphery gradient. It also sought to analyze its relationship with population density and the intensity of the built environment. The analysis covered all 44 administrative sectors. It was based on 2024 demographic data, the distance to the center, and the share of built-up area.

The results show a fairly clear center-periphery gradient. The share of under-15s increases from 19.61% within 5 km of the center to 24.05% beyond 15 km. The pooled population density decreases from 4604 to 123 inhabitants/km^2. The share

of built-up area decreases from 34.77% to 2.66%. Population density and built-up area are strongly associated (ρ = 0.806).

This gradient is not regular. The dependency ratio does not follow the same trend. There are also exceptions. Close sectors sometimes have different profiles. The classification by K-means distinguishes four types. They do not form distance bands around the center. Distance is therefore important. But it does not explain all the differences.

Future research could include accessibility through road networks. It could also follow the evolution of this gradient over time.

Greater Sfax thus presents a clear center-periphery gradient, but this is not sufficient to explain its entire demographic and urban organization.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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