ПӘНДЕР АРАЛЫҚ ҒЫЛЫМДАР
МЕЖДИСЦИПЛИНАРНЫЕ НАУКИ
INTERDISCIPLINARY SCIENCES

CENTRAL ASIAN SCIENTIFIC JOURNAL
ISSN 3135-3061
2026. No. 4 (32), Vol. 3. pp. 58–64
DOI: https://doi.org/10.5281/zenodo.24528725
Journal website: https://cajournal.kz

UDC 711.4:528.8(574)

WHERE SHYMKENT GREW: FORTY-FIVE YEARS OF URBAN EXPANSION FROM SATELLITE DATA, 1975–2020

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Abstract: This study measures how much, and in which directions, the built-up area of Shymkent grew between 1975 and 2020, and tests the author's hypothesis that it grew about fourfold, mainly to the north and north-west. It uses the 100 m building footprint and population grids of the European Commission's Global Human Settlement Layer and the Copernicus elevation model, with true distances and compass directions measured from the city centre. Within 20 km of the centre the area covered by buildings grew from 24.9 km^2 to 102.7 km^2, 4.1 times (3.8 to 4.6 times for radii of 15 to 30 km), and of the building area added within 25 km 60% went to the three northern sectors and 19% to the three southern ones, although each group covers three-eighths of the land. The north and the north-east led, their order depending on the radius and on whether the neighbouring town of Aqsukent is counted, and the north and north-west named in the hypothesis together received 36% (42% without the neighbouring towns). The southern land is hillier, but even on flat land that was empty in 1975 buildings covered only 1.8% of the south by 2020 against 6.9% of the north, so terrain explains only part of the difference.

Keywords: Shymkent, urban growth, urban expansion, satellite data, Global Human Settlement Layer, terrain, Kazakhstan

Introduction

In an earlier study the author found that Shymkent is one of nine urban centres of Kazakhstan at a peak ground acceleration of 0.15 g or above, and that among the large cities it has renewed its built-up area fastest: 38.7% of it appeared after 2005 [1]. Where such a city grows matters, because its new districts decide how many people live on which ground and how far from the centre.

Satellite records make it possible to measure this. The Global Human Settlement Layer (GHSL) of the European Commission's Joint Research Centre estimates, for every 100 by 100 metre cell of the Earth, the area covered by buildings and the number of residents, every five years from 1975 [2, 3]. This study uses these data to answer two questions: how much did Shymkent grow between 1975 and 2020, and in which directions.

Hypothesis

Before any data were analysed for this study, the author wrote on 15 October 2026: "I think Shymkent grew most strongly in the northern and north-western directions, where new residential districts appeared. Compared with 1975, the built-up area of the city could have increased about 4

times. This is my hypothesis for now; later it can be checked against satellite images" (translated from Russian).

Data and methods

The building footprint comes from GHS-BUILT-S R2023A [2], which gives the area covered by buildings, in square metres, in each 100 m cell; the population comes from GHS-POP R2023A [3]. Both were downloaded for the ten epochs 1975, 1980, …, 2020 (tile R4_C24, Mollweide projection) on 16 November 2026. GHSL estimates the building footprint from a 2018 Sentinel-2 image composite and works back in time with Landsat images of 1975, 1990, 2000 and 2014, removing buildings where those images show none; these five are the epochs it calls observed. The other epochs are obtained by interpolation between them or extrapolation beyond them, with the help of a static component that includes slope, elevation and water [4]. For this reason, trends over time are reported for the periods 1975–1990, 1990–2000 and 2000–2015, which start and end at or next to observed years, and 2020 is reported with its extrapolated status. For the 2018 Sentinel-2 layer, the data package reports 94.04% agreement with human visual inspection of the same images in telling built-up from non-built-up surfaces (94.05% in Asia) [4]. The areas in this study are not comparable with the 21,598 ha of built-up area given for Shymkent in [1]: that figure counts every 100 m cell classed as built-up inside the urban-centre outline, while this study sums the area under buildings themselves. The population grid is not an independent measurement: census or administrative counts are spread over grid cells according to the built-up layer [4].

The centre of the city was set at 42.32 N, 69.59 E, 0.95 km from the centre of mass of the 1975 building footprint within 10 km (42.316 N, 69.600 E), so that directions are measured from where the city stood at the start of the period; Table 3 repeats the main results for other centre points. Because the meridians cross the columns of the Mollweide grid at about 28 degrees at this longitude, distances and directions were not read off the grid: the centre of every cell was projected to an azimuthal equidistant projection centred on the city centre, which gives its true distance and compass bearing. The cells were then grouped into eight 45-degree sectors centred on north, north-east and so on, and into distance rings. The building area was summed within circles of 15, 20, 25 and 30 km; the area added between two epochs is the difference of the sums. "North" in this study means the three northern sectors (north-west, north, north-east) and "south" the three southern ones (south-west, south, south-east); each group covers three-eighths of a circle. The circles also contain two towns that the GHS Urban Centre Database used in [1] lists as separate urban centres: Sayram, 13.4 km to the east, and Aqsukent, 23.3 km to the north-east. The main results include them; Table 3 repeats the analysis with a disc of 3, 4 or 5 km around each town left out. Terrain comes from the Copernicus digital elevation model GLO-90 [5]: each cell takes the elevation and the slope of the nearest model point, and land with slopes above 5 degrees is called hilly.

Results

How much the city grew

Within 20 km of the centre, the area covered by buildings grew from 24.9 km^2 in 1975 to 102.7 km^2 in 2020, 4.1 times (Table 1). The factor depends on the radius: 3.8 times within 15 km, 4.4 within 25 km and 4.6 within 30 km, because the outer rings were almost empty in 1975. The 2020 value is extrapolated beyond the last observed year; for 2015, which lies between observed years, the factor within 20 km is 3.9. Growth sped up over time: within 25 km, 15.7 km^2 were added in the fifteen years 1975–1990, 21.4 km^2 in the ten years 1990–2000 and 50.0 km^2 in the fifteen years 2000–2015. The population within 25 km grew from 401 thousand to 1,419 thousand (3.5 times). The building area per resident rose from 70 square metres in 1975 to about 105 in 2005 and 2010 and was 87 in 2020; because the population grid is spread according to the building layer, this ratio describes the data more than people's living space.

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Table 1 – Building area and population around the centre of Shymkent, 1975–2020

Year	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020
Building area within 20 km, km²	24.9	27.8	31.7	36.6	44.5	54.1	65.5	80.3	95.9	102.7
Building area within 25 km, km²	28.1	31.8	37.1	43.8	53.5	65.2	79.0	96.7	115.2	123.2
Population within 25 km, thousand	401	455	508	567	600	635	755	919	1,153	1,419
Building area per resident within 25 km, m²	70	70	73	77	89	103	105	105	100	87

Source: computed from GHS-BUILT-S and GHS-POP R2023A [2, 3]. GHSL treats 1975, 1990, 2000, 2014 and 2018 as observed epochs; the others are interpolated or, for 2020, extrapolated [4].

In which direction

Of the 95.2 km² of building area added within 25 km between 1975 and 2020, 60.3% was added in the three northern sectors and 18.7% in the three southern ones, although each group covers three-eighths of the land (Table 2, Figure 1). The largest share went to the north-east (24.3%), followed by the north (19.7%) and the north-west (16.3%); the smallest went to the south (3.8%). The order of the northern sectors depends on the radius: within 20 km the north leads (22.8%, against 19.9% for the north-east), within 30 km the north-east leads more clearly (28.6%), while the northern group stays near 57–61% and the southern near 19–20% at each of the three radii tested (20, 25 and 30 km). Part of the north-east share is the growth of the neighbouring town of Aqsukent: with discs of 4 km around Aqsukent and Sayram left out, the north leads within 25 km (22.8%, against 21.1% for the north-east), the north and north-west together receive 41.5%, and the northern group receives 62.6% and the southern 20.8%. The city leaned north from the start, and the lean grew stronger: the north received 46% of the new building area in 1975–1990, 51% in 1990–2000 and 68% in 2000–2015, while the south received 26%, 24% and 14%.

Table 2 – Share of the building area added in 1975–2020, and terrain, by sector

Sector	N	NE	E	SE	S	SW	W	NW
Added area within 20 km, %	22.8	19.9	17.0	9.3	4.2	6.3	6.3	14.4
Added area within 25 km, %	19.7	24.3	15.3	9.5	3.8	5.3	5.7	16.3
Added area within 30 km, %	17.5	28.6	14.5	10.5	4.0	4.4	6.0	14.3
Median elevation at 5–25 km, m	456	554	689	666	593	482	411	397
Land with slope above 5° at 5–25 km, %	3.0	5.0	9.8	19.2	29.3	16.8	8.5	3.0

N – north, NE – north-east, E – east, SE – south-east, S – south, SW – south-west, W – west, NW – north-west. Each sector covers 12.5% of the land. Source: computed from GHS-BUILT-S R2023A [2] and Copernicus GLO-90 [5].

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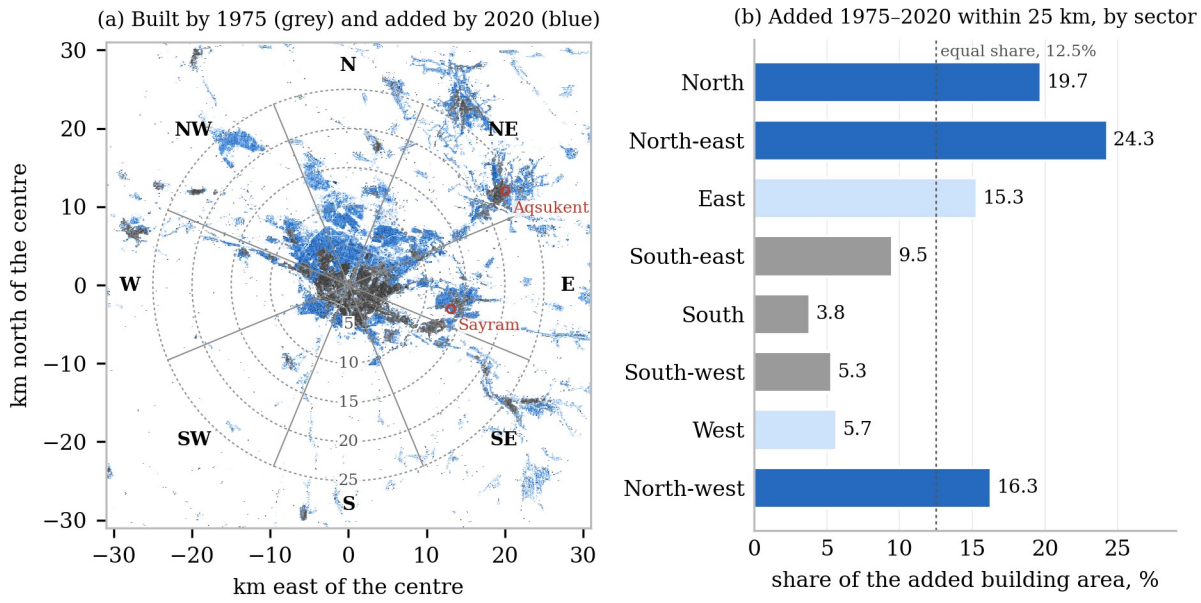

Figure 1 - Building area in 1975 and added by 2020 around the centre of Shymkent, with the neighbouring towns of Sayram and Aqsukent circled in red (a), and the share of the building area added within 25 km, by sector, with the northern sectors in dark blue, the southern in grey and the east and west in light blue (b). Source: computed from GHS-BUILT-S R2023A [2]

Other centre points and the neighbouring towns

The main results hold for every centre point and mask tested (Table 3). The growth factor within 20 km stays between 4.03 and 4.14, and the northern group always receives more than twice the share of the southern. The largest shift comes from the centroid of the urban centre in the GHS Urban Centre Database, 2.8 km north-north-east of the chosen centre: it is the centre of the recent outline of the city, which has moved north through the very growth measured here, and from it the north still receives 49% of the new building area within 25 km and the south 22%. Which northern sector leads, by contrast, depends on the centre and on the towns.

What was there before, and the terrain

Near the centre, the 1975 data do not show a stable difference between north and south (Table 3). Within 5 km of the chosen centre, buildings covered 21.4% of the land in the south and 14.3% in the north, but the comparison depends on the centre point: within 3 km it is 25.6% against 23.9%, and with the centre moved 1 km to the south it reverses. Further out, the land was almost empty in both directions in 1975 (2.0% in the south and 1.3% in the north at 5–10 km); by 2020 the north had reached 24.8% there and the south only 9.9%.

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Table 3 – Main results for different centre points and with the neighbouring towns left out

Centre point	Growth within 20 km, times	North, %	South, %	N + NW, %	Largest sectors	Built in 1975 within 5 km, N / S, %
Chosen centre (42.32 N, 69.59 E)	4.12	60.3	18.7	36.0	NE, N	14.3 / 21.4
Centre of the 1975 footprint (0.95 km)	4.12	62.3	17.7	37.8	NE, N	15.9 / 20.2
Urban Centre Database centroid (2.8 km)	4.14	49.4	22.4	28.4	NE, E	1.1 / 27.4
Centre moved 1 km north	4.14	56.1	19.9	33.2	NE, E	8.6 / 25.0
Centre moved 1 km south	4.11	64.8	16.8	39.5	NE, N	20.0 / 15.7
Centre moved 1 km east	4.12	61.0	18.4	36.8	NE, N	13.3 / 22.7
Centre moved 1 km west	4.10	59.4	18.9	35.1	NE, N	14.8 / 18.4
Chosen centre, towns left out (3 km)	4.09	61.9	20.4	39.9	NE, N	–
Chosen centre, towns left out (4 km)	4.07	62.6	20.8	41.5	N, NE	–
Chosen centre, towns left out (5 km)	4.03	63.7	20.7	43.2	N, NE	–

North, south and N + NW: share of the building area added within 25 km in 1975–2020. Largest sectors: the two sectors with the largest shares, largest first. Towns left out: a disc of the given radius around Sayram and Aqsukent is excluded; the 1975 comparison near the centre is then unchanged. Distances in brackets are from the chosen centre. Source: computed from GHS-BUILT-S R2023A [2].

The terrain differs much more. At 5–25 km from the centre, 21.8% of the land in the south has slopes above 5 degrees, against 3.7% in the north, reaching 29.3% in the south sector itself; slopes above 10 degrees are rare everywhere (3.1% of the land in the south, 0.3% in the north). Within 25 km, hilly land makes up 11.5% of the area but received only 2.8% of the new building area. Terrain does not explain the whole gap, however. On land at 5–25 km that had no buildings in 1975, buildings covered by 2020 6.9% of the flat land in the north but only 1.8% of the flat land in the south, and 3.5% against 0.5% of the hilly land. With the two neighbouring towns left out, the flat land figures are 6.6% and 1.8%.

Discussion

The author's hypothesis on the size of growth is supported: the building area grew 4.1 times within 20 km, close to the fourfold growth he expected, and between 3.8 and 4.6 times for the other radii. His hypothesis on the direction is supported in part. Most new building did go north, 60% within 25 km, but the two directions he named, north and north-west, together received 36% (42% without the neighbouring towns). Within 25 and 30 km the north-east took more than the north, partly through the growth of Aqsukent, and the north-west came third within 25 km and fourth, after the east, within 20 and 30 km.

After seeing preliminary figures, the author offered an explanation. On 28 October he wrote: "In my opinion, in the southern parts it was harder to build new houses, because there were many buildings there from the start and it would have been hard to demolish everything and build new ones, while in the northern part, because of the larger open spaces, it was easier and more profitable to build new houses" (translated from Russian). Near the centre the data can neither confirm nor reject this, because the 1975 comparison depends on where the centre is placed (Table 3). Beyond 5 km both directions were almost empty in 1975, so there the difference must have another cause.

Terrain is a likely contributor. The land rises to the east and south-east and is hilliest to the south, while the north and north-west are low and flat (Table 2), and one model of urban growth takes topography, together with road networks and the existing settlement, as an input [6]. Two cautions apply. GHSL itself uses slope and elevation when it estimates the epochs between

observed years [4], so part of the low share of building on hilly land may come from the data rather than from the city. And flat land in the south was built up only about a quarter as much as flat land in the north, with or without the neighbouring towns, so something besides slope, such as roads, land allocation or planning decisions, must also have favoured the north; the data used here cannot say which.

Limitations. GHSL is a model built from satellite images: only five input years are observed, the other epochs are estimated, and its agreement of 94.04% refers to the 2018 layer and to visual checks of the same images, not to a measurement in Shymkent [4]. It measures the footprint of buildings, not their height or use. The population grid is derived from the building layer, so building area per resident is not an independent measure. The elevation model is a surface model that includes buildings and vegetation [5], which can raise slopes slightly inside built-up areas. The centre point and the radii are choices of this study; the growth factor and the lean to the north change little with the centre and with the neighbouring towns, but the factor rises with the radius, the leading northern sector depends on the centre and the towns, and the comparison of the inner districts in 1975 depends on the centre. The analysis shows where building happened and what the terrain was, but not the decisions behind it.

Conclusion

Between 1975 and 2020 the area covered by buildings around Shymkent grew about four times (4.1 times within 20 km), and about three-fifths of the new building went to the north, a lean that became much stronger after 2000. The south grew little. Its hillier land is part of the reason, but not all of it, because flat land in the south was also built up far less than flat land in the north. For a city with elevated seismic hazard and a young building stock [1], knowing where it grows is a first step to knowing where new buildings need the most care.

Data availability

The GHSL and Copernicus data are public [2–5]. The analysis script and the results by sector, ring and epoch were prepared by the author's mentor and are available on request.

Author contributions and use of AI tools

The author chose the topic from several research directions proposed by his mentor, proposed the hypothesis quoted in the Hypothesis section before any data were analysed, offered the explanation discussed in the Discussion after seeing preliminary figures, and checked the division behind the headline growth ratio in an earlier draft. The data were analysed and the text was drafted with a generative AI assistant (Claude, Anthropic) under his mentor's direction. The author's own statements are quoted in translation from Russian. Every result in the Results section, the tables and the figure was computed by the analysis script from [2, 3, 5]; other figures are quoted from [1, 4].

Conflicts of interest

The author declares no conflicts of interest. No funding was received for this study.

References:

1. Amangeldy N. How much of Kazakhstan's urban built stock predates its seismic codes, and where does that stock sit relative to hazard? // Central Asian Scientific Journal. – 2026. – No. 4(32), Vol. 1. – P. 477–482. – DOI: 10.5281/zenodo.23758427.

2. Pesaresi M., Politis P. GHS-BUILT-S R2023A – GHS built-up surface grid, derived from Sentinel-2 composite and Landsat, multitemporal (1975–2030) [Electronic resource] / European Commission, Joint Research Centre. – 2023. – DOI: 10.2905/9F06F36F-4B11-47EC-ABB0-4F8B7B1D72EA (accessed: 16.11.2026).

3. Schiavina M., Freire S., Carioli A., MacManus K. GHS-POP R2023A – GHS population grid multitemporal (1975–2030) [Electronic resource] / European Commission, Joint Research Centre. – 2023. – DOI: 10.2905/2FF68A52-5B5B-4A22-8F40-C41DA8332CFE (accessed: 16.11.2026).

© Central Asian Scientific Journal, 2026

4. GHSL Data Package 2023 / European Commission, Joint Research Centre. – Luxembourg: Publications Office of the European Union, 2024. – JRC133256. – DOI: 10.2760/098587.

5. European Space Agency, Airbus. Copernicus DEM [Electronic resource]. – European Space Agency, 2022. – DOI: 10.5270/ESA-c5d3d65 (accessed: 16.11.2026).

6. Clarke K.C., Hoppen S., Gaydos L. A self-modifying cellular automaton model of historical urbanization in the San Francisco Bay area // Environment and Planning B: Planning and Design. – 1997. – Vol. 24, No. 2. – P. 247–261. – DOI: 10.1068/b240247.

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