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ANALYSIS OF GREEN ZONES AND HEAT ISLANDS OF ALMATY CITY BASED ON SATELLITE IMAGES

The ubiquitous process of urbanization leads to the expected trend of population growth that will live on the territory of urban space. The image of urban organization of life leads to an increase in anthropogenic impact on the environment and a decrease in the level of interaction with natural resources. Population growth, or rather an increase in population density within an urban area that does not correspond to quantitative indicators, leads to a change in climatic indicators, which will subsequently affect the quality of life of citizens. The purpose of this scientific study was to identify green areas indicating the coverage of the urban area based on the definition of heat islands and classification by land cover based on satellite images. The scientific significance of the study was justified by the trend aimed at improving urban spaces and improving the quality of life of urban residents. The research methodology consisted in processing satellite images for further reclassification according to generally accepted standards, taking into account the individual indicators of the city of Almaty. The main result of the study was the identification of the zones most unsuitable for the quality of life, and the conclusion was recommendations for improving the environmental situation based on surface temperature indicators that allow identifying heat islands associated with a low quality indicator of the standard of living within the city of Almaty. The value of the research was aimed at developing theoretical theses for subsequent implementation in potential projects to improve the quality of life of residents of Almaty.

Key words: Green zones, heat islands, geoinformation system, surface temperature, radiation of the Earth's surface, geospatial data, statistical analysis, remote sensing, cartography, spatial analysis and data science, buffer zones, network analysis, vegetation cover.

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Ғарыштық түсірілімдер негізінде Алматы қаласының жасыл аймақтары мен жылу аралдарын талдау

Урбандалудың жаппай процесі қала кеңістігі аумағында тұратын халықтың өсу үрдісіне алып келеді. Қалалық өмірді ұйымдастыру бейнесі қоршаған ортаға антропогендік әсердің жоғарылауына және табиғи ресурстармен өзара әрекеттесу деңгейінің төмендеуіне әкеледі. Халықтың өсуі, дәлірек айтқанда, сандық көрсеткіштерге сәйкес келмейтін қала аумағы шегінде халықтың тығыздығының артуы климаттық көрсеткіштердің өзгеруіне әкеледі, бұл кейіннен азаматтардың өмір сүру сапасына әсер етеді. Бұл ғылыми зерттеудің мақсаты – жылу аралдарын анықтау және ғарыштық суреттер негізінде жер жамылғысы бойынша жіктеу негізінде қала аумағын қамтуды көрсете отырып, жасыл аймақтарды анықтау. Зерттеудің ғылыми маңыздылығы қалалық кеңістікті жақсартуға және қала тұрғындарының өмір сүру сапасын жақсартуға бағытталған үрдіспен негізделді. Зерттеу әдіснамасы Алматы қаласының жеке көрсеткіштерін ескере отырып, жалпы қабылданған стандарттарға сәйкес әрі қарай қайта сыныптау үшін ғарыштық суреттерді өңдеу болды. Зерттеудің негізгі нәтижесі – өмір сапасы бойынша неғұрлым сәйкес келмейтін аймақтарды анықтау, ал қорытынды ретінде Алматы қаласы шегінде өмір сүру деңгейінің төмен сапалы көрсеткішімен байланысты жылу аралдарын сәйкестендіруге мүмкіндік беретін жер бетінің температуралық көрсеткіштері негізінде экологиялық жағдайды жақсарту жөніндегі ұсынымдар болды. Зерттеудің құндылығы кейіннен Алматы қаласы тұрғындарының өмір сүру сапасын жақсарту жөніндегі әлеуетті жобаларға енгізу үшін теориялық тезистерді әзірлеуге бағытталған.

Түйін сөздер: Жасыл аймақтар, жылу аралдары, геоақпараттық жүйе, жер бетінің температурасы, жер бетінің сәулеленуі, геокеңістіктік деректер, статистикалық талдау, қашықтықтан зондтау, картография, кеңістіктік талдау және деректер туралы ғылым, буферлік аймақтар, желілік талдау, өсімдік жамылғысы.

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Анализ зеленых зон и островов тепла города Алматы на основе космических снимков

Повсеместный процесс урбанизации ведет к ожидаемой тенденции роста населения, проживающего на территории города. Образ городской организации жизни ведёт к повышению антропогенного влияния на окружающую среду и понижению уровня взаимодействия с природными ресурсами. Рост населения, а точнее повышение плотности населения в пределах несоответствующей по количественным показателям городской территории, ведёт к изменению климатических показателей, что впоследствии будет отражаться на качестве жизни горожан. Целью данного научного исследования являлось выявление зеленых зон с указанием охвата городской территории на основе определения островов тепла и классификации по земельному покрову на основе космических снимков. Научная значимость исследования обосновывалась тенденцией, направленной на улучшение городских пространств и повышение качества жизни жителей городов. Методология исследования заключалась в обработке космических снимков для дальнейшей реклассификации согласно общепринятым стандартам с учетом индивидуальных показателей города Алматы. Основным результатом исследования являлось определение зон, наиболее неподходящих по качеству жизни, а выводом служили рекомендации по улучшению экологической обстановки на основе температурных показателей поверхности, позволяющих идентифицировать острова тепла, ассоциирующиеся с низким качественным показателем уровня жизни в пределах города Алматы. Ценность исследования была направлена на разработку теоретических тезисов для последующего внедрения в потенциальные проекты по улучшению качества жизни жителей города Алматы.

Ключевые слова: Зеленые зоны, острова тепла, геоинформационная система, температура поверхности, излучение земной поверхности, геопространственные данные, статистический анализ, дистанционное зондирование, картография, пространственный анализ и наука о данных, буферные зоны, анализ сетей, растительный покров.

Introduction

Growing urbanization increases the intensity and frequency of the Urban Heat Island (UHI) effect in highly developed cities. Advances in satellite measurements make it easier to analyze this phenomenon using Land Surface Temperature (LST) as an indicator of the urban thermal island of the surface (Daniel Jato-Espino 2022). Urban heat island is a phenomenon in which urban areas become warmer than the surrounding rural areas, which is one of the most important urban problems resulting from human activity (Wangchongyu Peng 2022). Since the scale of an urban agglomeration is much larger than that of an individual city, an urban agglomeration can represent spatiotemporal models of an urban heat island that differ from models of an individual city (Xu Zhang 2022). The urban heat island effect is widely observed around the world, causing impacts on climate, health and energy in cities. It was found that the intensity of the urban heat island largely depends on the background climate and the properties of the urban land cover (Ziyan Zhang 2022).

The urban heat island is a significant phenomenon that is currently receiving a lot of attention from the scientific community because of its importance to the environment, and it is mostly regarded as just a negative event. However, there is a clear knowledge gap to study its impact when choosing optimal measures for the modernization of buildings. Thus, a reproducible methodology is needed that also allows comparison between different studies, which is currently a difficult task (Laura Romero Rodríguez 2022). Urban heat island is one of the most studied environmental problems on a local climatic scale. This is a thermal anomaly resulting from the temperature difference between urban areas and adjacent rural areas, which add heat to the atmosphere and lead to thermal discomfort for part of the population (Gislene Figueiredo Ortiz Porangaba 2021). Typical pavement building materials such as concrete and cement can significantly enhance the urban heat island (UHI) effect in cities. However, optimized pavement designs can reduce the temporary intensity of the UHI effect by changing the absorption capacity of radiation and heating (D.M. Senevirathne 2021).

Current climate changes imply an increase in the average temperature in cities during hot periods. In order to help public policy be more effective in reducing urban heat islands, there is a

desire to determine the UHI (Urban Heat Island) risk indicator (Clément Marcel 2021). Climate change poses a great threat to people and the planet's ecosystem. There are many factors that cause climate change, and there are many side effects. One of the consequences is the urban heat island, recognized as the most obvious characteristic of the urban climate, which arises from dark, non-reflective surfaces. These surfaces absorb solar heat, radiate heat; thus, the temperature of the earth's surface increases. In addition, heat islands increase the cooling load in summer, which leads to an increase in energy consumption and the formation of more greenhouse gases (Vaibhav Rai Khare 2021). Long-term observations of urban heat islands are rare and where they are available, as a rule, do not allow distinguishing the factors influencing climate change from urban expansion; none of the factors are considered independently (R. Bassett 2021).

The city of Almaty is a city of republican significance and the largest settlement of the Republic of Kazakhstan with an area of 682 square kilometers. The climate of Almaty is continental and it is characterized by the influence of mountain-valley circulation, which is especially evident on the northern outskirts of the city, where the transition of mountain slopes into plains is observed. The total population of the city in 2020 is 1,936,314 people with a population density of 2,839 people per square kilometer. The location in the foothill basin is directly related to the difficult environmental situation, which is expressed in a high level of air pollution. The main sources of pollution in the urban environment of Almaty are motor transport and thermal power plants, which are planned to be converted to gas in the future in order to reduce the negative impact on the environmental situation. The city of Almaty administratively consists of 8 districts: Alatau, Almaly, Auezov, Bostandyk, Medeu, Nauryzbay, Turksib and Zhetysu. Each of the above areas has its own characteristics, which leads to the need for a comprehensive consideration of the issue of coverage of green zones (Figure 2).

The purpose of this study was to analyze green areas and heat islands, followed by the provision of a number of recommendations based on satellite images.

The objectives of the study were:

– collection of the necessary array of data from open sources on the studied territory;

– creation of a map of the earth's surface temperatures using a Raster Calculator using formulas using the ArcGIS Pro 2.9.4 program based on a satellite image of the artificial Earth satellite LandSat-8 dated July 27, 2021;

– calculation of the parameters of zones related to heat islands;

– creation of buffer and service zones for the green zones available in the city.

Materials and Methods

Object of research: green zones and heat islands of Almaty.

Source data: open spatial demographic data (World Pop Hub 2010-2020), Earth cover map based on Sentinel-1 and Sentinel-2 satellite images of the European Space Agency with a resolution of 10 meters for 2020 ((ESA) 2022), Satellite image of the artificial Earth satellite LandSat-8 of the US Geological Survey dated July 27, 2021 ((USGS) 2013) and a list of available green areas according to the register of the Almaty City Planning and Urbanism Department.

Research methods: analysis of the coverage of the earth's surface according to proportions to identify the percentage covering green spaces within the urban area. Next, to determine the heat islands, a spatial analysis tool is used – a Raster Calculator (Raster Calculator) (ESRI n.d.), based on a step-by-step calculation of indicators.

Initially, there was a need to turn to open sources focused on providing satellite images. A satellite image dating from July 27, 2021 was used for the analysis to determine the heat islands. The satellite image used for the analysis of thermal islands had a cloud cover index equal to 8.42, which partially affected the indicators of two districts – Turksib and Zhetysu. The first step was the process (Figure 1) of extracting the group No. 10 (Band 10) of the satellite image for further conversions using the raster calculator tool.

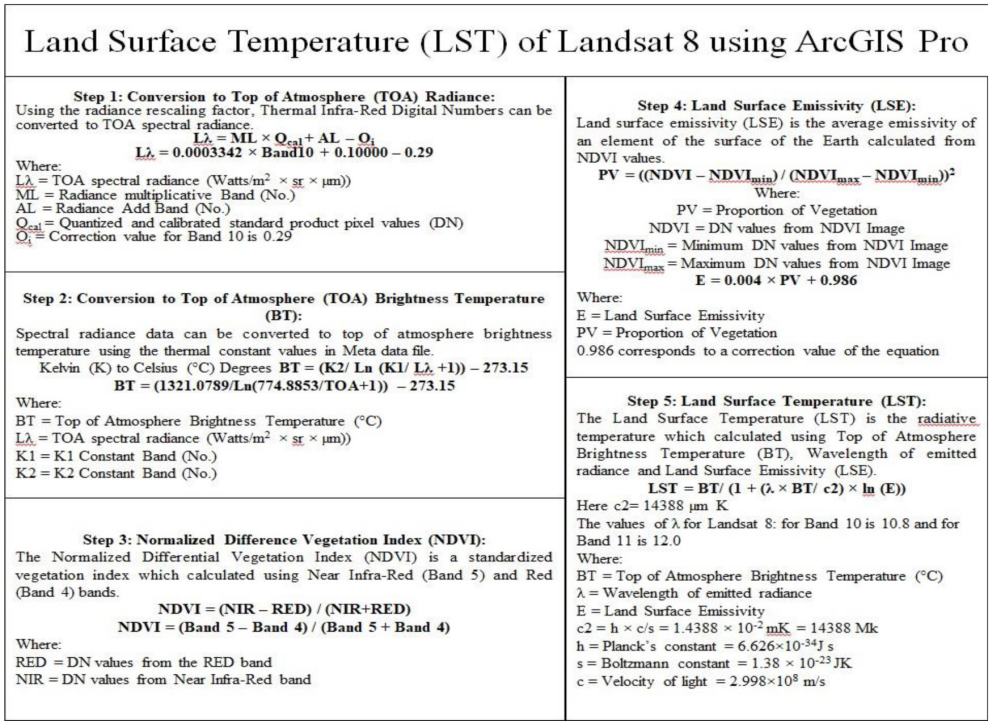

Figure 1 – A flowchart of the methodology steps for calculating Land Surface Temperature (LST)

The first calculation was related to the need to convert the values of the bitmap image taking into account the radiation indicators of the upper atmosphere (TOA) Radiance). When using the radiation scaling factor, thermal infrared digital numbers can be converted into the upper part of the spectral radiation of the atmosphere. After receiving the image updated according to the calculations, there is a step associated with the conversion to the upper part of the brightness temperature of the atmosphere (Top of Atmopshere (TOA) Brightness Temperature (BT)). Spectral radiation data can be converted to the upper brightness temperature of the atmosphere using the values of the thermal constant in the metadata file. The third step is the calculation of the Normalized Differential Vegetation Index (NDVI). The normalized differential vegetation index is a standardized vegetation index that is calculated using the near infrared (Band 5) and red (Band 4) ranges. The fourth step is aimed at calculating the radiation coefficient of the Earth's surface (Land Surface Emissivity (LSE)). The radiation coefficient of the Earth's surface is the average radiation coefficient of an element of the Earth's surface, calculated on the basis of NDVI values. The final stage of the calculations was the conversion of the output values for the output of the Earth's Surface Temperature (LST)). The Earth's surface temperature is the radiation temperature, which is calculated using the brightness temperature of the upper atmosphere, the wavelength of radiation and the radiation coefficient of the earth's surface.

Results

Residential areas play an important role in the formation of the urban heat island. Many studies have used hypothetical or simplified models to analyze UHI in residential areas based on numerical modeling. However, there is still no accurate and effective method for obtaining typical models of residential areas with regional characteristics (Xuexiu Zhao 2022). The Urban Heat Island (UHI) effect has been the subject of numerous studies due to its adverse effects on health, energy and the environment (Mohamad Ghadban 2020). Understanding how the components of cities affect the urban heat island has become a major serious problem for societies seeking to improve the quality of life through the introduction of urban planning criteria (David Hidalgo García 2021). Land Use and Land Cover Change (LULC)) at the local, regional and global levels, it is one of the

fundamental causes of global climate change (Sumita Kedia 2021). Urban heat island is the most recognized phenomenon associated with climate change, also because it affects the health of the population in densely populated urban areas, even getting worse during heat waves (Benedetta Pioppi 2020).

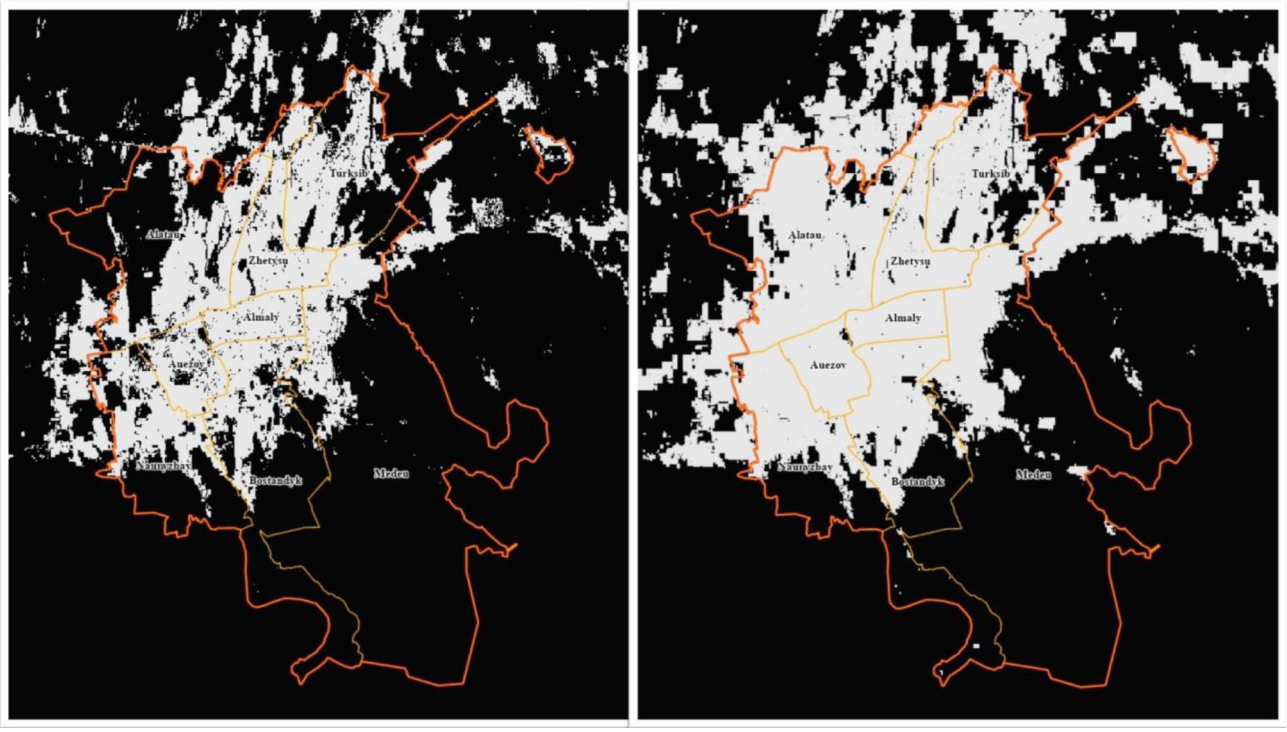

Figure 2 – Comparative maps of the built-up area of the city of Almaty for 2010 and 2020 (World Pop Hub 2010-2020)

The phenomenon of urban heat island is often associated with heat waves, both in the scientific literature and in the media. Health problems and other problems often arise as a result of the simultaneous occurrence of these two phenomena (Yves Richard 2021). The annual and daily behavior of temperature changes in urban areas is important for predicting the possible consequences of future land use development for climate change and air pollution in densely populated areas. The behavior of temperature, as well as spatio-temporal differences in wind, in turn, is closely interrelated with the variability of turbulent and radiation flows (Virginia Ciardini 2019). In the scientific fields of meteorology and climatology, official studies of the urban atmosphere date back to the beginning of the 19th century. Since then, hundreds of studies have been published in the scientific literature to measure the "urban temperature effect" — or the "heat island effect" (Stewart 2019). The growth of cities is associated with serious environmental consequences and affects the living conditions of people and the economy. To address such impacts, stakeholders should evaluate various mitigation strategies. Due to the complexity of these phenomena, such a comparison process can be complicated, which leads to subjective and unclear interpretations, which, as a result, limits the course of action for its implementation (Luis G.R. Santos 2021). Mitigation and adaptation measures should be strategically developed by urban planners, planners and decision makers to reduce the risks associated with urban heat islands (M.O. Mughal 2020).

Built-up areas with unnatural surface coverings create the effect of an urban heat island. To explore this in a larger spatial expansion, satellite data provides sufficient spatial coverage without the unnecessary effect of time delay within the region (Csenge Dian 2020). Spatial and temporal variability of meteorological variables in urban areas due to differences in the characteristics of the land surface is a common phenomenon. The influence of the

soil cover on the air temperature is most pronounced (Annette Straub 2019). Sustainable city planning usually focuses on compact human-scale cities. The urban paradigms underlying each city create a morphology that creates a special local urban climate (Bakul Budhiraja 2020). Most modern climate modeling systems distort the impact of urbanization on the local climate due to computational limitations, which creates serious limitations for urban climate forecasts (Miguel Nogueira 2020). The increase in the surface temperature of urban lands has become an environmental problem for urban residents and politicians. Adoption of mitigation plans, forecasting and recognition of future temperature models are very important approaches (Sk Ziaul 2021).

The intensity of an urban heat island can be scaled using a scale of urban extent and wind speed using a time-dependent energy balance. Heating of urban surfaces during the daytime sets the initial temperature, and this overheating dissipates at night due to the average convection movement over the urban surface. The energy balance shows that this cooling effect can be quantified in the form of an exponential decline over time (T.-W. Lee 2012). Urbanization leads to rapid construction, which uses materials with low albedo, which leads to high heat absorption in urban centers. In addition, the removal of vegetation cover and waste heat emissions from various sources contribute to the accumulation of thermal energy, which leads to the formation of urban heat islands. Urban heat islands have many adverse socio-ecological consequences. Therefore, spatial identification of urban Thermal Islands is a necessity for taking appropriate remedial measures to minimize their adverse effects. Remote sensing from satellites provides an economical and time-saving methodology for the spatial and temporal analysis of the distribution of land surface temperature (I.P. Senanayake 2013). Infrared thermography is an important tool for assessing urban heat islands. However, manual thermal imaging cameras are only designed to measure surface temperature. Near-surface air temperatures are physically different, and although these two temperatures are expected and assumed to correlate, their relationship remains an important research issue. It would be a methodological achievement if thermal imaging cameras could also measure air temperature, as this would make data collection from mobile devices more efficient, consistent and accurate (Andrew C. Chui 2018). Rising temperatures in urban areas are causing serious health-related economic problems that affect more than half of the world's population. This fact caused the need for assessment and monitoring of the thermal environment in cities and stimulated the development of auxiliary information for decision-making, such as heat wave risk maps. Most of them require access to high spatio-temporal temperature measurements to be fully effective. However, even to this day, such datasets are difficult to obtain. Many scientists involved in remote sensing support the view that spatial improvement of data on the temperature of the Earth's surface from geostationary satellites can provide the necessary data sets (Panagiotis Sismanidis 2015). Scientific research on mitigating the effects of the urban heat island phenomenon is expanding, reflecting a new understanding by scientists, planning authorities and government agencies of the impact of urban design and planning on the intensity of the summer urban heat island (Or Aleksandrowicz 2017).

The starting point of this study should be considered the data obtained from the Earth cover map based on the Sentinel-1 and Sentinel-2 satellite images of the European Space Agency with a resolution of 10 meters for 2020 (Figure 3). According to the data, the city of Almaty has a high level of green space coverage, but this is not a reason for optimism, because geographically the city includes the lands of the Ile-Alatau National Park. The entry of these lands into the urban area statistically increases the level of green space coverage and does not give a real picture of the shortage of green areas in Almaty. According to the basic data, the level of green space coverage in Almaty is 27.89%, which is 190 square kilometers out of the total area of the city of 682 square kilometers. Based on open data for 2020, the population of Almaty is 1,936,314 people, which according to the ratio is equal to 98 square meters of green spaces per person. This indicator exceeds the norm established by the World Health Organization (WHO) almost twice, but the development of urban areas involves an integrated approach to the issue of landscaping. Unfavorable are the conditions under which vegetation in the city occupies less than 10%, and favorable – 40-60%. Following this thesis, an assessment of each of the 8 districts of the city of Almaty was carried out on the number and percentage of the available territory of green spaces.

According to the input data, the initial goal was to inventory the available green areas with the definition of buffer zones focused on demonstrating the coverage of this type of natural good. The polycentricity factor of urban space should be considered as the basis for the approach to accounting for the coverage of green zones. The polycentricity of ur-

ban space focuses on the parallel development of smaller administrative units of the city, taking into account quantitative and qualitative indicators.

The first in the list of districts is the Alatau district with an area of 104 square kilometers. This district was formed in 2008 as a result of the unbundling of the Auezovsky district from Ryskulov Avenue with a direction to the north. There are 284,607 people living in this area, and the density is 2,842 people per square kilometer or almost 3 people per square meter. The level of green space coverage is 4,971 square kilometers, which is only 4.78% of the total area (with a citywide value of 27.89%). The Alatau district is one of the most problematic when considering the issue of covering with green spaces. With the ratio of the population to the territory that is occupied by green spaces, it turns out 17 square meters per person with a norm of 50 square meters per person and a citywide of 98 square meters per person. The level of the built-up area in the district is at the level of 39.75%, which automatically increases the actual population density when building the proportion of the population to the built-up area. This proportion leads to the fact that the above 284,607 people live in an area of 41 square kilometers, hence the higher level of population density – 6,884 people per square kilometer or almost 7 people per square meter. Visually, when examining the cartographic material, the difference in the level of development is highlighted – the main number of buildings is located next to the adjacent Zhetysu, Almaly, Auezov and Nauryzbay districts. Also, development is observed in the border areas with the Boraldai settlement of the Ili district and the Koksai village of the Karasai district, but mostly the border area in the northwestern part of the district is covered with arable land and pastures. The main place of covering with green spaces is the cemetery "Batys" (Western), which, according to the temperature map, reduces the risk of a thermal island. An industrial zone is located on the territory of the Alatau district, which occupies a solid territory covered with large buildings with sloping roofs that affect the artificial increase in surface temperature. The only park area in the Alatau district is the Halyk Park with an area of about 3 hectares on the territory of the Tomiris microdistrict, which is a catastrophic indicator on the scale of the district of the city of republican significance.

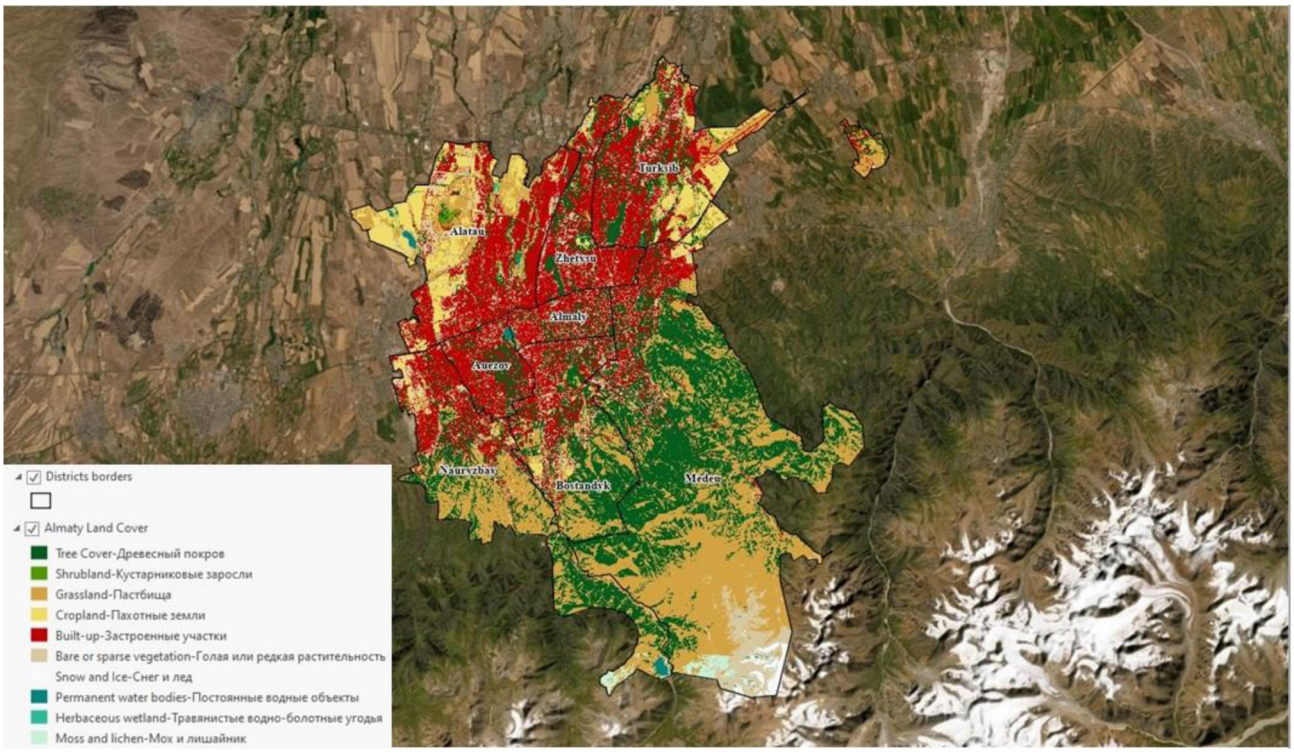

Figure 3 – Map of the earth cover of Almaty city based on Sentinel-1 and Sentinel-2 satellite data ((ESA) 2022)

According to the map of the earth's surface temperatures (Figure 4), the Alatau district has the greatest values, which is manifested in the presence of heat islands that lower the standard of living of local residents. One of these is the land mass in the Tomiris microdistrict (formerly the Trudovik microdistrict), covered with pastures and arable land according to the classification and fixed in the land register with the number 20-321-002-004. This land mass with an area of 4.3 square kilometers is fixed for the creation of the archaeological park "Boraldai Saka mounds", which leads to the understanding that the territory will not go under housing construction and subsequently, with the successful implementation of the park, it can integrate a number of green strips (and possibly zones) in order to lower the temperature regime of the nearby Boraldai village, residential districts of Ozhet and Tomiris. Slightly less than half of the territory of the Alatau district is covered by thermal islands, which correlates with changes in altitude from residential areas to pastures and arable lands that are located on the border territory. The artificial increase in temperatures in this area is also significantly influenced by 3 Almaty thermal power plants, one of which (CHP-2) is located in the Alatau district north of the Algabas microdistrict. Among other things, the artificial increase in temperature is characterized, as already described above, by sharp differences in altitude between nearby territories. These include the residential districts of Gazhayyp, Akmarzhan and Botakoz (with a total area of more than 250 hectares (2.5 square kilometers and assigned to cadastral number 20-321-044-247), located next to the residential districts of Algabas, Nurkent (the territory of the former athletic village), Daraboz, Zerdeli and 13th. These microdistricts are located above a tectonic fault, which, accordingly, cannot lead to dense development of the specified territory. The Department of Urban Planning and Urbanism of the city of Almaty planned the implementation of the park zone, but at the moment there is construction of objects listed in the cadastral database under the numbers 20-321-044-248, 20-321-044-250 and 20-321-057-406. To date, the indicator of green space coverage and, in general, environmental indicators of the Alatau district are several times inferior to other districts of Almaty, which is characterized by a large amount of arable land, pastures, private residential areas, CHP-2, shopping areas and an industrial zone with large buildings with sloping roofs and a commensurate parking area.

The second in the list of districts of the city for the analysis of green zones and temperature indicators is Almaly district with an area of 18.4 square kilometers, which is the smallest value for the districts of Almaty. This district borders with all others except Nauryzbaysky and is the center of the interface of urban space. Despite the small area, Almaly district is a backbone for the city, which affects the number of population – 153,989 with a population density of 8,475.7 people per square kilometer (~8 people per square meter). The area of vegetation cover of Almaly district is 4 square kilometers, which is equivalent to 21.95% of the total area of the district. According to the ratio of the number of population and the number of green spaces, it turns out 26 square meters per person, which, with the existing micro-district development, is a good result. The development area of the district is 56%, which is equivalent to 10 square kilometers. When calculating the population density per built-up area, the indicator doubles and equals 14,820 people per square kilometer (~15 people per square meter). On the territory of Almaly district there is one park – Komsomol Park (named after M.K. Gandhi) with an area of about 9 hectares. There are 5 small thermal islands in Almaly district, each of which has no critical influence on the temperature increase in the district. The first is an administrative building with an area of 5 hectares at the address: Tole bi Street, 189e/3. This structure has an increased temperature index due to the fact that the roof of the building is flat on the area of the entire building. Not far from the first building there are also two small zones of thermal islands formed on the site of a railway dead end and buildings on this territory also have sloping roofs. In the same part of the district, in 2021, the punching of Auezov Street from Gogol Street to Rayymbek Avenue was carried out, along which new residential zones will be built, which in the future can be equipped with green zones to lower the temperature regime in the specified territory. In the future, there is a direct need for a partial reorientation of land with an area of about 150 hectares from the production sector to a mixed type with the addition of green areas and the conversion of unused administrative buildings. Due to the historical component, Almaly district is the most stable in terms of covering with green spaces, but there is a direct need to reorient production areas for urban needs, taking into account the environmental component.

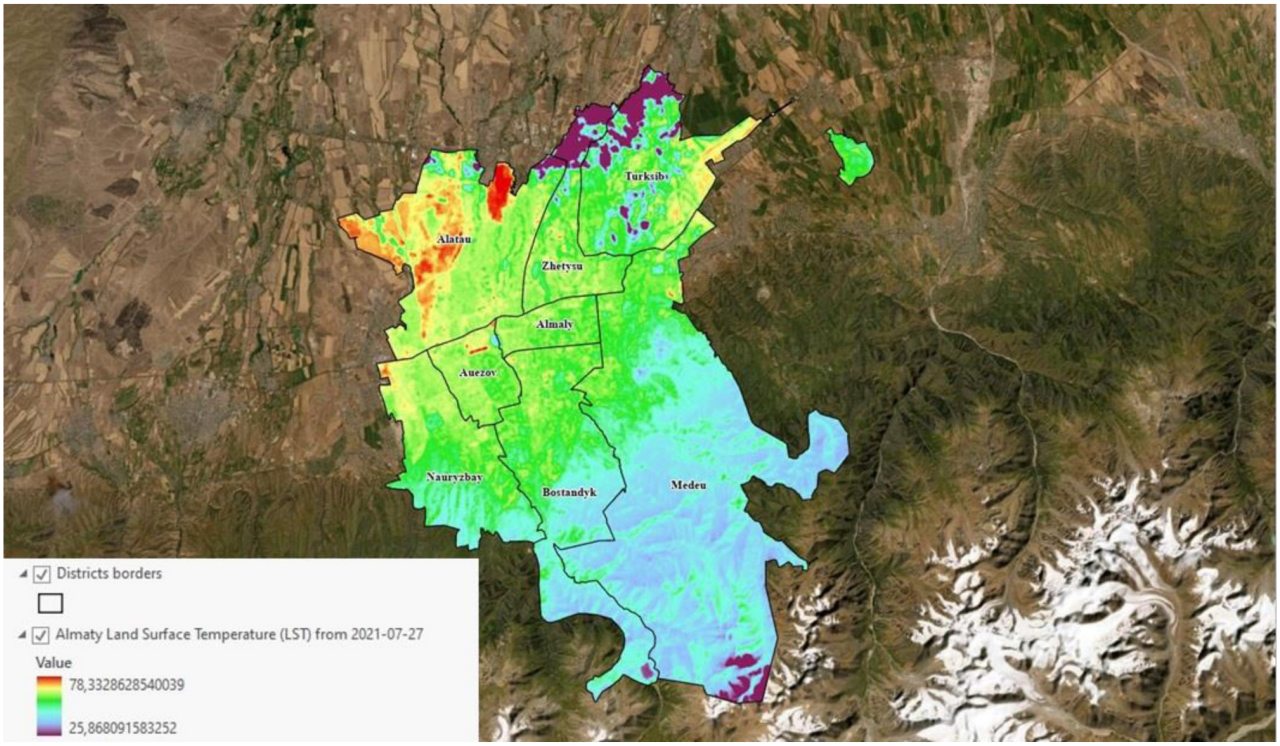

Figure 4 – Map of the temperature indicators of the earth's surface of the city of Almaty from July 27, 2021

Auezovsky district slightly exceeds Almalinsky in terms of territory and has a total area of 23.5 square kilometers, but this area is more focused on private residential areas. The population of this district is equal to 198,181 people and the density for the entire territory is 8,378.6 people per square kilometer. The coverage of green spaces in the area is 25.71%, which is equivalent to 6 square kilometers. The built-up area of the district is 59.34%, which is equal to 13.9 square kilometers. According to the built-up area, the total population density is 14,216 people per square kilometer (~14 people per square meter). There are a number of thermal islands on the territory of the district, but due to the presence of a large number of private arrays and the smooth transition of the number of storeys of buildings, temperature regimes do not have large fluctuations. The main thermal island is located in the square of Kabdolova – Utegen batyr – Tole bi – Sain streets. The reason for the formation is massive low-rise buildings with sloping roofs, namely the buildings of the Armada shopping complex, the Grand Park shopping and entertainment complex, the OBI shopping center and the Metro hypermarket. Also, one of the thermal islands of the Auezovsky district is a zone on the territory of the Tastak-1 microdistrict at the intersection of the Auezovsky, Almalinsky and Alatau districts with an area of about 20 hectares, and this despite the presence of Lake Sairan and the Bolshaya Almatinka riverbed nearby, which have the property of smoothing temperature differences within urban spaces. Auezovsky district historically developed taking into account the production needs of the city and many territories were realized for this purpose, and at the end of the service life, many lands went under private arrays, which provoked the subsequent spread of the city to the west.

Bostandyk district, along with Medeu district, has an intersection with the Ile-Alatau National Park, which is manifested in the ratio of the number of green spaces on the territory of urban space. Bostandyk district has an area of 99.4 square kilometers, and the population of the district is 234,145 people. The population density according to the above data is 2375.6 people per square kilometer, which practically corresponds to the citywide indicator. The coverage of green spaces in the area is 40.69%, which is equivalent to 40.45 square kilometers. Based on this, an indicator of 172 square kilometers of green spaces per person is obtained, which is obvious due to the reasons described above related to the presence of the Ile-Alatau Na-

tional Park zone within the territory of the district. The built-up area of the district is 17.46%, which is equal to 17.36 square kilometers. Based on the indicators of the development of the territory, it is necessary to deduce the population density, which is several times higher than the standard indicator, taking into account the entire territory – 13,487 people per square kilometer (~ 13 people per square meter). Turning to thermal islands, it is worth highlighting the presence of a number of green zones, which provide a comfortable environment for the recovery of citizens. The presence of Dostyk Park (Friendship Park), Yuzhny Park, the Park of the First President of the Republic of Kazakhstan and the Botanical Garden significantly increase the level of accessibility of residents of this area to recreational places, which in turn increases the attractiveness and value of residential areas located within walking distance. The main thermal island of the Bostandyk district is an area of 12 hectares, which includes the shopping and entertainment complex "ADK" and the shopping center "AVTODOM" with sloping roofs and an adjacent parking area. Next, you should pay attention to the territory located at Egizbayev, 9a and with other letters. The area with an area of about 6 hectares is given over to the manufacturing sector, focused on repairs and parking lots. The presence of sloping roofs and the absence of landscaping automatically increases the average temperature for nearby residential areas. In the future, it is possible to reorient this space with the implementation of underground parking and phased landscaping without compromising existing production. Then we move on to a very non-standard zone, which turned out to be the center of the thermal island, despite the presence of green areas, the Yuzhny Park and the Botanical Garden next door. The territory of the shopping and entertainment complex "Atakent Mall" with adjacent pavilions is the center of the thermal island, because it meets the necessary conditions with sloping roofs and adjacent parking area. The approximate area of the thermal island is about 15 hectares, which in the future needs to reorient the existing space, because the presence of these territories can increase the average temperature level of both green areas located in the neighborhood and residential areas stretched along Zharokov and Timiryazev streets. The last and the list of thermal islands are two territories located at a relatively small distance from each other. The first object is the Magnum supermarket on Gagarin Avenue, and the second is the Mega Center Alma–Ata shopping and entertainment complex on Rozybakieva Street. The two specified territories with a parking zone have a direct impact on the temperature regime of nearby objects, given the emerging trend of building the Khodzhanov-Rozybakiev-Kozhabekov-Gagarin square with residential complexes. The objects listed above are subject to a consistent revision of the profile purpose or re-equipment of roofs, taking into account their coverage with green spaces for the subsequent balancing of the temperature regime of these territories and nearby residential areas.

Medeu district is the largest, with an area of 253 square kilometers. The population in the district is 257,766 people with a density of 942.5 people per square meter. This area has the largest share of intersection with the lands of the Ile-Alatau National Park, hence 37.61% of green spaces, which is 95.17 square kilometers, and in relation to the population is 369 square meters per person. The level of development in the district is only 7.02%, equivalent to 17.78 square kilometers. According to the available buildings, the population density has a much more impressive indicator, equal to 14,497 people per square kilometer (~ 14 people per square meter), which in turn is 15 times higher than the initial density index for the entire territory of the Medeu district. On the territory of Medeu district, Friendship Square, the park named after 28 Panfilov Guards and the Central Park of Culture and Recreation of Almaty are available to residents. This area is the most favorable in terms of temperature conditions, because only less than a tenth of the area is under a built-up area. One of the thermal islands is a zone in the foothills above the Duman-1 microdistrict, but in this case, the formation of a thermal island could be influenced by natural factors related to the terrain features of this territory. The technogenic factor of the formation of a thermal island is observed at the intersection with the Turksib district and is associated with the presence of a building with a sloping roof – the Toyota City car dealership. In the near future, it is planned to erect another structure with a potentially flat roof next to the car dealership – the shopping and entertainment complex "Aport". In this regard, there is a need to organize a green zone on the available free territory along the Kuldzhinsky tract and Bukhtarminskaya Street, since projects to create new residential complexes are planned to be implemented within the same limits.

Nauryzbay district has an area of 69.7 square kilometers and borders the territory of the Ile-Alatau National Park. The population in this area is 146,912 people, and the settlement density is 2103.3 people per square kilometer. Green spaces on the territory

of Nauryzbay district are equal to 23.05%, which is equivalent to the occupied territory of 16.06 square kilometers. In terms of the number of people, the value is 109 square meters per person. The built-up area of the Nauryzbay district is 18.44 square kilometers, which corresponds to a value of 26.45% of the total territory. When recalculating the population density taking into account the built-up area, a number equal to 7,967 people per square kilometer (~8 people per square meter) is obtained. There are no park areas in the Nauryzbay district, and most of them are occupied by individual residential buildings. The only green area is located on the territory of the now private wellness center "Alatau Health and Wellness Complex" and inaccessible to most residents of the area. According to the available thermal islands of the Nauryzbay district, it is worth starting from the territory located in the Shugyla microdistrict near the district akimat. The area of 40 hectares increases the average temperature due to the lack of vegetation, which affects the nearby neighborhood. Also, following the same avenue Alatau along the Shugyla microdistrict, there is an opportunity to get acquainted with the second thermal island of the district, which occupies an area of 100 hectares on the border with the village of Abai Karasai district of Almaty region and with the Alatau district. Due to the large availability of commercial space, decorated in hangar-type buildings with sloping roofs, this area significantly increases the temperature regime of the area and in the future needs to create a recreational area for balancing thermal islands.

Turksib district has an area of 75.8 square kilometers, and is inhabited by 361,047 inhabitants with a density of 4,784.6 people per square kilometer. The area's green cover is 18.78%, which is equivalent to 14.23 square kilometers. According to these data, the ratio of green spaces per inhabitant of the district is 39.43 square meters to one. The level of development on the territory of the district is 40.72%, which corresponds to a value of 30.86 square kilometers. According to the building data, the population density is 11,699 people per square kilometer (~12 people per square meter). On the territory of the district there are two parks – named after Saken Seifullin with an area of 9.5 hectares and "Children's" with an area of 3 hectares, as well as the Baum grove. Initially, the Baum grove had an area of 150 hectares, but due to the presence of illegal logging with subsequent development, the territory today is 137.7 hectares. According to the temperature map digitized with subsequent analysis, the Baum grove is a zone that has a significant impact on reducing the temperature regime of nearby territories, which manifests itself in an average temperature twice lower in the grove compared to the surrounding development area. The main zone of thermal islands of this district is located on the border with Talgar district of Almaty region. The first thermal island with an area of more than 100 hectares is located at the intersection of the Kuldzhinsky tract and Bukhtarminskaya Street and where the construction of residential complexes "Altyn City" and "Nomad City" is potentially planned. To date, the territory adjacent to these residential complexes is covered with arable land and pastures, which in the future suggests that these plots can be implemented taking into account the design of green areas with an abundance of plantings to regulate the temperature regime of the territory, because according to the automated information system of the state land cadastre, it is planned to be issued for housing construction. The main thermal island of the Nauryzbay district is the international airport of Almaty, or rather the territory occupied by the runway and adjacent zones with an area of about 600 hectares. In addition to the above, the artificial increase in temperatures is facilitated by the presence of massive buildings of the logistics building along Zakarpatskaya Street. Statistics show that theoretically it is possible to move the new building of the Almaty International Airport outside the city territory, which is a common practice in developed countries. This transfer will lower the temperature regime of the Turksib district, and will also allow allocating a massive territory for other purposes. The case of the presence of a thermal island on the territory of Almaty International Airport is also supported by the presence of a thermal island on the territory of Boraldai airport, located on the territory of the Boraldai urban-type settlement of the Ili district of Almaty region and bordering the Alatau district next to the area of the archaeological park "Boraldai Saka Mounds" with an area of more than 400 hectares, previously designated as thermal island.

Zhetysu district is located between Alatau and Turksib with an area of 39.6 square kilometers. The population of the district is 284,607 people with a settlement density of 7,225 people per square kilometer. The level of green space coverage is equal to 20.65%, which is equivalent to an area of 8.17 square kilometers. The ratio of green spaces per person is 28.73 square meters, which corresponds to the average urban value. The built-up area of the district is 58%, which is equal to an area of 22.96 square kilometers. According to these data, the popula-

tion density is one and a half times higher than the standard, taking into account the entire territory and corresponds to 12,395 people per square kilometer (~12 people per square meter). On the territory of the district there is one park – Gulder with an area of slightly less than 12 hectares, taking into account the presence of the district akimat and the public service center on the territory. Next to this park there is one of the thermal islands of the district with a size of about 70 hectares and this is due to the abandoned state of the territory. In the future, this zone could become a point of attraction, because when organizing this territory, it is possible to connect it with the existing Gulder Park through the Big Almaty Canal named after Dinmukhamed Kunayev, which in turn will contribute to the regulation of the temperature regime of nearby areas. In the immediate vicinity there are warehouse, utility and production buildings – buildings with sloping roofs on an area of more than 40 hectares are the point of formation of a thermal island. The railway line leading from the Almaty-2 railway station ends on the territory of these buildings, which confirms the actual purpose of the territory. As statistics show, most of the thermal islands in the Zhetysu district, as well as on the territory of the entire city, are formed due to the voluminous storage areas and production sectors focused on the presence of a large area with a sloping roof.

To date, it is widely used to cover the roofs of buildings with reflective coatings, such as white silicone paint, which can reduce the temperature heating of buildings. The zones of the thermal islands of Almaty are heated to a temperature of 75 degrees Celsius. Such a maneuver will allow you to reduce the temperature by an average of 40%, taking into account the application of only one layer, and with the subsequent re-equipment of the roof with green spaces, there is a chance to give a balance to the temperature regime, which will allow you to abandon excessive use of air conditioning systems with a warm period, because these systems also expose the city to artificial heating, based on the processes of cooling the interior and heat output to the outside. In addition to painting the roofs of buildings with reflective white silicone paint, a method of painting the roadway is used, because asphalt contributes to an artificial increase in temperature during absorption by one and a half times. Additionally, the modern organization of cities implies the design of various types of buildings with the laying of elements of facades of light tones in the project with the addition of landscaping elements on balconies and roofs of buildings. One of the basic tools for lowering the temperature is water. Water sources (riverbeds, channels, etc.) allow you to balance temperature regimes within urban space. Almaty has a ditch system, which needs inventory with subsequent modernization according to the requests of the city, because there are difficulties in consistent development due to the peculiarities of the local terrain. In addition, there are mountain rivers (Shybynsai, Glubokaya Schel, Abylgazy, Zharbulak, Bedelbai, Terisbulak, Ermensai, Berkara, Kerenkulak, Esentai, Bolshaya Almatinka, Kargalinka, Oizhailau, etc.), which mainly have a south-north direction with movement from the mountain slopes through most of the city. Modern foreign examples are manifested in the return of water bodies that previously flowed in sewers under the highway, but due to deimmobilization, decisions were made to break up with the creation of landscape parks, which allowed to reduce the surface temperature by an average of 5 degrees. The revision of the approach to these water bodies can also make it possible to form zones of attraction with a comfortable temperature regime, which today have become the embankment by the Esentai River and the walking area "Terrenkur" on the Malaya Almatinka River. Do not forget about the natural possibilities of temperature balancing, since today the society offers a number of "innovative" methods in their simplicity. The city of Almaty is similar in its relief to the city of Stuttgart, which is also located in a hollow and surrounded by mountain ranges. Stuttgart is the center of the automotive industry (similar to the presence of a coal-fired CHP-2 in Almaty) and, like many European cities, has dense buildings. Awareness of the need to organize a wind rose system with permanent circulation forced city planners to organize a system of "green corridors" that allow natural air flows to circulate through urban space. Historically, the city planners of Almaty took into account the existing wind rose when designing, and this is manifested in the organization of the so-called "digital" microdistricts of the city, but today, due to point development, new difficulties have arisen with the organization of air circulation and compliance with the norms of the wind rose. Most efforts to cool urban communities are based on bringing vegetation back into the urban environment to mimic the natural cooling, shading and reflection techniques. For example, some cities are adding more parks, green spaces and tree-lined streets to their development projects. Communities are also increasingly adopting "green" or eco-architecture and incorporating elements such as green

roofs, which reduce indoor and outdoor temperatures, into building designs.

Conclusion

Summarizing the above in the study, it is worth noting the need to increase the number of green zones in the city of Almaty, taking into account the polycentricity factor. The presence of 8 districts in the city of Almaty implies parallel development in the field of creating green zones and working out the territories of heat islands, which, due to anthropogenic impact, increase temperature indicators and directly affect the quality of life of residents of the city. The green zones cited in the study demonstrate a lack of access to them, which leads residents of Almaty to travel outside their place of residence and thereby increases the transport load on the city, characterized by emissions of harmful substances, which, together with accompanying factors, worsen the quality of life of citizens. In parallel with the increase in green zones, there is a need to equalize the temperature regime of urban space with the isolation of thermal islands due to the modernization of these spaces to meet the modern requirements of the city. The use of modern foreign methods of cooling the urban area can allow the city to get rid of massive thermal islands, which will balance the temperature regime and improve the quality of life in the city of Almaty. The study showed that, along with the peculiarities of the development of individual blocks and microdistricts, it is necessary to take into account the heterogeneity of the territory on the scale of the entire city or its large districts. This makes it possible to better understand and predict the spatial picture of the heat island in the tasks of weather forecasting, thermal comfort assessment and urban planning.

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