Exploring New Development Prospects: Expanding of Bishkek City Territory in the Issyk-Ata Fault Zone

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Abstract
The industrial revolution and urbanization created conditions for improvement as people began moving from their villages to industrial areas. These migrations, combined with natural population growth, gave rise to the emergence of large cities around the world. Back in 1965, Kingsley Davis predicted that more than half of the world's population would eventually reside in urban areas. Living in cities offers several advantages; for instance, people have greater opportunities to improve their lives, including access to better jobs and higher incomes, quality education for their children, superior healthcare, diverse entertainment options, sports, and recreation. In other words, urban life is generally more conducive to leading a comfortable and healthy life. The 21st century is often regarded as the century of urban development, with the majority of the global population now living in urban environments. According to the United Nations, more than 50% of the world's population currently resides in urban areas, and by 2030, this figure is expected to rise to 60%. This article analyzes the development potential of the Bishkek area located near the Issyk-Ata fault. Geoinformation technologies and remote sensing materials are used for the analysis of seismic hazard and expanding of the Bishkek city territory. The study explores the possibilities of utilizing this fault zone as an additional area for urban infrastructure, capable of providing new spaces for the city's expansion and development.

Keywords: GIS, Earthquakes, Issyk-Ata Fault, Urban Planning, Urban Expansion

1. Introduction

Bishkek, the capital of the Kyrgyz Republic, has a population of over one million people. It is located in the central part of the Chuy Depression, a region with a complex tectonic environment, situated in the north of Kyrgyz mountain range at altitudes ranging from 500 to 1 100 meters above sea level. This area is one of the most seismically active regions in the country. As the largest city in the country, Bishkek is experiencing intensive development, including residential, cultural, public, and industrial construction, accompanied by a significant influx of population. The shortage of available land has led to the development of previously unsuitable areas due to natural conditions, such as the expansion of the city boundaries toward the south. In this direction, the Chon-Aryk and Pospeldek uplifts adjoin the city's territory. At the northern foothills of these uplifts, one of the segments of the Issyk-Ata marginal fault can be observed (Figure 1) [1] and [2]. The territory of Bishkek has accumulative type of relief, which is subdivided into two subtypes in a sub latitudinal direction. South of the city's central part, the alluvial-proluvial subtype of relief predominates. It is characterized by the gently undulating surfaces of foothill valleys and aprons of alluvial fans dating back to the Lower Quaternary period. This subtype is further dissected by the terraces of the Ala-Archa and Alamedin rivers. North of the central part of the city, an alluvial subtype of relief dominates. This subtype features flat terrace complexes that have been modified through urban planning within the city limits [3].

2. Research Method and Materials

To analyze the expansion of Bishkek, satellite images from the US Geological Survey (USGS) archive, accessible through the EarthExplorer portal (https://earthexplorer.usgs.gov/), were utilized.

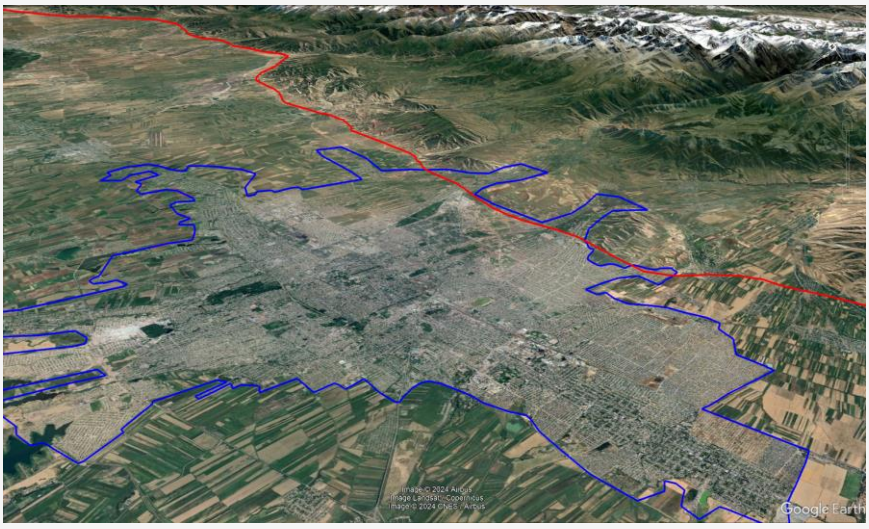

Figure 1: Bishkek city and Pre-Kyrgyz trough of the Kyrgyz mountain range

The primary source of data consisted of Landsat images spanning the period from 2000 to 2021. Landsat imagery was selected due to its extensive coverage, consistent acquisition, and long-term availability. The acquired images underwent standard pre-processing procedures, including geometric correction, radiometric correction, and cloud removal. To identify built-up areas, an automated classification of satellite images was performed using the supervised classification method. Two classes, "built-up area" and "unbuilt-up area," were defined. The model was trained using manually delineated polygons representing built-up and unbuilt-up areas from images captured during different time periods.

To evaluate changes in the extent of built-up areas over the years, a comparative analysis of the classified images was conducted. This approach involved comparing classification results for each year, which enabled the identification of increases in built-up areas. The data on built-up area sizes were consolidated into a single time series, allowing for the analysis of urban expansion dynamics and the identification of growth trends, particularly in the southern direction toward the Issyk-Ata fault. In addition, the change in the distance between built-up areas and active tectonic faults was calculated, providing critical insights for assessing seismic risks. This methodology enabled a detailed assessment of Bishkek's urban expansion over the period from 2000 to 2021, highlighting key trends and areas exposed to seismic hazards. The findings can serve as a foundation for future urban development planning and the formulation of strategies to mitigate seismic risks.

3. Study Area

The central part of the Chuy Depression, where the city of Bishkek is situated, is structurally characterized as an asymmetrical megasyncline of sublatitudinal strike. The modern boundaries of the city are located within the southern part of the Chuy syneclise, known as the Pre-Kyrgyz trough. This trough is filled with Paleogene-Neogene continental deposits, with a thickness of up to 4.5-5.0 km, overlying the eroded surface of the Paleozoic basement (Figure 2) [4]. The Pre-Kyrgyz trough is divided into two structural blocks: northeastern and southwestern. The Issyk-Ata fault is situated within the northeastern block. This fault intersects the synclinal structure of the main trough at an acute angle and is distinctly expressed in the relief, marking the boundary between the flat part of the Chuy Depression and the foothill zone [5].

The study of historical and archival records and paleoseismological dislocation analysis has allowed researchers to identify and document previously unknown historical and ancient seismic events. These findings play a crucial role in assessing the region's seismic hazard. A long-term dataset (spanning hundreds to thousands of years) detailing the coordinates of epicenters, the timing of seismic events, and the estimated energy released are essential for accurate hazard assessment. For example, archeoseismological studies at the Novopokrovsk settlement, located on the eastern outskirts of Bishkek, revealed traces of building destruction attributed to a seismic event with an intensity of 8–9 that occurred at the end of the 12th century AD [6]. Similarly, evidence of the 1475 Balasagun earthquake, with intensity of 8-9, was found.

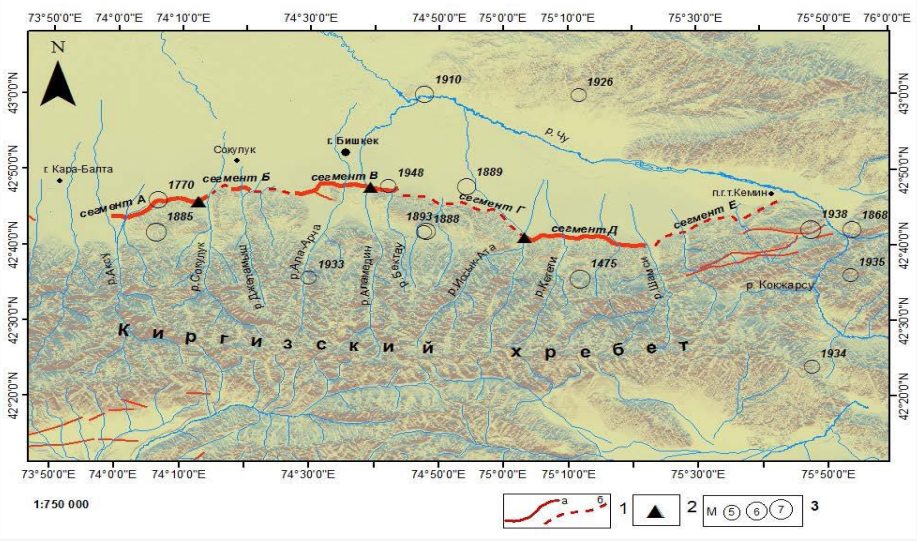

Figure 2: Segmentation of the Issyk-Ata fault - southern part of the Chuy depression. 1 - faults (a - expressed in the relief as a ledge, b - assumed and without a ledge); 2 - location of trenches; 3 - strong earthquake epicentres [1]

This earthquake led to the destruction of Balasagun, one of the capitals of the Karakhanid state (modern-day Burana settlement, 8 km from Tokmak, in the eastern part of the Chuy Depression). The epicenter of this event is believed to have been located on the northern slope of the Kyrgyz Range in the Shamsi River basin [7].

Fragmentary data also suggest a 1770 earthquake near the modern village of Belovodskoye, where a large lake was reportedly filled as a result of the event. The epicenter of this earthquake approximately coincides with that of the 1885 Belovodskoye earthquake [6]. In addition to the so-called "historical" earthquakes, evidence of more ancient seismic events, such as paleoseismic dislocations, has been identified in the territory of the Chui Depression. The highest concentration of these dislocations is found in the southern part of the region. Seismic dislocations along the southern margin of the Chuy Depression are organized into zones, each comprising several areas of dislocation accumulation. These areas are either associated with fault lines or situated within tectonic blocks bounded by faults [6][7][8][9] and [10]. Opposite the city of Bishkek, the Chonkurchak area of seismic dislocations has been identified. The formation of this area is linked to seismic events that occurred approximately 5180±70 years ago and 2450 years ago. To the east of Bishkek's boundary lies the Kyzylsuu-Alamedin area, characterized by a series of faults, including seismogravitational formations in the upper part of the Alamedin River valley [6] and [10]. The Issyk-Ata marginal fault, extending up to 150 km in length, has long been a focus of scientific study, particularly in recent years. This fault is a multi-segment structure comprising six distinct segments, each of which has the potential to generate an earthquake with an intensity of up to intensity of 7–8 (Figure 1) [1]. In three of these segments, trenches have been excavated and documented using the trenching method, revealing between one and four faults or thrusts, which serve as evidence of past major seismic events. In the segment located along the southern border of the city of Bishkek (the fault segment extends for approximately 10 km; Figure 1), evidence of two significant seismic events was identified. The first event occurred between 2830 ± 50 years and 5150 years ago, with datings of 5130 ± 50 and 5250 ± 60 years. The second event occurred between 1850 ± 40 years and 2830 ± 50 years ago [7].

4. Results and discussion

To ensure the reliability and seismic resistance of structures during the planning and development of areas within Bishkek and those adjacent to the Issyk-Ata fault, 22 construction rules (SP) and construction norms (SN) were developed in 2018 under the order of the State Agency for Architecture, Construction and Communal Services (Gosstroy) of the Kyrgyz Republic. These documents are developed by primary contributors included the State Institute of Earthquake Resistant Construction and Engineering Design of Gosstroy, the Institute of Seismology of the National Academy of Sciences of Kyrgyz Republic (NAS KR), JSC “Kazakh State Research and Design Institute”, OJSC “PROMPROEKT”, and Razzakov Kyrgyz State Technical University.

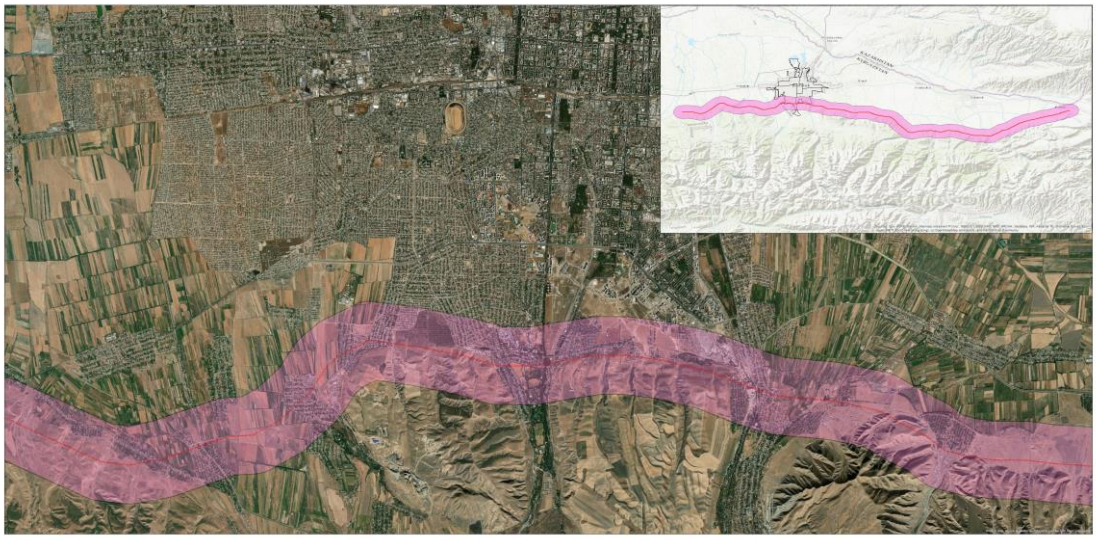

Figure 3: Buffer zone of the Issyk-Ata fault

One of the key outputs was the updated Building Code of the Kyrgyz Republic SNiP 31-02:2018 "Design and Development of the Territories of the Bishkek City and Villages Adjacent to the Issyk-Ata Fault", which was officially enacted on March 1, 2019. This Buidling Code reduced the Issyk-Ata fault zone's influence area (Figure 3) by almost half while simultaneously introducing Peak Ground Accelerations (PGA) and stricter seismic resistance requirements in line with new construction norms [11].

According to the updated SNiP, the fault influence zone is defined as extending 3 km in total: 1.5 km to the north and 1.5 km to the south of the fault. Within this zone, five subzones have been delineated, each with specific building restrictions. For example, in the first zone extending 250 meters to the north and 100 meters to the south of the fault construction is strictly prohibited. The second zone extends an additional 250 meters (previously 300 meters) from the fault line. What was formerly categorized as an intensity of 9 seismic hazard zone in the third subzone has now been reclassified as an intensity of 8 zone. This reclassification has resulted in the release of approximately 3,000 hectares of land in the southern part of the city for potential construction.

In the newly designated 8-point third zone, which extends 700 meters, construction of buildings up to 12 stories or 42 meters in height is now permitted. Additionally, certain areas of the private sector, which were previously included in the fault zone where construction was prohibited, are no longer subject to these restrictions.

The Issyk-Ata fault zone is undoubtedly the most seismically hazardous area within the city [12]. However, if buildings are constructed in strict compliance with Building Codes, their seismic resistance and safety primarily depend on the quality of construction practices. Under these conditions, the potential danger posed by earthquakes can be significantly mitigated [13] and [14].

Currently, seismological experts have permitted construction within the fault zone. Nevertheless, they strongly recommend adhering to established construction principles and guidelines to ensure the safety and resilience of structures.

5. Conclusion

Urbanization has the potential to drive economic growth, create new employment opportunities, and enhance access to education, healthcare, and other essential services. Cities often serve as hubs of innovation and development, attracting skilled and enterprising individuals. However, urban expansion also brings challenges, including environmental pollution, housing shortages, and the strain on infrastructure and public services. These issues can exacerbate social inequality and reduce the overall quality of life. Over the past three decades, the city of Bishkek has experienced significant territorial growth, particularly in its southern areas. This expansion has predominantly occurred in regions adjacent to the Issyk-Ata fault, an area characterized by heightened seismic activity. The primary driver of this growth has been the scarcity of available land in the central and northern parts of the city.

However, the southward expansion has heightened seismic risks, as the Issyk-Ata fault is a complex tectonic structure capable of generating powerful earthquakes. Many newly developed areas now fall within the fault zone, necessitating a specialized approach to construction that accounts for potential seismic threats. Historical and paleoseismological analyses confirm the region's high seismic activity, underscoring the importance of adhering to stringent seismic building standards. The introduction of updated building codes in 2019, which imposed stricter requirements for seismic resistance and revised the boundaries of the fault zone, has significantly influenced urban development in southern Bishkek. These measures have enabled the safe development of additional land for construction while maintaining high safety standards.

The findings of this study highlight that the new standards have improved urban infrastructure planning. Nonetheless, certain areas remain under-researched, requiring further study to enhance safety measures. In regions of high seismic activity, particularly those near active faults, strict compliance with construction quality standards is essential. This study reaffirms that seismic resistance is a critical factor in minimizing risks to the population during major earthquakes.

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