RS-GIS Monitoring of Afghanistan-Kazakhstan-Pakistan Cities Unsustainable Development

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Abstract: Afghanistan-Kazakhstan-Pakistan cities have similar unsustainable development with intensive urbanization, overexploitation of natural resources, groundwater uncontrolled extractions, intensive construction activities by destroying landscapes. Several cities from these countries are under comparison investigations: currently Kabul from Afghanistan, Almaty from Kazakhstan, and next target to add Pakistan cities. Kabul and Almaty are in the similar locations: valley area, surrounded by the mountains. Both cities have poorly managed housing construction in the very densely populated areas, which are under high risks of the big earthquake activities. Both cities destroy the surrounding mountains slope areas with elimination of the trees? Destroying the natural water movement water, watershed systems with devasting expansion of dangerous building constructions in the very dense overpopulated areas. Soil erosion, landslides in the mountainous areas are getting more intensive in both cities. Rapid cities populations increase water consumption, including groundwater extraction, which induce the ground subsidence. Kabul city was investigated by the spatial-temporal evolution of ground deformation phenomena and its main governing processes by using C-Band Sentinel-1 derived Interferometric Synthetic Aperture Radar (InSAR) time-series from both ascending and descending orbits to extract the two-dimensional (2D) surface displacement field. Four subsidence bowls were distinguished with highly variable spatial extents and deformation magnitudes over four separate aquifer basins, with the maximum value of −5.3 cm/year observed in the Upper Kabul aquifer basin, which potentially caused the land subsidence in Kabul and could be intensified during the earthquakes. The Kabul city research methods are under adaptation for Almaty city ground subsidence investigation. The RS-GIS based FEMA HAZUS tool for earthquake, flood events with financial estimations, construction damage impacts, planning scenarios programs are under our learning activities for adaptation also.

Keywords: geographic information system (GIS); remote sensing (RS).

1 Introduction

The real-time analysis and forecasting of weather, floods, and agricultural crops lost, or damaged owing to floods and rainfall are some typical uses for remote sensing and Geographic Information System (GIS) technology. Remote sensing (RS) and GIS technologies are invaluable for real-time weather forecasting, flood analysis, and assessing the impact on agriculture due to adverse weather events. In countries like Afghanistan, Pakistan, and Kazakhstan (Figures 1–3), which face challenges in sustainable urban development, the integration of remote sensing with GIS (RS-GIS) proves crucial. These rapidly urbanizing nations often witness unsustainable growth patterns, including haphazard urban planning, decaying infrastructure, and worsening environmental degradation (Gauhar et al. 2022) and (Herold et al. 2008).

Figure 1. Almaty (Kazakhstan) city view – Source: Google Images.

RS-GIS facilitates the monitoring of urban expansion, enabling policymakers, urban planners, and researchers to observe and analyze changes in land use, infrastructure, and environmental conditions over time. It combines aerial photos, satellite imagery, and geospatial data to provide vital insights into demographic shifts, urbanization trends, and their ecological impacts. RS-GIS is essential in disaster risk management in these regions, which are prone to earthquakes, landslides, and floods. By analyzing spatial data, identifying at-risk areas, and implementing risk reduction measures, authorities can reduce potential losses and enhance urban resilience.

Figure 2. Hometown a view of Mari Abad, City Quetta – Pakistan; Source: Google Images.

Role of RS-GIS in Monitoring Urban Development, RS, remote sensing involves acquiring data about the Earth's surface through satellite or aerial and environmental conditions (Jensen 2007) and (Li and Weng 2005). High-resolution satellite images and aerial photographs are invaluable for detecting and analysing urban growth patterns, infrastructure development. RS and GIS are pivotal in urban monitoring, providing detailed data about the Earth's surface through satellites and aerial images.

Figure 3. Kabul – Afghanistan city view – Source: Google Images.

Particularly in Afghanistan, Pakistan, and Kazakhstan, RS-GIS technologies are instrumental in tracking rapid urban growth, often marked by unregulated expansion due to socio-economic and political dynamics. These regions, with unique challenges like recovery from conflicts or rapid resource-driven urbanization, benefit significantly Pakistani cities to understand urban dynamics and their unsustainable development patterns. For example, RS and GIS in Pakistani cities, the integration of RS and GIS is critical for assessing urban dynamics and unsustainable development patterns. Also, as populations grow, cities like Kabul, Almaty, and Quetta face increasing demands for groundwater to support domestic, agricultural, and municipal needs. These rapidly expanding urban areas, which are among the most water-stressed in the world, are experiencing significant Drops in water levels due to overexploitation of aquifers. RS-GIS data supports strategic urban planning, helping to reduce ecological impacts and promote sustainable development practices. Such data-driven insights are essential for informed decision-making and effective urban management, their findings indicated a decline in green areas due to construction activities, stressing the importance of sustainable urban development practices. Challenges and Limitations, despite the advantages of RS-GIS technologies, several challenges and limitations need to be addressed (Longley et al. 2015) and (Murzagalieva et al. 2016). Up-to-date satellite imagery and spatial data can be a challenge, particularly in conflict-affected regions like Afghanistan, Pakistan.

2 Research areas

The research paper focuses on the use of RS and GIS to monitor and analyse the unsustainable development patterns in the cities of Afghanistan, Kazakhstan, and Pakistan. These countries, despite their geographical and cultural diversity, share common challenges related to urbanization and environmental sustainability.

2.1 Urban Sprawl and Land Use Changes

The growth of urban areas, alterations in land use patterns, and their effects on natural resources and agricultural land. Urban sprawl transforms green spaces into built environments, impacting ecosystems. By utilizing satellite imagery, the study identifies trends in urban expansion, highlighting critical areas and forecasting future changes. Urban sprawl is a widespread issue, especially prevalent in less developed countries where people increasingly move to mega cities and large urban centres. This trend has drawn the attention of experts in urban geography, environmental studies, and city and regional planning.

2.2 Environmental Degradation

Assessing the extent of environmental degradation due to rapid urbanization, including deforestation, loss of biodiversity, and pollution in targeted cities by integrating RS and GIS data, the study quantifies the environmental impact of urban development and identifies critical areas that require immediate intervention to prevent further degradation.

2.3 Water Resources Management

Analysing the impact of urban development on water resources, including issues related to water scarcity, quality, and distribution (Figure 4).

2.4 Socio-Economic Impacts

The research identifies socio-economic challenges such as housing shortages, infrastructure strain, and displacement of local communities. These issues underscore the importance of inclusive and sustainable urban planning and challenges faced by urban populations, such as increased living costs, inadequate housing, and the pressure on public services and infrastructure.

2.5 Policy and Governance

Effective policies and governance structures are essential for managing urban growth and promoting sustainable development current policies and governance structures are inadequate in addressing the challenges of urbanization.

3 Research methodology

Sentinel-1, a space mission of the European Space Agency (ESA), has resulted in a paradigm shift in the field of InSAR: configurations of the constellation, small perpendicular and temporal baselines, and free data availability allow accumulation of a long-term archive of globally consistent data. A stack of 106 ascending and 101 descending Sentinel-1 Single Look Complex (SLC) products obtained in Interferometric Wide Swath (IWS) mode spanning the period from October 2014 to May 2019 were utilized in this study. SAR data parameters used for this study are described in Table 1, while the spatial and temporal baselines of the generated interferograms are shown in Figure 5 and Figure 6.

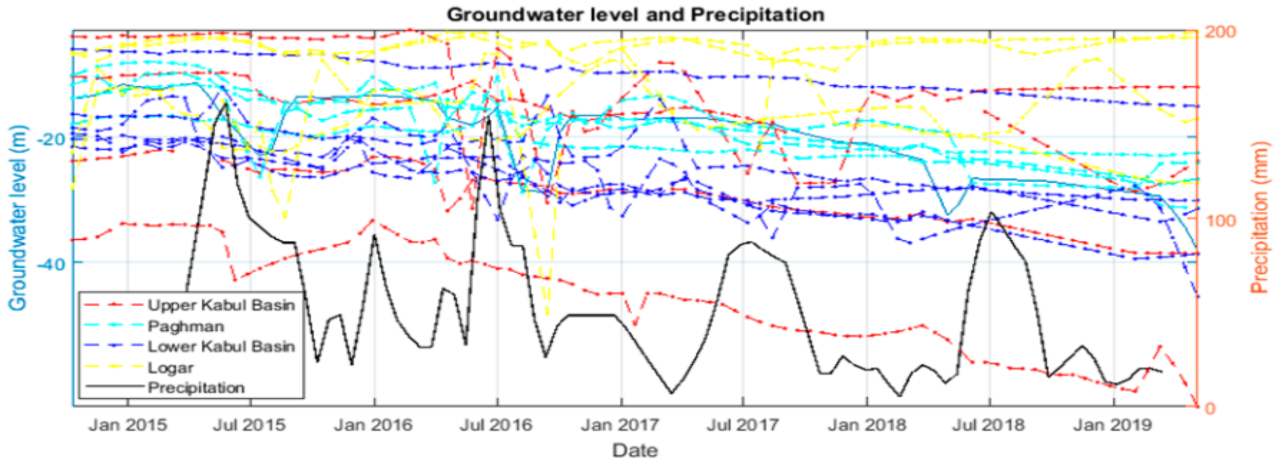

Figure 4. Observed groundwater drawdown in fourteen wells across the network. Precipitation time-series is retrieved from CRU TS 4.03 (Meldebekova et al. 2020).

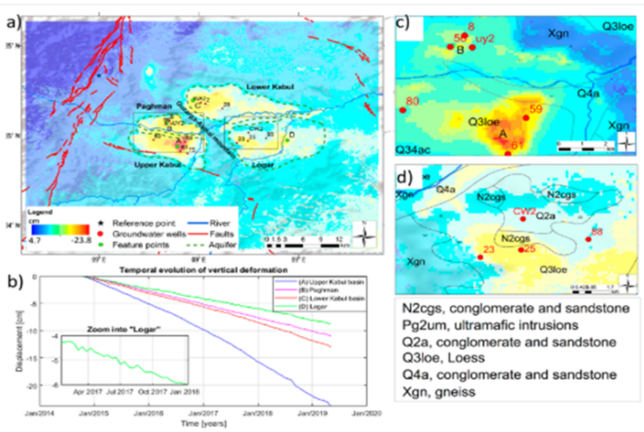

Figure 5. Spatial and temporal characteristics of subsidence: (a) Spatial distribution of subsidence bowls, displayed as cumulative vertical displacement (unit: cm). Red solid lines are mapped faults. (b) Temporal evolution of maximum vertical deformation at each of the four-subsiding bowls. The inset plot illustrates small-scale deformation variations in Logar. (c) Magnified view of the Paghman riverbanks (Meldebekova et al. 2020).

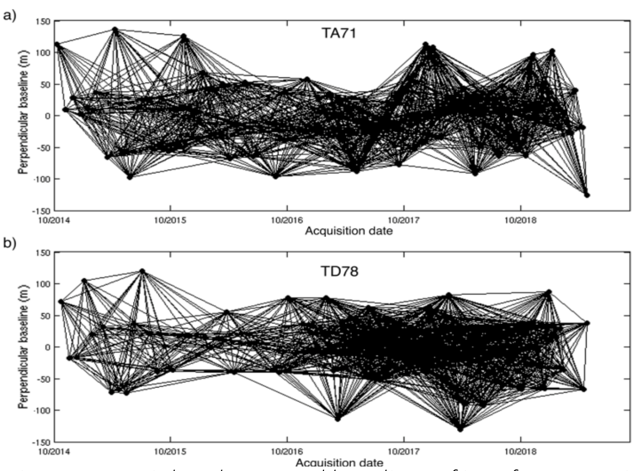

Figure 6. Spatial and temporal baselines of interferograms in (a) ascending TA71 and (b) descending TD78 tracks (Meldebekova et al. 2020).

Table 1. Summary of Synthetic Aperture Radar (SAR) Data used.

Satellite	S-1	S-1
Orbit	Asc	Desc
Path	71	78
Mean Angle of Incidence	39.9040	41.6189
Heading Angle	-13.018	-193.011
Number of Scenes	106	101
Number of Interferograms	1822	1825

Cross-correlation of datasets allows computing the time lag between the cause-effect events using the following equation (1) (Meldebekova et al. 2020):

$$\Delta t = \frac{\Delta\phi * T}{2\pi}. \quad (1)$$

Data preprocessing includes the following steps: (1) ensuring that irregularly spaced datasets have a uniform time increment by interpolating missing gaps between the consecutive InSAR acquisition dates; (2) interpolating groundwater level time-series to a more temporally dense InSAR time-series; and (3) removing the trend from InSAR-derived results.

4 Discussion and conclusion

The integration of RS and GIS has provided a robust framework to monitor unsustainable urban development and facilitate sustainable growth strategies in cities across Afghanistan, Kazakhstan, and Pakistan. This study utilized multi-geometry Sentinel-1 InSAR data from 2014–2019 to analyse ground subsidence in Kabul caused by groundwater overexploitation, revealing significant vertical displacements and localized horizontal shifts across various aquifer basins. Key findings indicate substantial subsidence, particularly in areas with soft clay sediments, closely correlating with the decreases in groundwater levels. The study underscores the anthropogenic origins of these deformations, highlighting broader urban challenges such as rapid expansion at the cost of natural spaces and agricultural lands, escalating environmental issues, and the intensification of water scarcity. It stresses the urgent need for collaborative efforts among policymakers, urban planners, and stakeholders to embrace comprehensive policy reforms and innovative governance models. These efforts are critical to mitigate the impacts of urban sprawl, ensure water sustainability, and achieve socio-economic stability, ultimately guiding cities towards resilient and sustainable development.

5 References

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