Urban Expansion and Land Utilization in Post-Conflict Capitals: Kabul and Baghdad

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Abstract

Urban growth in post-conflict contexts reflects the intersection of reconstruction priorities, population return, and governance capacity. The cities of Kabul, Afghanistan, and Baghdad, Iraq, both capitals shaped by decades of war and recovery, offer critical examples of how state-led and informal development dynamics interact in post-conflict urban environments. This study compares their urban growth trajectories and land utilization patterns over a period (2016–2024), corresponding to the decade following the withdrawal of international military involvement and the onset of national-led recovery efforts. The research aims to understand how land-use policies, zoning regulations, and reconstruction initiatives have influenced the spatial organization and density of urban expansion in both cities. The analysis employs harmonized Sentinel-2 satellite imagery from 2016 and 2024 to derive land-use classifications, supported by spectral indices including the Normalized Difference Built-up Index (NDBI) and the Normalized Difference Vegetation Index (NDVI). A Random Forest classifier is used to delineate built-up, vegetation, and bare-soil classes, with Sentinel-1 Synthetic Aperture Radar (SAR) data integrated to improve built-up area detection in cloud-affected or heterogeneous environments. Urban change is quantified using a ratio-based framework, including the Built-to-Green ratio and the Bare-to-Built ratio, to assess relative shifts in land-use composition and urban intensity over time. Results of a ratio-based analysis reveal that Baghdad's post-conflict recovery between 2016 and 2024 is characterized by urban consolidation and a decline in transitional land, whereas Kabul's recovery is marked by fragmented growth, persistent bare surfaces, and increasing environmental vulnerability, highlighting divergent pathways of urban resilience and sustainability.

Keywords: Random forest, Spatial ratio, land use, Urban expansion

Übersetzung

Das städtische Wachstum in Postkonfliktsituationen spiegelt das Zusammenspiel von Wiederaufbauprioritäten, Rückkehr der Bevölkerung und Regierungsfähigkeit wider. Die Städte Kabul in Afghanistan und Bagdad im Irak, beides Hauptstädte, die von Jahrzehnten des Krieges und des Wiederaufbaus geprägt sind, bieten wichtige Beispiele dafür, wie staatlich gelenkte und informelle Entwicklungsdynamiken in städtischen Umgebungen nach Konflikten zusammenwirken. Diese Studie vergleicht ihre städtischen Wachstumskurven und Landnutzungsmuster über einen Zeitraum (2016–2024), der dem Jahrzehnt nach dem Abzug der internationalen Streitkräfte und dem Beginn nationaler Wiederaufbaumaßnahmen entspricht. Die Forschung zielt darauf ab, zu verstehen, wie Landnutzungsrichtlinien, Bebauungsvorschriften und Wiederaufbaumaßnahmen die räumliche Organisation und Dichte der städtischen Expansion in beiden Städten beeinflusst haben. Die Analyse verwendet harmonisierte Sentinel-2-Satellitenbilder aus den Jahren 2016 und 2024, um Landnutzungsklassifikationen abzuleiten, unterstützt durch Spektralindizes wie den Normalized Difference Built-up Index (NDBI) und den Normalized Difference Vegetation Index (NDVI). Ein Random-Forest-Klassifikator wird verwendet, um die Klassen „bebaut", „Vegetation" und „unbebauter Boden" abzugrenzen, wobei Sentinel-1-Synthetic-Aperture-Radar-Daten (SAR) integriert werden, um die Erkennung bebauter Flächen in wolkenverhangenen oder heterogenen Umgebungen zu verbessern. Der städtische Wandel wird anhand eines verhältnismäßigen Rahmens quantifiziert, der das Verhältnis von bebauter zu begrünter Fläche und das Verhältnis von unbebauter zu bebauter Fläche umfasst, um relative Verschiebungen in der Landnutzungszusammensetzung und der städtischen Intensität zu bewerten. Ein Random-Forest-Klassifikator wird verwendet, um bebaute Flächen, Vegetation und kahle Böden abzugrenzen, wobei Sentinel-1-Synthetic-Aperture-Radar-Daten (SAR) integriert werden, um die Erkennung bebauter Flächen in wolkenverhangenen oder heterogenen Umgebungen zu verbessern. Der städtische Wandel wird anhand eines auf Verhältnissen basierenden Rahmens quantifiziert, darunter das Verhältnis von bebauter zu begrünter Fläche und das Verhältnis von unbebauter zu bebauter Fläche, um relative Veränderungen in der Landnutzungszusammensetzung und der städtischen Intensität im Laufe der Zeit zu bewerten. Die Ergebnisse einer auf Verhältnissen basierenden Analyse zeigen, dass die Erholung Bagdads nach dem Konflikt zwischen 2016 und 2024 durch eine städtische Konsolidierung und einen Rückgang der Übergangsflächen gekennzeichnet ist, während die Erholung Kabuls durch fragmentiertes Wachstum, anhaltende kahle Flächen und zunehmende Umweltanfälligkeit geprägt ist, was die unterschiedlichen Wege der städtischen Resilienz und Nachhaltigkeit verdeutlicht.

Schlüsselwörter: Random Forest, Räumliches Verhältnis, Landnutzung, Städtische Expansion

1 INTRODUCTION

The extensive damage in urban infrastructure is one of the significant impacts of the war. Several countries affected by war, e.g. Syrian [1] and Iraq [2] had hugely affected by losing the building and urban area of the city. In the post-conflict condition, Baghdad and Kabul are samples of the two cities which affected by conflict[3]. After 2001, all major cities in Afghanistan experienced significant population growth, with Kabul has the highest pressure of urbanization[3]. The rapid population growth becomes the challenges for the government to build the regulation for urban planning and management for land utilization.

Thus, the importance of reconstruction study is significance as the economic revitalization to apply strategic modernization and reviving the markets to gain economic stabilization. The reconstruction study is important to restore the identity of the country or the city.

Earth observation (EO), e.g. remote sensing is one of the efficient technologies that can be used to monitor the city development because of its advantage to cover the areas which are inaccessible for ground survey due to difficult terrain or conflict situation[3]. Current availability of global satellite mission such as Sentinel-1, Sentinel-2, and Landsat 8 – 9 enabled consistent and multitemporal dataset to monitor the land use and land cover include the changes[4][5]. Sentinel-2 satellite are complemented with multi spectral imaging (MSI) which contain 13 bands with range of spatial resolutions are vary from 10m to 60m[6][7]. The visible and the near-infrared (NIR) bands have 10m resolution, whereas the infrared bands have 20m of spatial resolution, and the other bands have 60m of spatial resolution[8].

Various tasks are carried out using remote sensing data to detect the land use changes, e.g. urban expansion detection through Indices-Based Built-Up Index (IBI) derived from Landsat 8 satellite imagery[9], urban land cover changes in Baghdad which derived from Landsat 8 affected by socioeconomic progress which pushed the urban border into the country side affecting the changes in the urban area, agriculture, barren, and water land [10], and detecting patterns growth in Kabul city utilizing high resolution earth observation data (aerial photograph) and IKONOS imagery utilizing spatial logistic regression modelling[3].

Various research conducted in land cover land use classification in Sentinel-2 images has positive impacts, specifically in monitoring of crops, forest, urban area, and water resources. The use of Sentinel-2 data produces high accuracies (more than 80%) with machine learning classifiers such as support vector machine (SVM) and random forest (RF)[8]. Related to the urban expansion in the post-conflict capitals, the development of the machine learning and the deep learning in the remote sensing data help to analyze the damage of the building which is great significance of monitoring war crimes and to do the damage assessment that destroy civilian infrastructure indiscriminately[11].

Several research studies have been conducted using remote sensing data that combine deep learning methods for post-conflict and during-conflict monitoring. For instance, a monitored conflict destruction in Syria by utilizing high-resolution satellite imagery and deep learning techniques employed a Convolutional Neural Network (CNN) for feature extraction, which was then combined with label augmentation and a two-stage classification process [1]. This process uses a random forest classifier to perform spatial and temporal smoothing. This methodology effectively exploits the underlying spatial and temporal structure of destruction to improve detection accuracy. Other research performed by [12] analyze the building damage detection from the Luojia3-01 satellite by applying automated deep learning techniques, complemented by estimation of multiple levels of damage categories. To enhance the detection accuracy, the author integrates multiscale features and cross-directional attention mechanisms. This research able to quantify the estimation of partial and completely destructed house and changes in agricultural land.

The combination of optical and SAR imagery also implemented to monitor the post-war. A research conducted to analyze the building damage estimation in Ukraine using Synthetic Aperture Radar image time series[13]. This research focus on training the machine learning model, e.g. random forest classifier in SAR image time series from Sentinel-1 to generate the probabilistic damage estimates at the building level, leveraging existing damage assessments and open building footprints. Other research conducted by [14] performed the significant change in the landscape of Eastern Ukraine, which affected the ecological and cultural aspects. This research integrates Sentinel-1 and Sentinel-2 surface reflectance, along with social media data such as Twitter and Flickr to assess the spatial variations in landscape suitability before and during war. The random forest machine learning approach was used along with the 2 sampling methods. The result identifies that although many landscapes remained unchanged, regions near the frontlines experienced increased vegetation due to the abandonment of land.

The benefit of the remote sensing utilization in post-war study is potential of monitoring war crimes, conduct large-scale war loss assessment, and provide preliminary reference for humanitarian and reconstruction planning. The automated detection of building deconstruction in conflict zones is crucial for human rights monitoring, humanitarian response, and academic research[15]. Through this research, we would like to analyze the urban expansion and land utilization change through the satellite imagery in Baghdad and Kabul within 2016 to 2024.

2 STUDY AREA AND METHODOLOGY

2.1 Study Area

The study compares two post-war capital cities, Kabul and Baghdad. Kabul is the capital and largest city of Afghanistan[16], located in the eastern part of the country within a high-altitude basin of the Hindu Kush mountains. The city lies at approximately 34.53° N; 69.17° E**.** Kabul, as the capital city of Afghanistan experienced rapid urbanization with very limited of the local authority to deal with this growth, led to unplanned urbanization and challenges for urban planning and management[3]. The rapid population growth driven by rural-to-urban migration and conflict-related displacement. As of recent estimates from statista, the population in Kabul is approximately 4.8 million inhabitants as per 2025[17]. The study covers the core urban area, characterized by dense residential, commercial, and administrative land use, and covers roughly 450–550 km², concentrated along the Kabul River and surrounding valleys.

Baghdad, the capital of Iraq, is in the central part of the country along the Tigris river on the Mesopotamian plain. This city is divided into two parts by Tigris river: Al-Karkh (the western part) and Al-Resafa (the eastern part)[4]. The city’s central coordinates are approximately 33.31° N, 44.36° E**.** Baghdad is Iraq’s primary political, economic, and cultural center and has undergone substantial urban expansion over recent decades. It is the most populated city in Iraq[12] [13], where the metropolitan population is estimated to be approximately 8–9 million inhabitants as of the early 2020s[18]. The core built-up city area, comprising continuous urban development on both sides of the Tigris River, spans approximately 700–800 km², representing the most densely urbanized portion of the city. Figure 1 below shows the location of the two case studies.

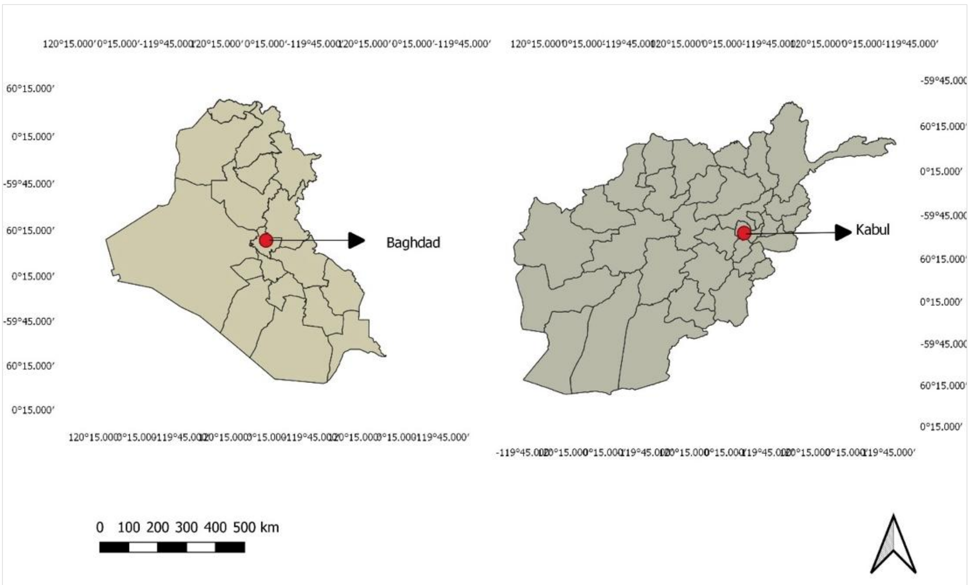

Figure 1 Geographical location of the cities Baghdad and Kabul

2.2 Methodology

This study utilizes Sentinel-2 and Sentinel-1 satellite data, accessed and processed within the Google Earth Engine (GEE, https://developers.google.com) platform to characterize land surface and urban features within the defined areas of interest. In this research, author utilize Sentinel imagery, e.g. Sentinel-2 and Sentinel-1. The Sentinel-2 imagery comprising of Sentinel-2A and Sentinel-2B which equipped with multispectral instrument (MSI)[20]. The Sentinel-2 products provide surface reflectance (SR) data, which valuable for earth surface analysis [21].

Sentinel-2 surface reflectance (S2 SR Harmonized) imagery used to derive optical and spectral indices. It is applied for investigation of vegetation dynamics using spectral indices [22] and land use land cover (LULC) analysis via artificial intelligence (AI) models [23]. Images acquired within the study period were filtered by the AOI and date range, and scenes with more than 80% cloud cover were excluded. Cloud and cirrus contamination were removed using the QA60 band. This correction aims to mitigate atmospheric effects and provide more accurate information of surface reflectance information [24] to obtain accurate ground vegetation analysis [25]. The analysis utilized six spectral bands—blue (B2), green (B3), red (B4), near-infrared (B8), and shortwave infrared (B11 and B12)—rescaled to surface reflectance values. A median composite was generated to reduce residual cloud effects. From this composite, multiple spectral indices were calculated, including NDVI, NDWI, MNDWI, BSI, NDBI, and SAVI, which together capture vegetation, water, bare soil, and built-up characteristics.

Sentinel-1 Ground Range Detection (GRD) has VV and VH polarization modes that measures radar backscatter amplitude using C-band SAR instrument[26]. This dataset is originally available at 10-m spatial resolution. Sentinel-1 GRD synthetic aperture radar (SAR) data were used to complement the optical information with cloud-independent observations. Images acquired in Interferometric Wide (IW) mode were filtered by date and AOI. A median composite was generated, and the difference between VV and VH backscatter (VV–VH) was computed to enhance sensitivity to urban structures and surface roughness.

The combined Sentinel-1 and Sentinel-2 datasets provide a robust multi-sensor representation of surface conditions, improving the discrimination of urban, vegetation, water, and bare land classes within the core urban areas of Kabul and Baghdad. Google Earth Engine (GEE) was used as an open-source, cloud-based geospatial computing platform to efficiently perform land-use classification using a Random Forest classifier over large urban extents. GEE provides direct access to multi-temporal satellite archives, including Sentinel-1 and Sentinel-2 imagery, and enables scalable image preprocessing, feature extraction, and machine-learning–based classification without the need for local data storage or high-performance hardware. In this study, GEE was used to generate cloud-filtered composites, derive spectral indices, integrate multi-sensor datasets, and train supervised classifiers using user-defined training samples. The cloud computing architecture of GEE allowed rapid experimentation, consistent processing across multiple years, and reproducible analysis workflows, making it particularly well-suited for comparative land-use assessment in data-intensive, post-conflict urban environments.

To move beyond absolute area, change and better understand how land was being utilized within the urban system, this study employed a set of dimensionless area ratios derived from classified land-cover classes. These ratios provide a normalized framework for comparing land-use structure across cities and time periods, independent of differences in total area.

2.2.1 Ratio indices

The ratio used in this research are defined as below.

Built-up to Green ratio (Built / (Vegetation + Fields)) was used to assess the balance between urban development and ecologically productive land. Higher values indicate increasing urban dominance and pressure on green infrastructure, while lower values reflect greater ecological balance and potential sustainability. Temporal changes in this ratio were interpreted as indicators of shifts in development intensity and land-use prioritization.

Bare-to-Built ratio (Bare/Built) served as a proxy for the prevalence of transitional or disturbed land relative to permanent urban fabric. Elevated values were interpreted as evidence of land-use instability, such as demolition, delayed redevelopment, or abandonment, whereas declining values indicated consolidation and absorption of transitional land into formal urban uses. This ratio was particularly informative for identifying post-conflict restructuring processes that are not captured by built-up area alone.

Water to Built ratio (Water / Built) was used to evaluate hydrological presence relative to urban extent and to infer potential environmental stress associated with urban expansion. Declining ratios were interpreted as increasing pressure on surface water resources or reduced hydrological visibility within expanding urban systems, highlighting potential sustainability concerns.

By jointly analyzing these ratios alongside absolute area changes, the study was able to distinguish between urban growth, consolidation, fragmentation, and ecological rebalancing. This ratio-based approach provided a more nuanced understanding of land-use utilization, enabling meaningful comparison between Baghdad and Kabul and revealing divergent post-conflict recovery and sustainability trajectories that would not be apparent from area statistics alone. The definition of the ratios is defined in the Table 1 below.

Table 1 The formulas used for calculating the ratios

S. No.	Ratio	Formula	Description / Interpretation
1	Built: Green	B / (V + F)	Measures the dominance of built-up land relative to ecologically productive land (vegetation and fields). Higher values indicate stronger urban pressure and reduced ecological balance.
2	Green: Built	(V + F) / B	Represents ecological balance relative to urban land. Higher values indicate greater availability of green land per unit of built-up area.
3	Bare: Built	R / B	Indicates the extent of transitional, disturbed, or undeveloped land relative to permanent urban fabric. Higher values suggest urban instability or delayed redevelopment.

4	Built: Bare	B / R	Reflects the degree of urban consolidation. Higher values indicate that permanent built-up areas dominate over transitional or vacant land.
5	Water: Built	W / B	Measures surface water availability relative to urban extent. Declining values indicate increasing hydrological stress associated with urban expansion.
6	Built: Total	B / T	Represents the proportion of the total study area occupied by built-up land, indicating overall urban dominance.
7	Green: Total	(V + F) / T	Represents the share of ecologically productive land within the total area, relevant for assessing environmental sustainability.
8	Water: Total	W / T	Indicates the proportion of surface water within the study area, reflecting hydrological presence and environmental conditions.

3 RESULTS

Baghdad and Kabul represent two post-conflict capitals with markedly different geographic, climatic, and governance contexts. Baghdad's study area (approximately 856 km²) is larger, flatter, and strongly influenced by riverine systems, whereas Kabul's smaller (approximately 709 km²) basin-constrained setting limits outward expansion and promotes fragmented urban growth. These structural differences are reflected not only in absolute land-cover areas but also in the relative balance between built-up, green, bare, and water surfaces, as captured by key ratios shown in Table 2. The results of the classification are shown in Figures 2 and 3.

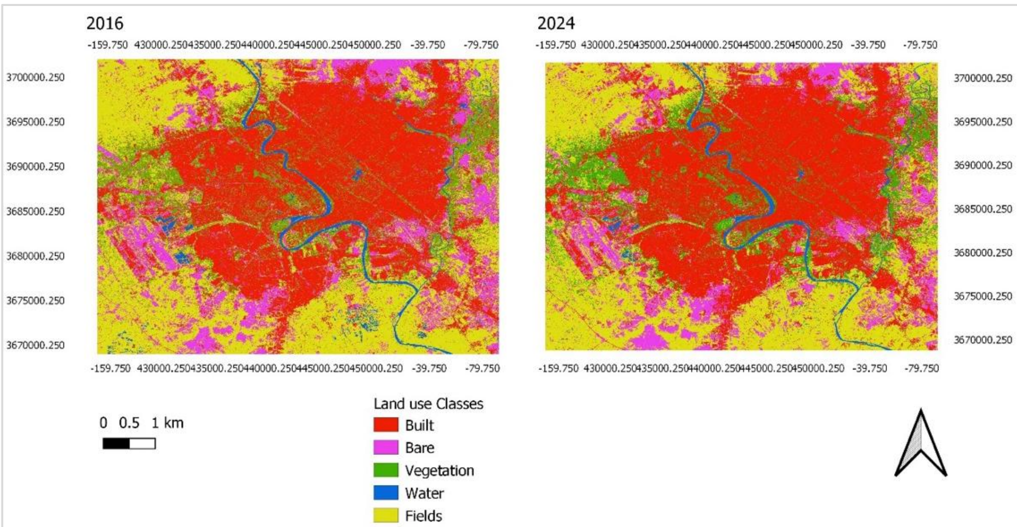

Figure 2 Results of land use classification for the city of Baghdad (left: 2016, right:2024)

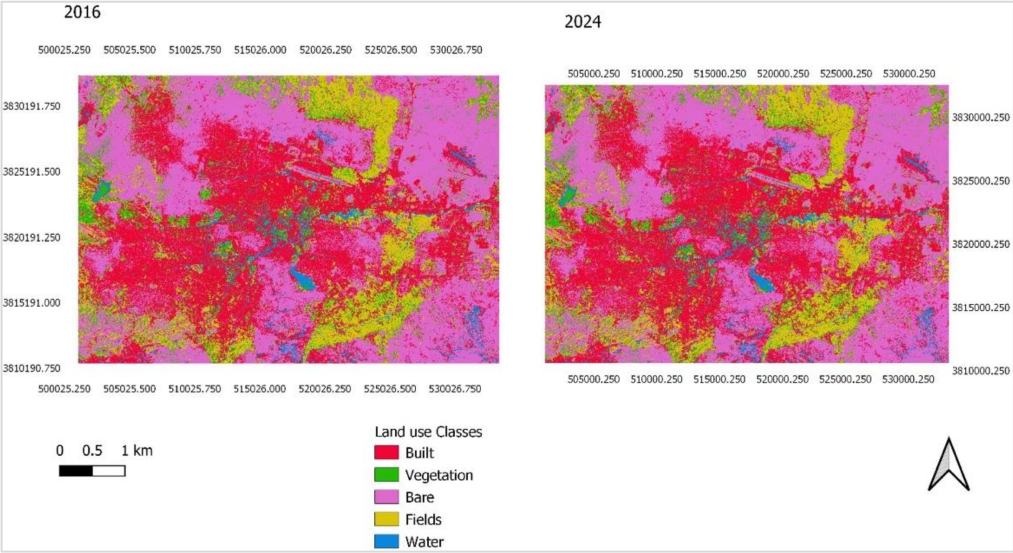

Figure 3 Result of land use classification for the city of Kabul(left: 2016, right:2024)

Table 2 Comparative land-cover structure and ratio indicators for Baghdad and Kabul (2016–2024)

City	Year	Built (km²)	Green (Veg+Fields) (km²)	Bare (km²)	Water (km²)	Built : Green	Bare : Built	Water : Built
Baghdad	2016	419.5	305.3	109.0	21.8	1.37	0.26	0.052
Baghdad	2024	462.9	286.8	89.3	16.8	1.61	0.19	0.036
Kabul	2016	239.8	132.7	268.9	41.6	2.00	1.01	0.157
Kabul	2024	265.5	154.6	289.7	24.7	1.55	1.21	0.103

3.1 Ratio-Based Interpretation in a Post-Conflict Context

3.1.1 Built-up to Green Ratio (Urban Pressure vs Ecological Capacity)

The Built: Green ratio provides a first-order indicator of the balance between urban expansion and ecologically productive land, a key dimension of urban sustainability in post-conflict settings.

In Baghdad, this ratio increased from 1.37 (2016) to 1.61 (2024)**,** reflecting that built-up expansion outpaced the retention of vegetation and agricultural fields. This trend indicates urban consolidation and growth-led recovery, where reconstruction and infill development progressively absorb peri-urban green spaces. From a recovery theory perspective, this pattern is characteristic of cities transitioning from stabilization to growth-oriented recovery, albeit with increasing pressure on ecosystem services.

In Kabul**,** the built-to-green ratio declined from 2.00 to 1.55, despite an absolute increase in built-up area. This decline indicates that green and agricultural land expanded faster than built-up surfaces, suggesting a recovery trajectory in which ecological or subsistence land uses remain resilient. This pattern aligns with adaptive or subsistence-oriented recovery, rather than growth-driven urban consolidation.

3.1.2 Bare to Built Ratio (Urban Stability vs Transitional Landscapes)

The Bare: Built ratio captures the prevalence of transitional or disturbed land relative to permanent urban fabric and serves as a strong proxy for urban stability in post-conflict cities.

Baghdad's ratio declined from 0.26 to 0.19, accompanied by a reduction in absolute bare land area. This indicates that previously disturbed or vacant surfaces were progressively converted into permanent built-up areas. In recovery-theory terms, this reflects institutional and economic capacity to absorb post-conflict disruption, signaling consolidation and formalization of urban land use.

In contrast, Kabul's Bare: Built ratio increased from 1.01 to 1.21, meaning bare land expanded faster than built-up land. This suggests persistent urban fragmentation, where construction, demolition, abandonment, and delayed redevelopment coexist. Such a pattern is consistent with prolonged or uneven recovery, where instability and limited investment prevent the full absorption of disturbed land into stable urban form.

3.1.3 Water to Built Ratio (Hydrological Stress and Urban Resilience)

The Water: Built ratio reflects the relationship between surface water availability and urban extent, an important indicator of environmental sustainability and climate vulnerability.

Both cities exhibit declining water-to-built ratios, but the magnitude and implications differ. Baghdad's ratio decreased modestly from 0.052 to 0.036, likely reflecting urban expansion and river regulation rather than acute water scarcity. This suggests managed hydrological stress within a growing urban system.

Kabul's Water: Built ratio declined more sharply from 0.157 to 0.103, driven by both increasing built-up area and substantial loss of surface water. This highlights greater hydrological vulnerability, reinforcing concerns about long-term urban sustainability in a water-scarce, basin-constrained city.

3.2 Synthesis: Linking Ratios to Post-Conflict Recovery and Sustainability

Taken together, the ratio-based analysis reveals two distinct post-conflict recovery trajectories:

- Baghdad exhibits a consolidation-led recovery, characterized by increasing urban dominance (higher Built: Green), declining transitional land (lower Bare: Built), and manageable hydrological stress. This trajectory aligns with a recovery pathway focused on reconstruction, densification, and economic reintegration, but with growing pressure on green infrastructure.
- Kabul follows a fragmented and adaptive recovery trajectory, where built-up growth is modest and accompanied by expanding green and bare land. Declining Built: Green and rising Bare: Built ratios point to persistent transitional landscapes and uneven

development, while declining Water: Built ratios signal increasing environmental stress. This pattern reflects recovery under continued political, economic, and environmental constraints.

4 DISCUSSION AND CONCLUSION

Between 2016 and 2024, Baghdad and Kabul both experienced growth in built-up area; however, ratio-based analysis reveals fundamentally different recovery dynamics that reflect not only physical urban change but also underlying land-use governance and policy contexts. In Baghdad, post-conflict reconstruction has been accompanied by sustained planning efforts and comprehensive urban frameworks that aim to guide development in the post-war era. For example, the *Baghdad Comprehensive City Development Plan 2030* establishes land-use, transportation, and environmental strategies intended to manage growth and promote urban livability following decades of conflict and unplanned expansion [27]. This policy orientation aligns with Baghdad's increasing Built-to-Green ratio and declining Bare-to-Built ratio, suggesting an emphasis on consolidating urban fabric and regulating land-use change rather than allowing unchecked sprawl.

In contrast, Kabul's urbanization and recovery trajectory have been shaped by weaker land-use governance and limited regulatory capacity, which have historically undermined orderly urban expansion. Research on land-use management in Kabul highlights the city's rapid urban growth and the *necessity of appropriate policy frameworks* to limit linear sprawl and guide sustainable land conversion [28]. Moreover, broader analyses of land administration and housing policy in Afghanistan note that institutional challenges, including corruption and informal land allocation practices, have influenced land distribution and urban development patterns in Kabul. These governance constraints are consistent with Kabul's declining Built-to-Green ratio and increasing Bare-to-Built ratio, reflecting fragmented expansion and the persistence of transitional surfaces in the absence of robust planning implementation.

While the Sentinel-1 and Sentinel-2 datasets accessed through the Google Earth Engine repository enabled consistent, multi-temporal land-use classification at high spatial resolution, several limitations should be acknowledged. Optical Sentinel-2 imagery is affected by atmospheric conditions, seasonal variability, and spectral confusion between built-up, bare soil, and disturbed surfaces, particularly in semi-arid environments like Baghdad and Kabul. Although cloud masking and temporal compositing were applied, residual uncertainty remains, especially in years with limited high-quality observations. Sentinel-1 SAR data improved class separability by providing sensitivity to surface roughness and structural features; however, SAR backscatter is influenced by incidence angle, surface moisture, and urban geometry, which can introduce ambiguity when distinguishing between dense built-up areas and compacted or rubble-covered land.

Additionally, land-use classification accuracy is influenced by the quality, representativeness, and spatial distribution of training samples, which may vary across years due to changing urban conditions. Despite the use of consistent classification workflows within GEE, differences in sensor revisit frequency, data availability, and classification confidence across time periods may contribute to interannual variability. Consequently, the observed trends should be interpreted as robust indicators of relative land-use change rather than exact measurements of absolute urban extent.

Overall, the integration of multi-sensor Sentinel data within Google Earth Engine provides a powerful and reproducible framework for urban analysis, while the ratio-based approach mitigates some of the inherent uncertainties by emphasizing relative structural change. Embedding these remote sensing-based recovery trajectories within the context of land-use policy and governance underscores how planning frameworks, institutional capacity, and regulatory implementation can shape post-conflict urban recovery. Future work could further strengthen these findings through integration with independent datasets, higher-resolution imagery, or ground-based validation, as well as more detailed policy document analysis and stakeholder interviews to better capture fine-scale urban dynamics and the institutional drivers of recovery.

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3. Audita Widya Astuti

Audita Widya Astuti holds a bachelor's degree in Geodetic Engineering from Gadjah Mada University (2017). After graduating, she spent two years at a mapping consultancy company, working as a GIS Engineer. During her time at the consultant mapping agency, she was involved in some large-scale mapping projects using airborne photogrammetry in Indonesia. After that, she shifted her career into the construction industry. She worked for one of the largest construction companies in Indonesia, PT Hutama Karya (Persero), where she served as a Geodetic Engineer for five years. Beyond her professional practice, Audita is a dedicated researcher, having presented papers at local and international conferences. For the international conferences, she presented at the Geomatic International Conference (2021), the International Federation of Surveyors (FIG) Congresses in 2022 and 2023, as well as the Asia Australasia Road Conference in 2023. She is currently pursuing a Master's degree in Geodesy and Geoinformation at the Technical University of Munich.

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