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Dynamics of Urban Expansion in the Northwest Mesoregion of Minas Gerais: Analysis and Trends with the Urban Expansion Index

Arthur Pereira dos Santos
Doctor in Environmental Sciences, UNESP, Brazil.
arthur.p.santos@unesp.br
ORCID: 0000-0002-1913-3562

Leticia Tondato Arantes
Doctor in Environmental Sciences, UNESP, Brazil.
leticia.tondato@unesp.br
ORCID: 0000-0002-5541-1304

Mayra Vanessa Lizcano Toledo
Doctoral student in Environmental Sciences, UNESP, Brazil..
mayra.lizcano@unesp.br
ORCID: 0000-0002-4092-1838

Juliana Heloisa Pinê Américo-Pinheiro
Doctor Professor, UNESP, UB, Brazil.
juliana.heloisa@unesp.br
juliana.pinheiro@ub.edu.br
ORCID: 0000-0001-6252-828X

Darllan Collins da Cunha e Silva
Doctor Professor, UNESP, Brazil.
darllan.collins@unesp.br
ORCID: 0000-0003-3280-0478

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Dinâmica temporal da expansão urbana na mesorregião Noroeste de Minas Gerais: análise e tendências com o Índice de Expansão Urbana

RESUMO

Objetivo – Investigar a evolução do Índice de Expansão Urbana (IEU) na mesorregião Noroeste de Minas Gerais (MG) entre os anos de 1990 e 2020, utilizando dados de Sensoriamento Remoto (SR) provenientes do projeto MapBiomas.

Metodologia – O IEU foi calculado com base na proporção da área urbanizada em relação às demais classes de uso do solo em cada município. Os valores foram normalizados para possibilitar a comparação temporal e espacial entre os municípios, e posteriormente classificados em cinco categorias de urbanização. A análise espacial foi conduzida por meio da elaboração de mapas temáticos, permitindo visualizar as tendências e variações geoespaciais do crescimento urbano ao longo do período estudado.

Originalidade/relevância – O estudo oferece uma abordagem sistemática para monitorar a expansão urbana em uma escala regional, integrando dados de SR e análises espaciais com foco na gestão territorial. Destaca-se a aplicação de um índice próprio (IEU) e a categorização espacial para interpretação das dinâmicas urbanas.

Resultados – Os resultados revelam variações significativas nos níveis de urbanização dos 19 municípios analisados. Vazante apresentou o IEU mais elevado em 2020, seguido por Paracatu e Unaí, indicando crescimento urbano expressivo. Por outro lado, Formoso e Guarda-Mor mantiveram os menores níveis de urbanização, refletindo menor desenvolvimento urbano. Os dados apontam para a influência de fatores econômicos, como a agropecuária, a mineração e os investimentos em infraestrutura, sobre os padrões de urbanização da região.

Contribuições teóricas/metodológicas – A aplicação do IEU e o uso de dados do projeto MapBiomas demonstram a eficácia do Sensoriamento Remoto na análise da expansão urbana regional. O estudo contribui metodologicamente ao propor uma ferramenta útil para análises comparativas e planejamento territorial.

Contribuições sociais e ambientais – Os resultados reforçam a importância do uso de dados de SR para a formulação de políticas públicas voltadas ao ordenamento urbano e à promoção de um desenvolvimento urbano sustentável, alinhado às especificidades locais da mesorregião Noroeste de Minas Gerais.

PALAVRAS-CHAVE: Gestão Territorial. Sensoriamento Remoto. Desenvolvimento Urbano Sustentável.

Dynamics of Urban Expansion in the Northwest Mesoregion of Minas Gerais: Analysis and Trends with the Urban Expansion Index

ABSTRACT

Objective – To investigate the evolution of the Urban Expansion Index (UEI) in the Northwest mesoregion of Minas Gerais (MG), Brazil, between 1990 and 2020, using Remote Sensing (RS) data from the MapBiomas project.

Methodology – The UEI was calculated based on the proportion of urbanized area in relation to other land use classes in each municipality. The values were normalized to enable temporal and spatial comparisons across municipalities and then classified into five urbanization categories. Spatial analysis was conducted through the creation of thematic maps, allowing a detailed visualization of urban growth trends and geospatial variations over time.

Originality/relevance – The study provides a systematic approach to monitoring urban expansion at the regional scale, integrating RS data and spatial analysis with a focus on territorial management. It emphasizes the application of a specific index (UEI) and its spatial categorization to interpret urban dynamics.

Results – The findings reveal significant variations in the level of urbanization among the 19 municipalities analyzed. Vazante recorded the highest UEI in 2020, followed by Paracatu and Unaí, indicating substantial urban growth. In contrast, Formoso and Guarda-Mor maintained the lowest levels of urbanization, reflecting limited urban development. The data suggest that economic factors such as agriculture, mining, and infrastructure investments influence urbanization patterns in the region.

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Theoretical/methodological contributions – The application of the UEI and the use of MapBiomas data demonstrate the effectiveness of Remote Sensing in analyzing regional urban expansion. The study contributes methodologically by proposing a useful tool for comparative analysis and territorial planning.
Social and environmental contributions – The results underscore the importance of using RS data to support public policy formulation aimed at urban planning and the promotion of sustainable urban development, tailored to the local characteristics of the Northwest mesoregion of Minas Gerais.

KEYWORDS: Territorial Management. Remote Sensing. Sustainable Urban Development.

Dinámica temporal de la expansión urbana en el mesorregião Noroeste de Minas Gerais: análisis y tendencias con el Índice de Expansión Urbana

RESUMEN
Objetivo – Investigar la evolución del Índice de Expansión Urbana (IEU) en la mesorregión Noroeste de Minas Gerais (MG) entre los años 1990 y 2020, utilizando datos de Sensoriamento Remoto (SR) del proyecto MapBiomas.
Metodología – El IEU se calculó a partir de la proporción del área urbanizada en relación con las demás clases de uso del suelo en cada municipio. Los valores fueron normalizados para permitir la comparación temporal y espacial entre los municipios, y posteriormente clasificados en cinco categorías de urbanización. Se realizó un análisis espacial mediante la elaboración de mapas temáticos, lo que permitió visualizar tendencias y variaciones geoespaciales del crecimiento urbano durante el período analizado.
Originalidad/relevancia – El estudio ofrece un enfoque sistemático para monitorear la expansión urbana a escala regional, integrando datos de SR y análisis espaciales con un enfoque en la gestión territorial. Destaca la aplicación de un índice específico (IEU) y su categorización espacial para interpretar las dinámicas urbanas.
Resultados – Los resultados revelan variaciones significativas en los niveles de urbanización de los 19 municipios analizados. Vazante presentó el IEU más alto en 2020, seguido por Paracatu y Unaí, lo que indica un crecimiento urbano expresivo. En cambio, Formoso y Guarda-Mor mantuvieron los niveles más bajos de urbanización, reflejando un desarrollo urbano limitado. Los datos indican que factores económicos como la agropecuaria, la minería y las inversiones en infraestructura influyen en los patrones de urbanización en la región.
Contribuciones teóricas/metodológicas – La aplicación del IEU y el uso de datos del proyecto MapBiomas demuestran la eficacia del Sensoriamento Remoto para analizar la expansión urbana regional. El estudio aporta metodológicamente al proponer una herramienta útil para análisis comparativos y planificación territorial.
Contribuciones sociales y ambientales – Los resultados refuerzan la importancia del uso de datos de SR para la formulación de políticas públicas orientadas al ordenamiento urbano y la promoción de un desarrollo urbano sostenible, adaptado a las especificidades locales de la mesorregión Noroeste de Minas Gerais.

PALABRAS CLAVE: Gestión Territorial. Detección remota. Desarrollo Urbano Sostenible.

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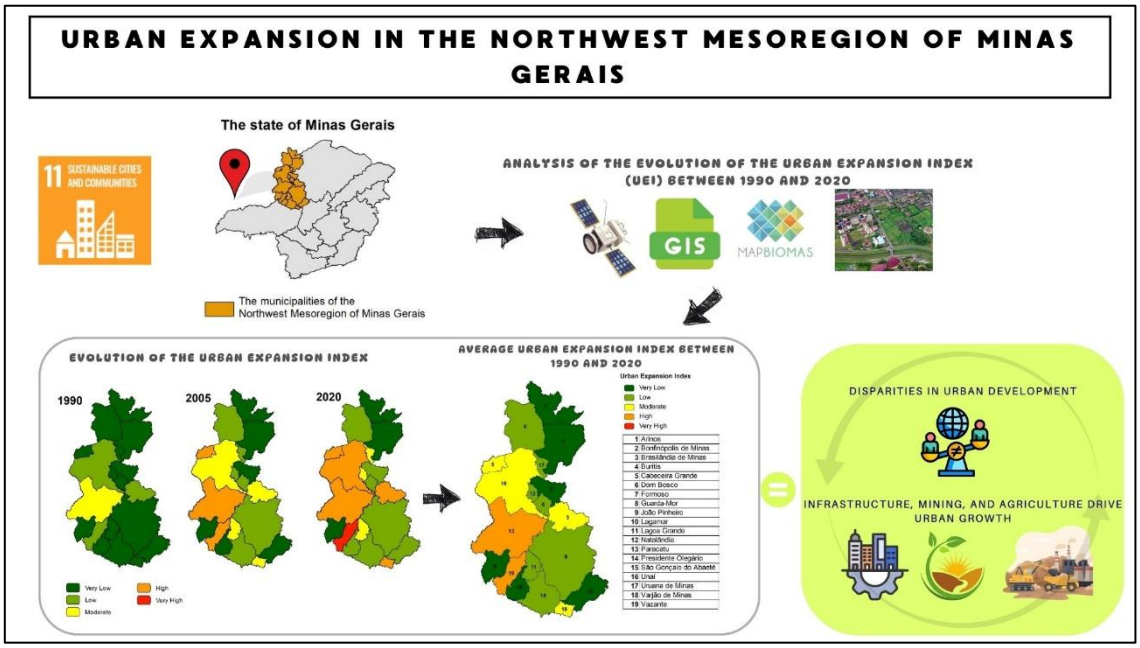
GRAPHICAL ABSTRACT



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1 INTRODUCTION

The technological advancement, intensified over the past decade, has been crucial for analysing the influence and monitoring of the impact of anthropogenic activities on the environment. This progress has been driven by applications involving Remote Sensing (RS) (Lu *et al.*, 2025), which enables the collection and analysis of data about the Earth's surface using satellites and sensors, providing a detailed and comprehensive view of land use changes (Taiwo *et al.*, 2024).

From this perspective, the use of RS data for territorial management stands out by enabling not only the temporal analysis of land use changes but also by exploring less studied areas, supporting decision-making processes for managers and the formulation of public policies (Cima; Amaral; Massi, 2023). This approach will allow monitoring, among other aspects, microclimate conditions (Rizzo; Santos; Silva, 2024; Sola-Caraballo *et al.*, 2025), environmental degradation (Santos *et al.*, 2024; Mbalibulha *et al.*, 2025), ecosystem transformations (Pastick *et al.*, 2019; Feng *et al.*, 2025), and urban expansion (Talema; Nigusie, 2024; Bhailume; Choudhari; Singh, 2025).

When it comes to less explored areas, the Northwest mesoregion of Minas Gerais (MG) stands out, characterized by its significant agricultural potential and an increasing number of inhabitants attracted by the opportunities provided by its fertile lands (Santos *et al.*, 2024). Nevertheless, population growth and land use changes in this region have been insufficiently analysed.

In this context, the use of RS data becomes an essential tool for filling knowledge gaps and thoroughly analysing land use transformations over time, as well as urban expansion and its impact on the environment (Sonet *et al.*, 2025). Thus, by mapping these changes, the results support the formulation of measures to mitigate the negative effects of these transformations (Dhanaraj; Angadi, 2022), contributing to sustainable urban development (Anthony *et al.*, 2024).

Therefore, the aim of this study is to develop an Urban Expansion Index (UEI) for the Northwest mesoregion of MG, covering the years 1990, 2005, and 2020, as well as to assess the temporal trends of this growth at the municipal and regional scale.

It is worth noting that this work fills an important gap in research on land use in the region in question, and the analysis of the UEI will provide support for natural resource management and strategic planning, contributing to sustainable development and the formulation of public policies.

2 METHODOLOGY

2.1 Study Area

The Northwest mesoregion of MG, entirely located within the Cerrado biome, includes 19 municipalities covering a territorial area of approximately 62,412 km². The regional population, estimated at 370,786 inhabitants, is unevenly distributed between urban and rural areas, with a current predominance in the cities (IBGE, 2024).

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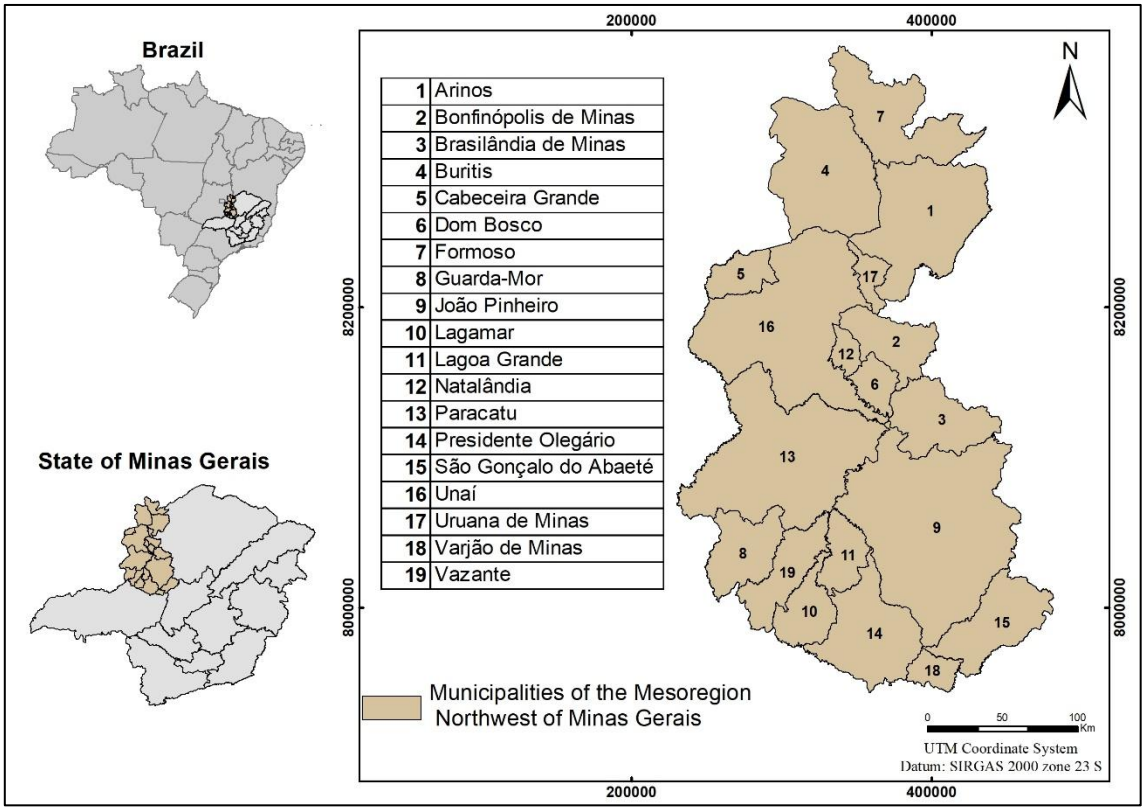
The municipalities that make up the study area are: Arinos, Bonfinópolis de Minas, Brasilândia de Minas, Buritis, Cabeceira Grande, Dom Bosco, Formoso, Guarda-Mor, João Pinheiro, Lagamar, Lagoa Grande, Natalândia, Paracatu, Presidente Olegário, São Gonçalo do Abaeté, Unaí, Uruana de Minas, Varjão de Minas, and Vazante (Figure 1).

Figure 1 – Location of the study area: Northwest mesoregion of MG.



Source: The authors (2025).

Paracatu, Unaí, and João Pinheiro stand out among the municipalities in the mesoregion, accounting for approximately 54% of the population and urban infrastructure. They also play a central role in the economy and territorial organization, acting as important hubs for services, commerce, and agricultural production (Santos *et al.*, 2024; Santos *et al.*, 2021).

Moreover, more advanced infrastructure in these areas attracts internal migration flows, increasing urbanization and population density in these cities (FIEMG, 2017). This fact reinforces the importance of these municipalities in the economic and social dynamics of the mesoregion, consolidating them as regional centers of development.

The economic development of the mesoregion is driven by, and currently dependent on, agricultural activities (Santos *et al.*, 2024) and mining, with a focus on gold extraction, which is predominantly carried out in the municipality of Paracatu, home to one of the largest open-pit gold mines in the world (Santos *et al.*, 2022).

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In addition to gold, the Northwest region of Minas Gerais has reserves of other minerals, such as phosphate, zinc, and limestone, which are extracted on a smaller scale but also contribute to the economic diversification of the area, especially in the municipality of Vazante (Santos *et al.*, 2022; Santos *et al.*, 2024).

The mesoregion experienced significant population and economic growth throughout the 20th century, driven by agricultural expansion and the attraction of infrastructure investments. Furthermore, the development of highways and improvements in access to education and healthcare contributed to population settlement, leading to an increase in rural-to-urban migration, particularly to municipalities offering better job opportunities and services (Santos *et al.*, 2024).

The climate of the study area is typical of the Cerrado, with two well-defined seasons: a hot and rainy period and a dry one. The average annual temperature ranges between 20°C and 26°C, with the hottest months mainly occurring between October and March (INMET, 2024; Jardim; Silva, 2017). The average annual precipitation ranges from 1,200 to 1,600 mm, primarily concentrated during the summer period. This climatic pattern favors agriculture, allowing for a good distribution of rainfall throughout the growing cycle of the region's main crops (INMET, 2024; Jardim; Silva, 2017).

Grain production in the Northwest region of Minas Gerais is driven by the fertility of the Oxisols and the modernization of agricultural techniques, including the adoption of irrigation practices and Precision Agriculture (PA), which improve production efficiency and, consequently, stimulate agricultural growth. This also contributes to the urbanization of the region, reflecting in the expansion of urban areas and the increase in population density (Santos *et al.*, 2024).

2.2 Methodological Procedures

At this stage, temporal analysis data on land use and cover classes from the study by Santos *et al.* (2024) were used. Next, based on validated data from MapBiomas's Annual Mapping Project of Land Cover and Use in Brazil, an index capable of evaluating agricultural expansion in the municipalities that comprise the mesoregion under study was developed.

Regarding the UEI, the index was calculated as the ratio between the urbanized area in a specific year and the territorial extent of the other land use classes, as described in Equation 1 and recommended by Santos *et al.* (2024).

$$IEU = \frac{AU}{ATM} * 100 \quad (1)$$

Where:
UEI: Urban Expansion Index;
UA: Urbanized Area (km%C2%B2);
ATM: Area allocated to other land uses (km%C2%B2).

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In analysing these data, it was found that the percentage of urbanized areas is significantly lower compared to other land use percentages in the studied municipalities. Thus, to ensure consistent comparisons across different years and municipalities, data normalization was performed.

For this, the min-max normalization technique was applied to the urbanized area class, converting the original percentage values to a scale from 0 to 1, as specified in Equation 2.

$$UEIn = \frac{Porcentage_{Urbanization} - MinimumValue}{Maximum\,Value - Minimum\,Value} \quad (2)$$

Where:
UEIn: Normalized Urban Expansion Index;
Urbanization Percentage: the original percentage value of the urbanized area;
Minimum Value: the lowest urbanization value found across the three years of the time series (1990, 2005, and 2020);
Maximum Value: the highest urbanization value found across the three years of the time series (1990, 2005, and 2020).

After normalization, the values were categorized into five classes to facilitate the interpretation and classification of the data. Table 1 presents the classification of the values, reflecting the degree of urban area expansion in the 19 municipalities over 30 years.

Table 1 – Classification of the Urban Expansion Index (UEI)

UEI	UEI classification
≤ 0,20	Very low
0,21 – 0,40	low
0,41 – 0,60	Moderate
0,61 – 0,8	High
<0,8	Very high

Source: The authors (2025).

Areas classified as "Very Low" have a UEI of ≤ 0.20, indicating minimal urban growth. The "Low" class (UEI from 0.21 to 0.40) reflects moderate urbanization increase, while the "Moderate" (UEI from 0.41 to 0.60) and "High" (UEI from 0.61 to 0.80) categories correspond to balanced and significant growth, respectively. Finally, a UEI above 0.80 is classified as "Very High," indicating a substantial increase in urbanization.

Finally, the data were spatialized and analysed using the ArcGIS software, version 10.6 (ESRI, 2017), producing thematic maps that illustrate the distribution and evolution of urbanization in the Northwest mesoregion of MG over 30 years. These maps also highlight the municipalities with the greatest increase in urbanization throughout the analysed period.

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3. RESULTS AND DISCUSSION

Table 2 presents the UEI of each municipality in the Northwest mesoregion of MG for the years 1990, 2005, and 2020, and Figure 2 illustrates the UEI calculated for each municipality in those years, providing a comparative analysis over 30 years.

The results obtained for the UEI in the study area reveal distinct trends in urbanization over the 30 years analysed. Initially, it is worth noting that in 1990, most municipalities were classified as having "Very Low" urbanization, with only Paracatu standing out with an index indicating moderate or more advanced urbanization for that time.

Nevertheless, the predominance of agricultural activities with still rudimentary techniques and the lack of advanced urban infrastructure limited the growth of some urban areas. Moreover, investments in infrastructure and urban services were still limited, as highlighted by Sousa *et al*. (2011).

Table 2 – Urban Expansion Index of the municipalities in the Northwest mesoregion of MG for the years 1990, 2005, and 2020.

Municipality	1990	2005	2020
Varjão de Minas	0,15	0,42	0,67
Uruana de Minas	0,09	0,37	0,43
Unaí	0,25	0,56	0,71
São Gonçalo do Abaeté	0,06	0,19	0,24
Presidente Olegário	0,17	0,24	0,34
Paracatu	0,44	0,62	0,78
Natalândia	0,01	0,29	0,41
Lagoa Grande	0,13	0,46	0,59
Lagamar	0,06	0,18	0,25
João Pinheiro	0,13	0,21	0,31
Guarda-Mor	0,06	0,11	0,15
Formoso	0,02	0,11	0,15
Dom Bosco	0,04	0,28	0,37
Buritis	0,11	0,25	0,32
Brasilândia de Minas	0,25	0,56	0,67
Bonfinópolis	0,08	0,19	0,21
Arinos	0,04	0,15	0,17
Cabeceira Grande	0,14	0,73	0,80
Vazante	0,39	0,74	1,00

Source: The authors (2025).

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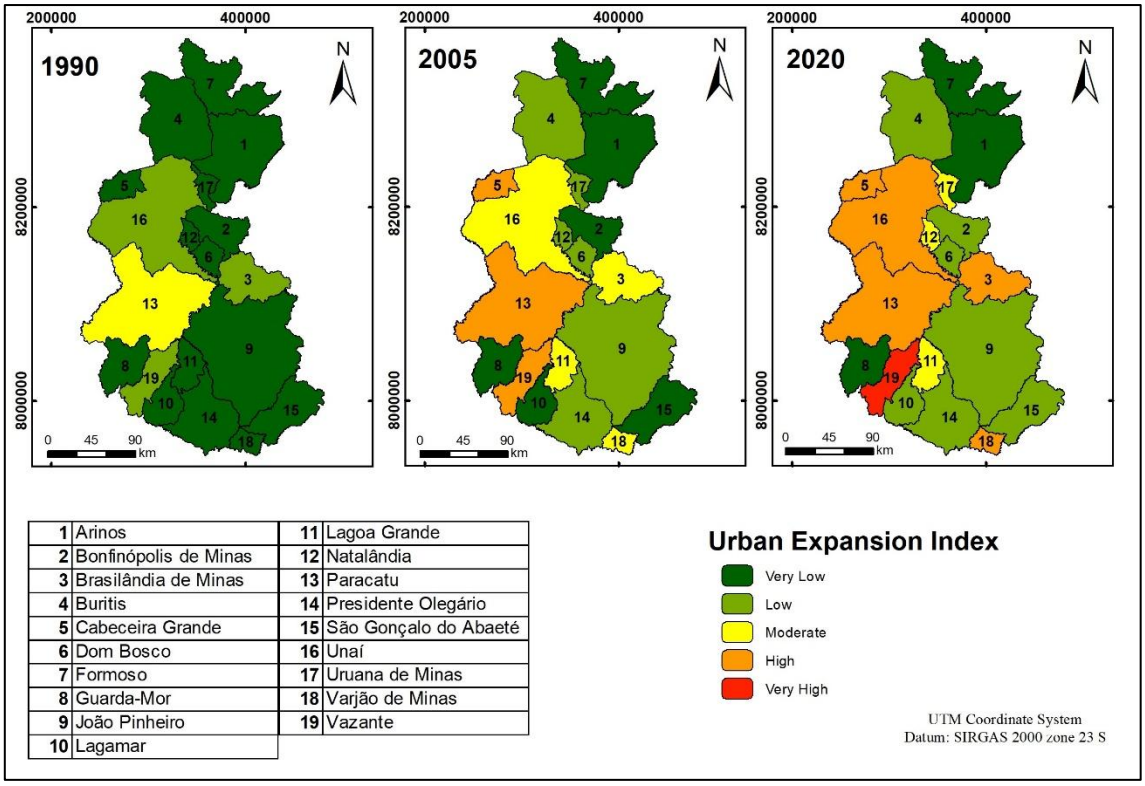
Figure 2 – Temporal Evolution of the Urban Expansion Index in the analysed municipalities (1990, 2005, 2020).



1	Arinos	11	Lagoa Grande
2	Bonfinópolis de Minas	12	Natalândia
3	Brasilândia de Minas	13	Paracatu
4	Buritis	14	Presidente Olegário
5	Cabeceira Grande	15	São Gonçalo do Abaeté
6	Dom Bosco	16	Unaí
7	Formoso	17	Uruana de Minas
8	Guarda-Mor	18	Varjão de Minas
9	João Pinheiro	19	Vazante
10	Lagamar		

Source: The authors (2025).

A related study by Santos *et al.* (2022) highlights that Paracatu, in turn, exhibited characteristics distinct from other municipalities in the region, including its strategic location relative to the nation's capital and greater local economic development, driven by mining. These factors indeed contributed to more advanced urbanization compared to the others.

In the year of 2005, a general increase in the UEI was observed in many municipalities of the mesoregion. However, Vazante, Cabeceira Grande, and Paracatu became the leaders in terms of urbanization for this period, with indices of 0.74, 0.73, and 0.62, respectively. This reflected a significant expansion compared to 1990 and resulted in an "High" level of urbanization classification for 2005.

Municipalities such as Unaí and Brasilândia de Minas also showed progress in urbanization, with indices of 0.56, indicating moderate urbanization. However, many municipalities still had low levels of urbanization, such as Guarda-Mor and Formoso, which remained in the "Very Low" UEI category.

The increase in the UEI observed between 1990 and 2005 can be attributed to regional development factors. The significant growth in Paracatu and Vazante was driven by investments in infrastructure and public services, as well as the attraction of commercial and industrial investments, which facilitated more pronounced urban expansion (Silva *et al.*, 2017; Santos *et al.*, 2022).

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Based on the study by Silva *et al.* (2017), regarding the progress of Unaí and Brasilândia de Minas, for example, it can be correlated to improvements in infrastructure, transportation, and basic services, which supported moderate urbanization during that period. However, municipalities with similar development levels, such as Guarda-Mor and Formoso, faced limitations in terms of investments and infrastructure improvements, resulting in low levels of urbanization, as discussed by Pereira *et al.* (2011).

For the year 2020, the urbanization pattern showed a trend of expansion, with a highlight on Vazante, which had a "Very High" UEI, indicating substantial urban growth. Paracatu and Unaí, with indices of 0.78 and 0.71, respectively, maintained their positions as centers of advanced urbanization.

Furthermore, municipalities such as Cabeceira Grande and Brasilândia de Minas advanced to the "High" or "Moderate" categories, reflecting a continued increase in urbanization. However, areas like Guarda-Mor and Formoso still had low indices, remaining in categories such as "Very Low."

The pronounced urban growth in Vazante, Paracatu, and Unaí up to 2020 can be attributed to significant investments in infrastructure, expansion of commercial activities, and improvements in public services (Silva *et al.*, 2017), which stimulated urbanization. It is believed that Vazante, in particular, benefited from its strategic location and regional development projects, enhanced by mining.

On the other hand, municipalities like Guarda-Mor and Formoso faced limitations due to the lack of investments and economic development, which hindered significant progress in urbanization and perpetuated their low indices. Thus, the disparity in urban growth between Vazante, Paracatu, and Unaí compared to the other municipalities highlights the importance of efficient public management that leverages the natural and economic potential of each location.

The urban growth of Unaí, in particular, which evolved from "Low" in 1990 to "Moderate" in 2005 and "High" in 2020, can be attributed to the intensification of agricultural activity and the development of agribusiness in the region, boosted by irrigation practices. These practices created new economic opportunities and attracted internal migration, as highlighted by Santos *et al*. (2024).

Vazante and Paracatu, however, with their economies driven by mining and the tertiary sector, managed to expand their infrastructure and urban services, reflecting a substantial increase in urbanization, as discussed in related studies by Silva *et al*. (2017) and Santos and Simionatto (2023).

In contrast, it is believed that the other municipalities, despite their relatively small populations, were unable to advance in urbanization due to less effective management and the lack of targeted investments (Sun *et al.*, 2020; Pereira *et al.*, 2011).

Such a scenario, therefore, highlights that population size is not the only determinant for urbanization, but rather the capacity to leverage resources and develop public policies that promote balanced and sustainable growth, as pointed out by Oliveira, Cardoso and Piffer (2024). In this perspective, Figure 3 presents the average UEI of each municipality for the 30-year time series.

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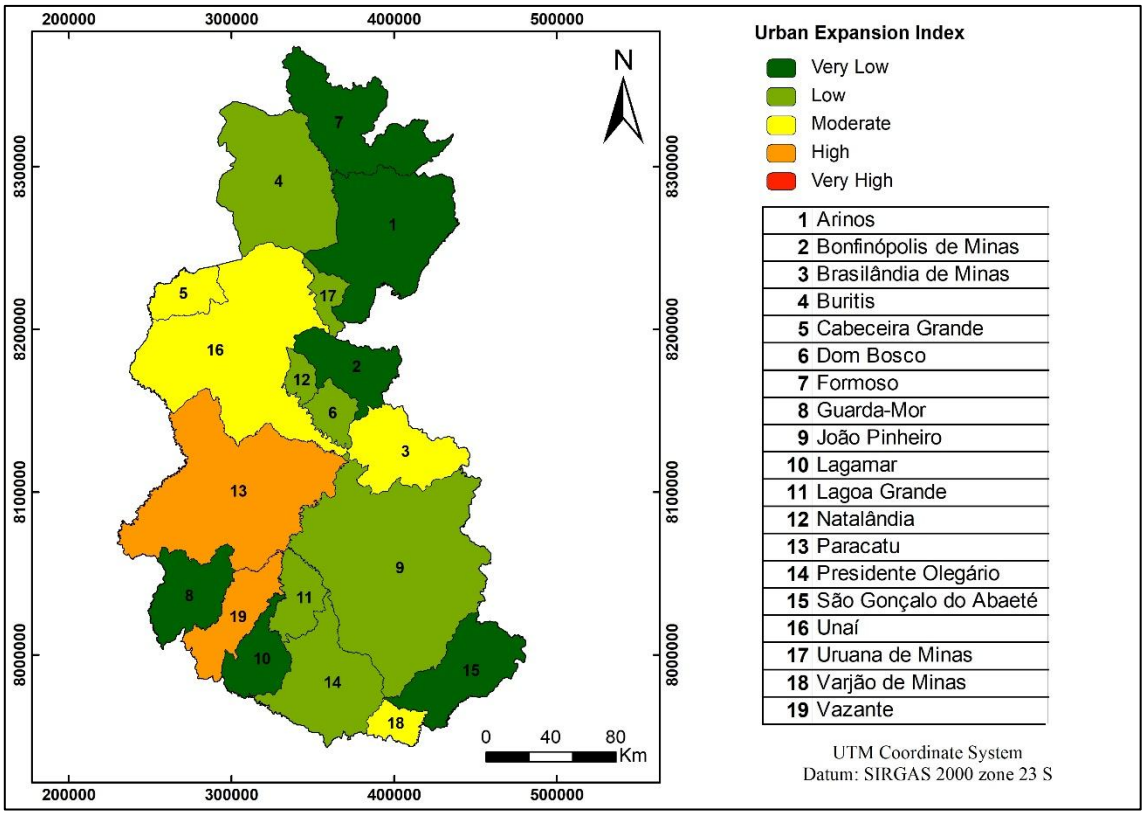
Figure 3 – Average of the Urban Expansion Index for the municipalities of the Noroeste de MG mesoregion between 1990 and 2020.



Source: The authors (2025).

The analysis of the data reveals that urbanization in the Noroeste de MG mesoregion is uneven, with some areas experiencing substantial urban growth while others maintain low levels of urbanization, as presented in the related study by Pereira *et al*. (2011).

The evolution of the UEI also demonstrates a growing urbanization pattern, with some municipalities reaching advanced levels of urban development, while others are still in the early stages, corroborating the conclusions of Sun *et al*. (2024) regarding global urbanization patterns in recent decades.

The results also reveal a significant variation in the UEI among the municipalities in the Noroeste de MG mesoregion, as the average index for the region indicates a predominance of low to moderate levels of urbanization, with a notable concentration in the "Very Low" and "Low" categories.

The average urbanization of the municipalities in the region shows that the capacity for urban growth is influenced by public management and targeted investments, highlighting that effective policies and development strategies are crucial for fostering urban expansion. Moreover, these results emphasize the need for a more balanced approach to promote sustainable urban development across the entire mesoregion.

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4. CONCLUSION

The temporal results of the UEI for the Northwest Mesoregion of Minas Gerais reveal significant variations in the degree of urbanization among the municipalities. The average UEI of the analysed municipalities falls within the low urbanization range, indicating that while some cities have achieved significant growth, the majority of the mesoregion still shows low indices. Therefore, the discrepancy between the levels of urbanization highlights the need for a strategic approach to promote more balanced and sustainable urban development in the Noroeste de Minas region.

Our study reaffirms the importance of using remote sensing data (RS) to diagnose territorial management, enabling the assessment of underexplored areas and identifying growth potentials. Furthermore, the effectiveness of the methodology applied in the study also demonstrates how modern tools can guide urban interventions and promote development in regions experiencing exponential urban growth.

The results obtained, as well as the proposed methodology, contribute to achieving the goals of Sustainable Development Goal (SDG) 11, making cities and communities more inclusive, safe, resilient, and sustainable.

REFERENCES

ANTHONY, T. et al. Spatial analysis of land cover changes for detecting environmental degradation and promoting sustainability. **Kuwait Journal of Science**, v. 51, n. 2, p. 100197, 2024. Disponível em: https://doi.org/10.1016/j.kjs.2024.100197.

BHAILUME, S.; CHOUDHARI, P. P.; SINGH, S. K. Monitoring and modeling urban growth dynamics. In: PETROPOULOS, G. P. et al. (Orgs.). **Earth Observation for Monitoring and Modeling Land Use**. Elsevier, 2025. p. 45-82. ISBN 9780323951937.

CIMA, I. S.; AMARAL, S.; MASSI, K. G. Mapping Cerrado remnants in an anthropized landscape in southeast Brazil. **Remote Sensing Applications: Society and Environment**, v. 32, p. 101032, 2023. Disponível em: https://doi.org/10.1016/j.rsase.2023.101032.

DHANARAJ, K.; ANGADI, D. P. Land use land cover mapping and monitoring urban growth using remote sensing and GIS techniques in Mangaluru, India. **GeoJournal**, v. 87, p. 1133–1159, 2022. Disponível em: https://doi.org/10.1007/s10708-020-10302-4.

ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE – ESRI. **ArcGIS 10.6**. Redlands, 2017.

FEDERAÇÃO DAS INDÚSTRIAS DO ESTADO DE MINAS GERAIS – FIEMG. **Perspectivas de desenvolvimento socioeconômico do Alto Paranaíba e Noroeste de Minas Gerais**. 2017. Disponível em: https://patosdeminas.mg.gov.br/fiemg-lanca-o-plano-de-perspectivas-de-desenvolvimento-socioeconomico-do-alto-paranaiba-e-noroeste-de-minas/.

FENG, L. et al. Exploring rangeland dynamics in Punjab, Pakistan: integrating LULC, LST, and remote sensing for ecosystem analysis (2000–2020). **Rangeland Ecology & Management**, v. 98, p. 377-388, 2025. Disponível em: https://doi.org/10.1016/j.rama.2024.09.008.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE. **Estimativas da população residente para os municípios e para as unidades da federação brasileiros com data de referência em 1º de julho de 2024**. Rio de

ISSN 2318-8472, v. 13, n. 88, 2025

Janeiro: IBGE, 2024. Disponível em: https://ftp.ibge.gov.br/Estimativas_de_Populacao/Estimativas_2024/estimativa_dou_2024.pdf. Acesso em: 15 jan. 2025.

INSTITUTO NACIONAL DE METEOROLOGIA – INMET. **Dados históricos**. Disponível em: https://portal.inmet.gov.br/servicos/bdmep-dados-hist%C3%B3ricos.

JARDIM, C. H.; SILVA, A. A. F. Aplicação de técnicas de preenchimento de falhas de dados de pluviosidade mensal e anual para o Noroeste do estado de Minas Gerais – Brasil. **Revista Geografias**, v. 13, n. 2, p. 83-106, 2017. Disponível em: https://doi.org/10.35699/2237-549X.2017.16058.

LU, D. et al. Patterns and drivers of terrace abandonment in China: monitoring based on multi-source remote sensing data. **Land Use Policy**, v. 148, p. 107388, 2025. Disponível em: https://doi.org/10.1016/j.landusepol.2024.107388.

MBALIBULHA, E. et al. Coupling Geographic Information Systems and remote sensing to evaluate riverbank erosion and accretion in an arid environment: a blueprint for sustainable transformation. **Sustainable Water Resources Management**, v. 11, n. 8, 2025. Disponível em: https://doi.org/10.1007/s40899-024-01177-1.

OLIVEIRA, J.; CARDOSO, A. A.; PIFFER, M. Dinâmica econômica municipal em Mato Grosso: um enfoque setorial de 2005 a 2020. **Geosul**, v. 39, n. 90, p. 347, 2024. DOI: 10.5007/2177-5230.2024.e99497. Disponível em: https://geosul.ufsc.br.

PASTICK, N. J. et al. Spatiotemporal remote sensing of ecosystem change and causation across Alaska. **Global Change Biology**, v. 25, n. 3, p. 1171-1189, 2019. Disponível em: https://doi.org/10.1111/gcb.1427.

PEREIRA, J. R. et al. Gestão social dos territórios da cidadania: o zoneamento ecológico-econômico como instrumento de gestão do território noroeste de Minas Gerais. **Cadernos EBAPE.BR**, v. 9, p. 724-747, 2011. Disponível em: https://doi.org/10.1590/S1679-39512011000300004.

RIZZO, F. A.; SANTOS, A. P.; SILVA, D. C. C. Técnicas de geoprocessamento aplicadas para análise temporal do microclima na bacia hidrográfica do córrego do Pequiá, Maranhão. **Boletim Goiano de Geografia**, Goiânia, v. 44, n. 1, 2024. Disponível em: https://doi.org/10.5216/bgg.v44i1.78032.

SANTOS, A. et al. Utilização da lógica Fuzzy como suporte ao zoneamento ambiental: um estudo de caso em Paracatu – MG. **Revista Brasileira de Geografia Física**, v. 14, n. 4, p. 2352–2368, 2021. Disponível em: https://doi.org/10.26848/rbgf.v14.4.p2352-2368.

SANTOS, A. P.; SIMIONATTO, H. H. Methodological proposal for evaluating the transformation of urban microclimate in medium-sized cities: a case study in the urban mesh of the municipality of Paracatu, Minas Gerais. **RAEGA – O Espaço Geográfico em Análise**, v. 57, p. 46-65, set. 2023. ISSN 2177-2738. Disponível em: http://dx.doi.org/10.5380/raega.v57i0.88156.

SANTOS, A. P. et al. Avaliação da expansão agropecuária como forma de indicador de degradação ambiental na mesorregião Noroeste do estado de Minas Gerais, Brasil. **GeoFocus. Revista Internacional de Ciencia y Tecnología de la Información Geográfica**, n. 33, p. 7-26, 2024. Disponível em: https://doi.org/10.21138/GF.839.

SANTOS, A. P. et al. The influence of urban and mineral expansion on surface temperature variation. **Acta Scientiarum. Technology**, v. 45, n. 1, p. e60114, 2022. Disponível em: https://doi.org/10.4025/actascitechnol.v45i1.60117.

SILVA, H. et al. Agropecuária e urbanização: uma análise multivariada para Minas Gerais, 1995-2000. **Revista Econômica do Nordeste**, v. 39, n. 2, p. 285–305, 2017. Disponível em: https://doi.org/10.61673/ren.2008.459.

SOLA-CARABALLO, J. et al. Multi-criteria assessment of urban thermal hotspots: a GIS-based remote sensing approach in a Mediterranean climate city. **Remote Sensing**, v. 17, n. 2, p. 231, 2025. Disponível em: https://doi.org/10.3390/rs17020231.

ISSN 2318-8472, v. 13, n. 88, 2025

SONET, M. S. et al. Spatiotemporal analysis of urban expansion, land use dynamics, and thermal characteristics in a rapidly growing megacity using remote sensing and machine learning techniques. **Theoretical and Applied Climatology**, v. 156, p. 79, 2025. Disponível em: https://doi.org/10.1007/s00704-024-05264-3.

SOUSA, D. N. et al. A dinamização dos assentamentos rurais para o desenvolvimento econômico do Noroeste de Minas Gerais. **Revista de Ciências Humanas**, v. 11, n. 1, p. 1-22, jan. 2011. Disponível em: http://www.cch.ufv.br/revista/sumario.php?id=20.

SUN, Y. et al. Recognizing urban shrinkage and growth patterns from a global perspective. **Applied Geography**, v. 166, p. 103247, maio 2024. DOI: https://doi.org/10.1016/j.apgeog.2024.103247.

SUN, L. et al. Urbanização desigual dramática de grandes cidades em todo o mundo nas últimas décadas. **Nature Communications**, v. 11, p. 5366, 2020. Disponível em: https://doi.org/10.1038/s41467-020-19158-1.

TAIWO, B. E. et al. Monitoring and predicting the influences of land use/land cover change on cropland characteristics and drought severity using remote sensing techniques. **Environmental and Sustainability Indicators**, v. 18, p. 100248, 2023. Disponível em: https://doi.org/10.1016/j.indic.2023.100248.

TALEMA, A. H.; NIGUSIE, W. B. Spatio-temporal analysis of urban expansion using remote sensing data and GIS for the sustainable management of urban land: the case of Burayu, Ethiopia. **Management of Environmental Quality: An International Journal**, v. 35, n. 5, p. 1096-1117, 2024. Disponível em: https://doi.org/10.1108/MEQ-07-2023-0196.