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Spatio-temporal Changes of Land Use Land Cover in Bolpur Municipality: A Study in Urban Geography

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Abstract

This research aims to explore the changes that have occurred in the landscape of Bolpur Municipality regions because of rapid urbanization, population growth, and development in the period from 1950 to 2025. By using the combination of Remote Sensing and GIS, it analyzed the changes in the land use of the region by satellite images taken at various times. The results show that there is a trend – in the past thirty years, a large area of agricultural land and forests has been transformed into residential and developed land. The only category of land use that is truly increasing is land under buildings, but this is at the cost of agricultural land and natural beauty. The growth is driven by the development of infrastructure that is a result of policies aimed at economic freedom, the development of the tourism and education sectors (which is associated with Santiniketan), and the consequent movement of people into the area from the surrounding rural areas. The study indicates that to reduce the negative effects of the changes in the use of land and achieve balanced development in the future, it is important to have proper urban planning that is centered on environmental sustainability.

Keywords: *Rapid urbanization, Land use, Satellite images, Development, Urban planning.*

1. Introduction

The study of Land Use and Land Cover (LULC) change over time has emerged as a major area of interest in contemporary urban geography, particularly in the rapidly developing regions of the Global South (Mandal, 2014). Bolpur Municipality in the Indian state of West Bengal is an interesting case study for examining such changes because of its unique social, cultural, and geographical characteristics. Bolpur Municipality is famous for being the home of Rabindranath Tagore's Visva-Bharati University. The municipality has witnessed a substantial amount of urban development in the last few years, thanks to the growing population, development of infrastructure, and changing patterns of economic activity. The study of land use and land cover change provides us with a systematic approach to examine how both human and natural factors affect the physical environment over time (Dolui & Sarkar, 2023).

Such a study is extremely important for urban planners, policymakers, and environmental scientists. It will help them understand how cities are expanding, agricultural land is being converted into urban land, green spaces are being reduced, and buildings are encroaching on unoccupied land. In India, the rapid development of cities has resulted in major, largely unplanned, changes to the land, which affect groundwater, natural habitats, and the urban environment (Das & Das, 2019).

The application of remote sensing (RS) and Geographic Information Systems (GIS) has become a necessity in analysing these changes in land use and land cover. Satellite images, particularly Landsat satellites, provide us with a rich and time-critical dataset of land surface information. This enables us to identify and quantify changes in land use and land cover patterns of varying scales and over time. By integrating remote sensing and GIS analysis with ground truth data and socio-economic data, we can really get down to the roots of what is causing and what is being produced by the changes in urban land use (Shikary & Rudra, 2021). This research aims to investigate the changes that have occurred in the landscape of Bolpur Municipality over a given period through satellite images, classification, and accuracy assessment. The aim is to improve our understanding of the development of urban areas in small and medium-sized towns in India, particularly in the Birbhum District.

2. Conceptual Framework: Land Use Land Cover Change in Urban Geography

2.1 Defining LULC and Its Significance

Land use and land cover, although people tend to confuse them with each other, are two different but related concepts. Land cover is what the Earth's surface looks like, and this can include vegetation, water, soil, and structures, while land use is how humans use a particular area of land, such as for agriculture, residential, or leisure purposes. This distinction is crucial in urban geography, as one type of land cover can be used for many different purposes, and one type of land use can look very different depending on the surrounding environment (Ologunde *et. al.*, 2025). LULC change is recognized to have a huge effect on the environment globally. It affects factors such as biodiversity, climate, water cycles, soil quality, and the functioning of nature on a local and global scale. In urban geography, land use change is primarily driven by population increase, economic development, infrastructure expansion, and policy changes. The substitution of natural land with asphalted surfaces in urban areas has a huge effect on the energy balance in cities. This results in the urban heat island effect and affects climate conditions (Tikader, 2016).

2.2 Drivers of LULC Change

There are many reasons for land use and land cover changes in Bolpur Municipality, such as demographics, economy, infrastructure, and governance. Population growth is the major factor that really fuels the growth of cities. As more people require housing, shopping, and infrastructure, we are left with no choice but to convert agricultural land and green areas into developed land. It is very important to have a variety of transportation

systems such as roads, highways, and railways to attract more people to move to urban areas and hence develop cities (Sadhukhan & Trivedy, 2025). In Bolpur, however, things are changing quite a lot. Economic factors, such as the development of schools, more tourists arriving, and the development of businesses, are causing the city to grow and the land use to change. In India, cities are expanding as people are earning more money and moving to cities. Advancements in science, technology, and eco-friendly systems can reduce the pressure on the environment, but in the case of Bolpur, these factors have not been fully tapped yet. In addition, issues associated with governance, such as the effectiveness of local urban institutions and their capacity to handle urban development, are also major factors that influence land use and land cover change. Studies carried out on the management of cities in West Bengal have shown that the level of people's participation and influence in decision-making varies from one town to another (*Haque, 2018*).

3. Study Area: Bolpur Municipality in the Context of Birbhum District

3.1 Geographical Setting

Bolpur Municipality is in the Birbhum district of West Bengal, which is an eastern state in India. From a geographical perspective, Bolpur is an important urban center in the Rarh area of the state, located in the south-central part of Birbhum district (see Fig. 1). Birbhum, in turn, experiences a variety of land types – plain land in the eastern part and hill land in the western part. The western part has hard rock, making it difficult for groundwater and agriculture, while the eastern part has rich soil that is ideal for agricultural purposes. The southwestern part of Birbhum has lateritic soil that is highly susceptible to erosion, particularly rill and gully erosion (Das, 2020).

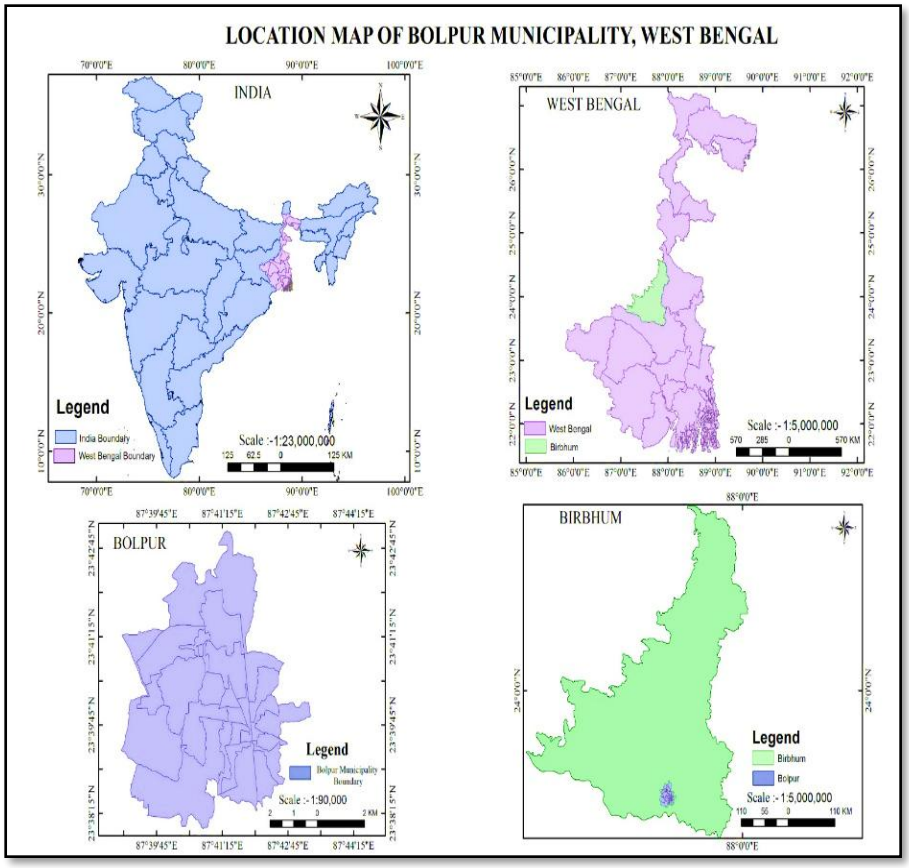

Figure-1: Location map of the study area

(Source: National Atlas and Thematic Mapping Organization, Kolkata; Bolpur Municipality)

3.2 Socio-Economic and Historical Context

Over in Bolpur, it has been a center for culture and learning for a long time because of Rabindranath Tagore and Visva-Bharati University. Over the past few decades, the town has expanded considerably with more people moving in and the city expanding. This was largely due to more schools and colleges being established, more tourists visiting, and more businesses being set up. In the Birbhum District as a whole, agriculture has become more intense in the eastern part, which is exerting a lot of pressure on the water resources in that region. The population in the district has been increasing, and this has resulted in more difficulties for the poor. Moreover, there is not enough land to support the number of people, and urbanization is taking place rapidly as everyone tries to keep up with the increasing demands. All these have contributed to the landscape not being as healthy as it used to be (Mondal, 2025).

4. Research Objectives:

The objectives of the present research entitled 'Spatio-temporal Changes of Land Use Land Cover in Bolpur Municipality: A Study in Urban Geography' are the followings:

- To analyze the Spatio-Temporal Changes of the Bolpur Municipality.
- To highlight the Urban Expansion and Land Conversion of the Study area.
- To find out the Environmental Consequences of Urban Landscape.
- To investigate the Sustainable Planning Strategies for the prospects of this area.

5. Database and Methodology:

The study's chosen methodologies determine the validity and dependability of any kind of research. Therefore, methodology is crucial in highlighting the main research findings.

5.1 Data Sources and Satellite Imagery

The analysis of the changes in the land use and land cover of Bolpur Municipality over the years requires the analysis of various satellite images taken at different times, using the Google Earth Explorers. Landsat data is employed in this research because of the vast amount of information it has over the years, and it is free to access. ArcGIS software has been employed to classify the land use and land cover changes to analyze the changes in urban growth and land use over the years. In addition to the analysis of the satellite images, it also analyzes topographic maps, census information, and field work to validate the land use and land cover maps obtained from remote sensing (Arif *et.al.*, 2023).

5.2 Classification Methodology

The research work has been applied with a technique known as the maximum likelihood classifier to produce a categorized image of land use and land cover (LULC). The technique applied in this research work included the

selection of training samples for each LULC class, followed by the categorization of all pixels in the images according to their spectral properties (Chamling & Bera, 2020). The land use types identified in Bolpur Municipality include built-up land, agricultural land, vegetation/forest, water bodies, and fallow/barren land. These are like the types of land use identified in other research works and can be identified by examining the categories mentioned above, which can teach a lot about land use patterns and provide us with a clearer picture of how the land is being used.

5.3 Change Detection and Spatio-Temporal Analysis

Change detection requires the comparison of land use and land cover maps at various times to identify and quantify the nature, extent, and location of changes. Through the analysis of land use transition processes, it is possible to interpret the trends and processes of change in land use, including the conversion of agricultural land to urban land, the reduction of vegetation, and the expansion of impervious surfaces (Jha *et.al.*, 2022). The analysis of changes in land use and land cover in Bolpur Municipality will enable us to better understand the changes that are taking place in the landscape. Through the examination of variables such as fragmentation, connectivity, and spatial relationships between various land use classes, it is possible to gain a deeper insight into the processes of change that are taking place.

6. Spatio-Temporal Changes of Land Use Land Cover Area

6.1 Temporal Dynamics of LULC Change:

Analysis of multi-temporal satellite images shows considerable changes in LULC patterns in Bolpur Municipality. The most noticeable change is the increase in built-up areas at the cost of agricultural land and vegetation cover, as noticed in other rapidly growing Indian towns (see the Fig. 2 & 3). The transition of agricultural land to built-up land is a very important trend in Bolpur Municipality, which is an indication of the overall trend of urban encroachment on prime agricultural land. Agricultural land displacement, urban sprawl, and deforestation, which result in habitat destruction, loss of agricultural land, and reduction of natural greenery areas, are features of rapid land cover change. In the context of Bolpur municipality, the loss of agricultural land has implications not only for food security but also for groundwater recharge, as LULC changes directly influence the recharge and demand of groundwater (Baral & Ghimire, 2026).

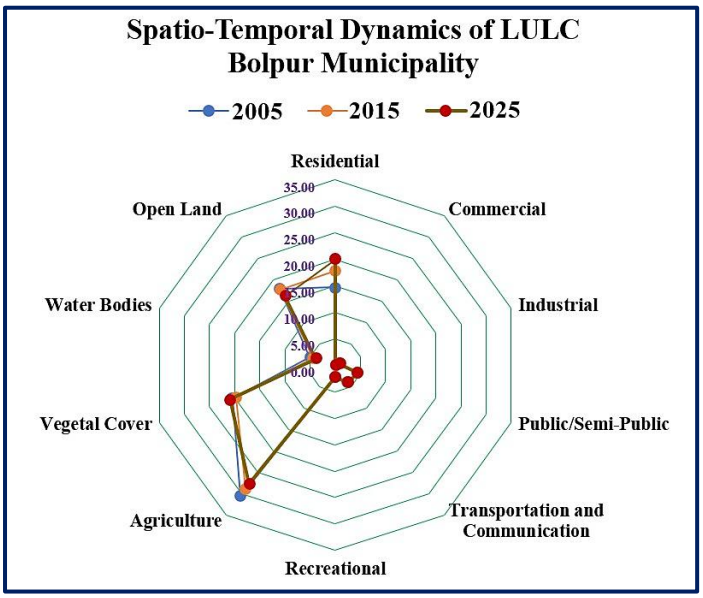

Figure-2: Location map of the study area

(Source: Prepared from LULC Maps of Bolpur Municipality)

6.2 Spatial Patterns of Urban Expansion:

The pattern of urban expansion in Bolpur Municipality is defined by the expansion of the built-up area from the traditional urban core, with new development taking place along major transportation routes and in areas that were previously agricultural or vegetated (Dolui & Sarkar, 2023). This is in line with the general trend of urban sprawl, which is defined by unplanned and irregular growth that is the result of a variety of processes that lead to inefficient resource use. The presence of multimodal infrastructure such as roads, highways, and rail lines is a key factor that facilitates the migration of people to urban areas, thus leading to urban expansion (Sarkar & Basak, 2026). The spatial analysis of LULC change in Bolpur Municipality shows a similar trend, with the greatest rate of expansion of built-up land in areas with easy accessibility to the urban core and major transportation routes (see the table-1).

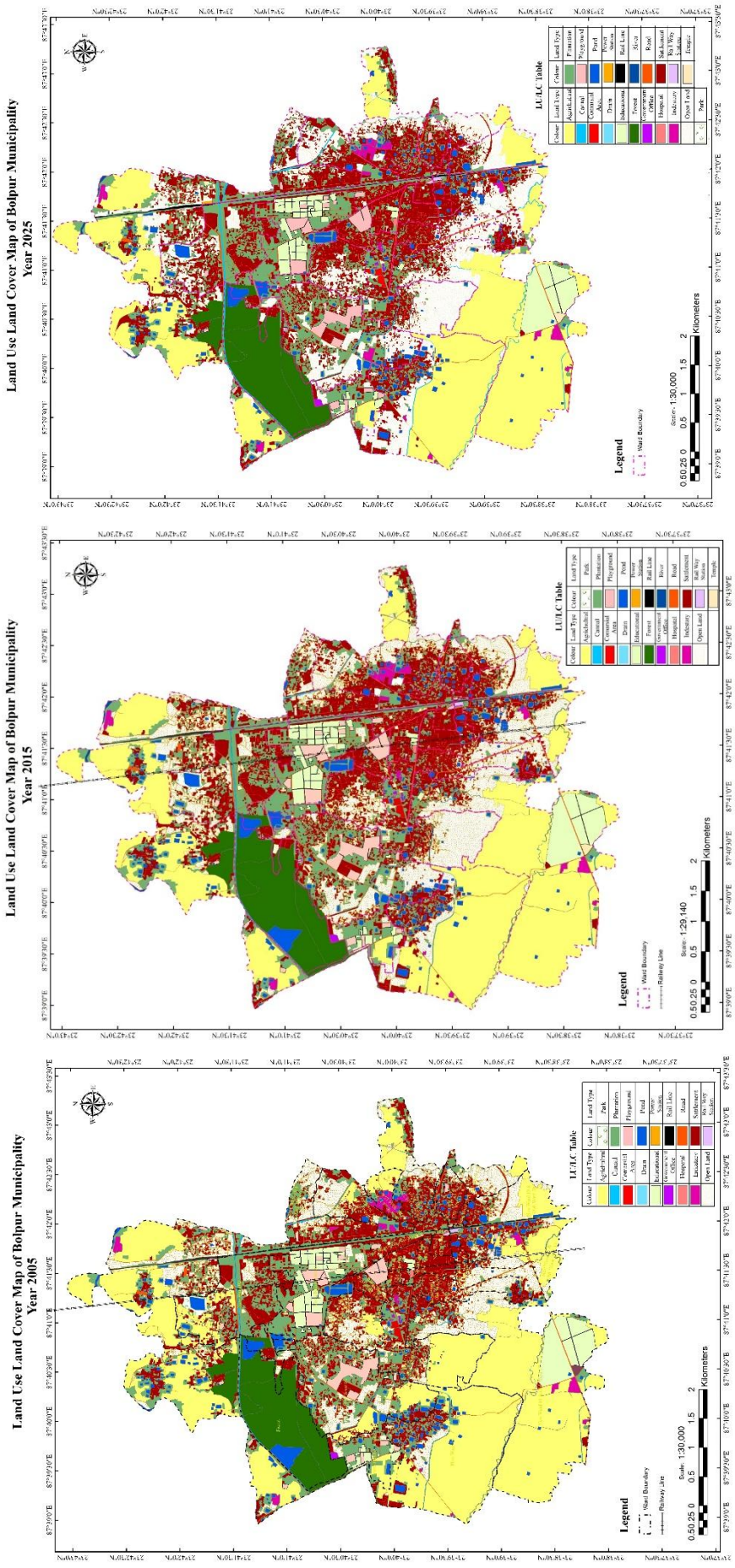

Figure-3: Spatio-Temporal dynamics of Urban Expansion at Bolpur Municipality

Table-1: Pattern of LULC Changes at Bolpur Municipality

(2005 to 2025)

Sl. No.	*LULC Types*	*Area in Sq km*			*Area in Percentage*		
		2005	*2015*	*2025*	*2005*	*2015*	*2025*
1	Residential	5.21	6.31	7.08	14.70	17.80	19.97
2	Commercial	0.04	0.04	0.04	0.11	0.11	0.11
3	Industrial	0.25	0.27	0.30	0.71	0.76	0.85
4	Public/Semi-Public	1.56	1.57	1.57	4.40	4.43	4.43
5	Transportation and Communication	1.4	1.43	1.44	3.95	4.03	4.06
6	Recreational	0.79	0.77	0.76	2.23	2.17	2.14
7	Agriculture	10.86	10.24	9.8	30.63	28.89	27.64
8	Vegetal Cover	7.23	7.00	7.38	20.39	19.75	20.82
9	Water Bodies	1.78	1.55	1.36	5.02	4.37	3.84
10	Open Land	6.33	6.27	5.72	17.86	17.69	16.14
	Total	**35.45**	**35.45**	**35.45**	**100.00**	**100.00**	**100.00**

(Source: LULC Maps of Bolpur Municipality)

7. Influences of Changing pattern of Land Use Land Cover

7.1 Vegetation and Agricultural Land Dynamics:

Analysis of LULC change in Bolpur Municipality indicates a substantial reduction in vegetation cover and agricultural land, which is in line with the trends identified in other rapidly urbanizing Indian towns (see the table-1). The reduction in agricultural land in Bolpur Municipality is also linked to the dynamics of groundwater, as LULC exerts a direct influence on the recharge and demand for groundwater. The reduction in agricultural land to built-up land results in a reduction in the area available for groundwater recharge, thus contributing to groundwater depletion (Das & Das, 2019).

7.2 Water Bodies and Hydrological Implications:

From the analysis of LULC changes in Bolpur Municipality, it is also observed that there are changes in the area and distribution of water bodies such as ponds, tanks, and seasonal water bodies. The destruction of water bodies due to urban encroachment has serious implications for hydrology and biodiversity (see the table-1). The hydrological effects of LULC change in Bolpur Municipality are further exacerbated by the lateritic geology of the Birbhum District, which is prone to erosion processes. The reduction in vegetation cover and the increase in

impervious surfaces contribute to increased runoff and decreased infiltration, which can further contribute to erosion and flooding. The effects of Bolpur Municipality are substantial, as the increase in impervious surfaces due to urbanization leads to reduced infiltration of rainfall into the soil, resulting in reduced groundwater recharge and potentially contributing to water scarcity (Mondal, 2025; Sarkar & Basak, 2026; Bhandary & Roy, 2024).

7.3 Impacts on Land Surface Temperature and Urban Heat Island:

The link between LULC change and land surface temperature (LST) is one of the important issues with urban expansion and the conversion of natural land cover to built-up land resulting in higher land surface temperatures and the urban heat island (UHI) effect. Urban areas experience warming because of the conversion of natural land cover to built-up land, which affects solar radiation receipt, shade provision, and heat and moisture fluxes between land and atmosphere, resulting in modified climate conditions and temperature enhancement in urban areas (Basu & Datta, 2018). There is a direct impact on Bolpur Municipality, where the increase in built-up land at the cost of vegetation and water bodies is likely to cause an increase in surface temperatures.

8. Inferences for Urban Planning and Urban Environment Management:

- ***Urban Planning Implications:*** Urban expansion prediction can be a powerful tool for decision-makers to prepare suitable future urban planning while protecting the regional ecosystem. Technologies of remote sensing and GIS can provide effective assistance in the process of urban planning like - monitoring and estimation of changes in LULC and unplanned development in Bolpur Municipality (Basu & Datta, 2018).
- ***Environmental Management Implications:*** The management of environment in the context of fast LULC change needs the development of spatial models that predict changes in the different land use change scenarios. These models can offer important scientific evidence to control or prevent future potential land degradation (Das & Das, 2019).
- ***Future Scenarios and Predictive Modeling:*** The creation of future LULC scenarios and models is a significant tool for assisting in the planning of Bolpur Municipality. The CA-Markov model is one of the most ideal and widely accepted models for urban growth of past and future time to predict the probability of LULC change (Mandal, 2014).

9. Conclusion:

This research work attempts to examine the way in which the land use and land cover have been varying over time in Bolpur Municipality. The application of remote sensing, GIS, and field techniques is combined in this research work to give a holistic approach. The findings of this research work have revealed that there are some significant and continuous changes occurring in the landscape of Bolpur Municipality. These changes are

occurring due to several factors such as population, economy, infrastructure, and management. These changes are having a significant impact on the ground water, help of nature, and the way in which the city feels. This research work emphasizes the significance of applying technology such as remote sensing and GIS in planning and managing the environment of Bolpur Municipality. Proper management of the city is needed to ensure that Bolpur Municipality grows in a sustainable and environmentally sound way.

This study makes its contribution to the existing literature on urban geography in India by providing a clear understanding of the development of the town over the years, given its historical and cultural importance. Future studies could focus on the development of more sophisticated models, integrating socio-economic and governance data in land use change analysis, and assessing the effectiveness of planning efforts in controlling the growth of cities and the environment.

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