iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: II Month of publication: February 2023

DOI: https://doi.org/10.22214/ijraset.2023.49227

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue II Feb 2023- Available at www.ijraset.com

Land Use and Land Cover Change Scenario of the Betwa River Basin of Madhya Pradesh: An Analysis Using Remote Sensing and GIS

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Abstract: An essential aspect of comprehending the dynamic nature of the environment is to examine the changes in land use and land cover (LULC).
This research work employed remote sensing and GIS approaches to explore the transformations of LULC in the Betwa River Basin of Madhya Pradesh, India. Satellite images from 2005 and 2021 were analyzed to identify the temporal evolution of land use and land cover in the region.
The results of the study demonstrate that the Betwa River Basin has witnessed a remarkable increase in agricultural land and built-up areas at the expense of forest cover. The study provides valuable information that can be incorporated in any land management policies and aid in sustainable development.
Keywords: Betwa River, GIS, LULC, Remote sensing,

I. INTRODUCTION

The transformation of land use and land cover is an ongoing and fluid procedure that embodies the interdependent relationship between human endeavours and the surrounding ecosystem. The alteration of land use and land cover has the potential to cause a substantial influence on the ecosystem and the variety of living organisms within a particular area. A scientific study by [1] specialists focused on assessing changes made to land use and land cover, as well as the underlying components involved, carry significant implications for both the natural environment and the well-being of human society.

A comprehensive understanding of the past and present modifications to land use and land cover is vital for proficiently managing the land and water resources of the basin, and it is equally important to anticipate and simulate the potential future changes [2]. Therefore, studying LULC variation is crucial for understanding the changes in the environment and formulating sustainable land management policies.

Remote sensing and GIS techniques have proven to be useful in studying impact of LULC change, as they offer precise and comprehensive data concerning the alterations in land use and land cover that have occurred within a specific region.

The Betwa River Basin is an important agricultural region in India, covering an area of approximately 29,059 km². The basin is located in the central part of India and is an important source of water for irrigation, hydroelectric power, and domestic use. The region is characterized by a diverse landscape, including forests, grasslands, wetlands, agricultural lands, and urban areas. The Betwa River Basin is also home to a rich biodiversity, including several endangered species.

The primary goal of this research is to investigate the LULC in the Betwa River Basin of Madhya Pradesh from 2005 to 2021, using remote sensing and GIS techniques.

By identifying changes made to land use and land cover, this study intends to evaluate the potential consequences of these changes on the environment and human activities within the region.

II. STUDY AREA

The Betwa river starts its journey from 576 mean sea level, and flows through near Barkhera village south-west of Bhopal, Madhya Pradesh, India shown in Figure 1.

The present study utilizes the remote sensing data product, that is satellite imagery used in the GIS platform to study the upper part of the Betwa river basin of Madhya Pradesh, in a dry subhumid region which covers part of Bhopal, Vidisha, Ashoknagar, Sagar, Raisen, Guna, Sehore, Shivpuri (Narwar) districts of Madhya Pradesh and Lalitpur district of Uttar Pradesh, India.

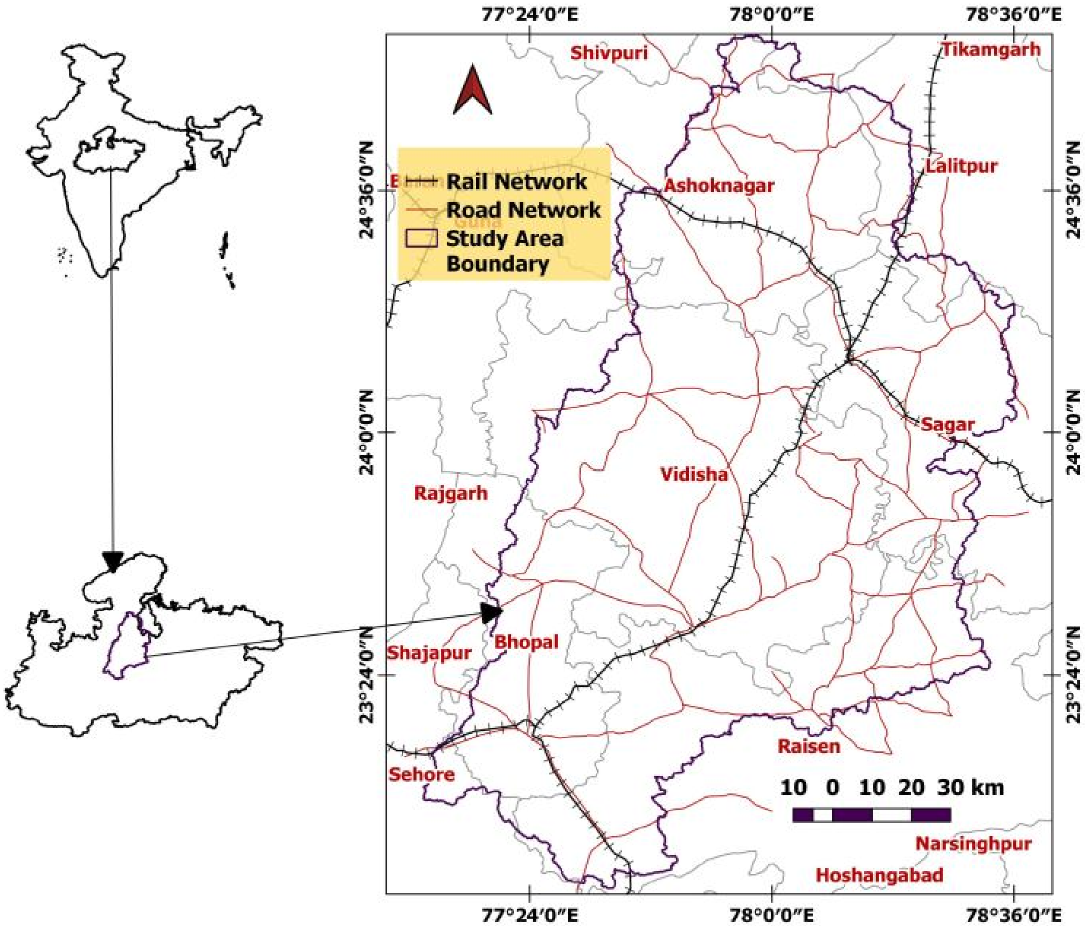

Fig 1 Geographical location of study region

III. MATERIAL AND METHODS

To conduct this analysis, Satellite images from the Landsat series acquired in 2005 and 2021 were used. The satellite images were downloaded from the USGS Earth Explorer website and processed them using 'semi-automatic classification' plug-in in QGIS software. Supervised classification techniques were used to classify the images into different land cover types, including built-up areas, forests, agricultural lands, barren land, and waterbody. The classified map of land use/land cover for the two specified periods was facilitated through the use of GIS techniques. Table 1 contains details on the satellite images employed in this process.

TABLE I
DESCRIPTION OF SATELLITE IMAGES USED FOR LAND USE/LAND COVER CLASSIFICATION

Satellite	Path/Row	Acquisition Date	Resolution
Landsat 5 TM	145/43 145/44	09-Feb-2005	30 meter
Landsat 8 OLI	145/43 145/44	20-Jan-2021	30-meter

IV. RESULTS

A. Accuracy Assessment

To ensure the accuracy of historical LULC classified map that is obtained via remote sensing satellite (Landsat) imagery, it is essential to conduct an accuracy assessment. Sitthi et al. (2016) [3] and Morales-Barquero et al. (2019) [4] proposes that an confusion/error matrix can be employed to perform a comparative analysis of a classified map against a reference classification map.

This analysis enables the determination of the accuracy of the classified LULC map. The conclusions drawn from this research are in agreement with the findings of other studies carried out in India, such as the research by Rimal et al. (2018) [5]. The investigation's prediction accuracy indicates that it falls within the acceptable range of precision for the use of maximum likelihood classification of Landsat images.

TABLE II
RESULT OF ACCURACY ASSESSMENT FOR THE YEAR 2005 AND 2021

LULC - 2005	Agriculture	Built-up	Waterbody	Forest	Barren Land	Total	User accuracy	Total class area (km²)	Area Proportion (Wi)
Agriculture	107	3	34	7	10	161	0.66	13274.40	0.7016
Built-up	1	89	1	3	4	98	0.91	377.28	0.0199
Waterbody	1	0	55	0	1	57	0.96	466.19	0.0246
Forest	3	1	5	76	8	93	0.82	3513.48	0.1857
Barren Land	15	4	7	27	38	91	0.42	1289.71	0.0682
Total	127	97	102	113	61	500		18921.06	
Producer accuracy	0.96	0.50	0.13	0.75	0.32				
Kappa = 0.61, **Overall Accuracy** = 73%, **Standard deviation** = 0.03									

LULC - 2021	Agriculture	Built-up	Waterbody	Forest	Barren Land	Total	User accuracy	Total class area (km²)	Area Proportion (Wi)
Agriculture	141	0	28	12	19	200	0.71	13926.26	0.7360
Built-up	5	90	3	3	4	105	0.86	961.15	0.0508
Waterbody	0	0	45	0	0	45	1.00	371.15	0.0196
Forest	2	2	5	74	5	88	0.84	3013.50	0.1593
Barren Land	4	5	6	24	23	62	0.37	649.00	0.0343
Total	127	97	102	113	61	500		18921.06	
Producer accuracy	0.98	0.87	0.10	0.69	0.10				
Kappa = 0.63, **Overall Accuracy** = 74.6%, **Standard deviation** = 0.03									

The accuracy assessments of LULC classified map were determined by producing error matrices for each LULC category of classified maps for the year 2005, and 2021. The evaluation used kappa statistics, accuracy of the producer and user, and overall accuracy. The years 2005 and 2021 exhibited an overall accuracy and kappa statistics of 0.61 and 0.63, and 73% and 74.6%, respectively, as depicted in Table 2. An accuracy of more than 70% is deemed acceptable, while classifications can be considered to have a remarkable level of agreement when the Kappa value is within the range of 0.40 to 0.85 [6].

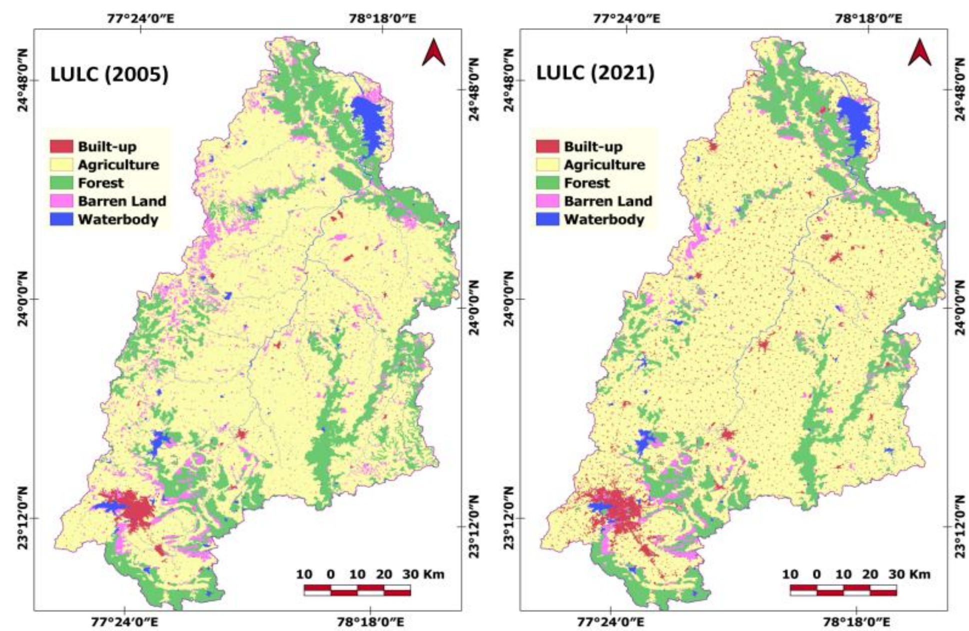

Fig. 2 Classified land use and land cover for year 2005 and 2021.

B. Classification Result

The spatiotemporal variations in land use and land cover classes between the year 2005 and 2021 are shown in Figure 2. The investigation indicates substantial transformations in land use and land cover categories within the Betwa River Basin from 2005 to 2021. The results show that there has been a substantial increase in agricultural land, which accounted for 70.16% is increased to 73.6% in 2021. The forest cover, on the other hand, has decreased from 18.57% in 2005 to 15.93% in 2021. The barren lands and waterbody have also decreased, while the built-up areas have increased from 1.99% in 2005 to 5.08% in 2021.

TABLE III
PERCENTAGE AND RATE OF CHANGE IN LULC CLASSES

LULC Classes	Area in 2005 (km²)	Area in 2005 (%)	Area in 2021 (km²)	Area in 2021 (%)	Change in area (km²)	Change in area (%)	Rate of Change (km²/year)
Agriculture	13274.3961	70.16	13926.2562	73.60	651.86	4.91	40.74
Built-up	377.2818	1.99	961.1541	5.08	583.87	154.76	36.49
Waterbody	466.1946	2.46	371.1465	1.96	-95.05	-20.39	-5.94
Forest	3513.4758	18.57	3013.5042	15.93	-499.97	-14.23	-31.25
Barren Land	1289.7099	6.82	648.9972	3.43	-640.71	-49.68	-40.04
Total	18921.06	100.00	18921.06	100.00			

The land use maps created using GIS techniques revealed that there is substantial modification at remarkable scale in the land use patterns are present within the study site. The study identified four main land use classes that shows significant transitions, includes, built-up areas, agriculture, forest lands, and barren lands. The land use assessment carried out for the years 2005 and 2021 in the Betwa River Basin revealed that agriculture was the most extensive land use category in the region, followed by forest lands. However, the analysis showed a noteworthy increase in urbanization as the built-up areas expanded by 2 to 5% at the expense of other land use classes in the study area. Loss, and gain change of LULC are shown in Figure 3. A visual representation of the five LULC categories and the area they cover for the years 2005, and 2021 are shown in Figure 4.

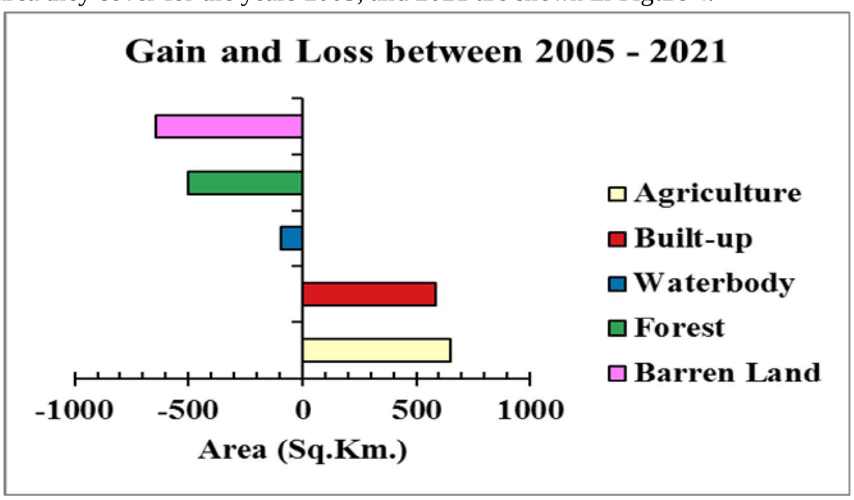

Fig. 3 Gain and Loss from 2005-2021

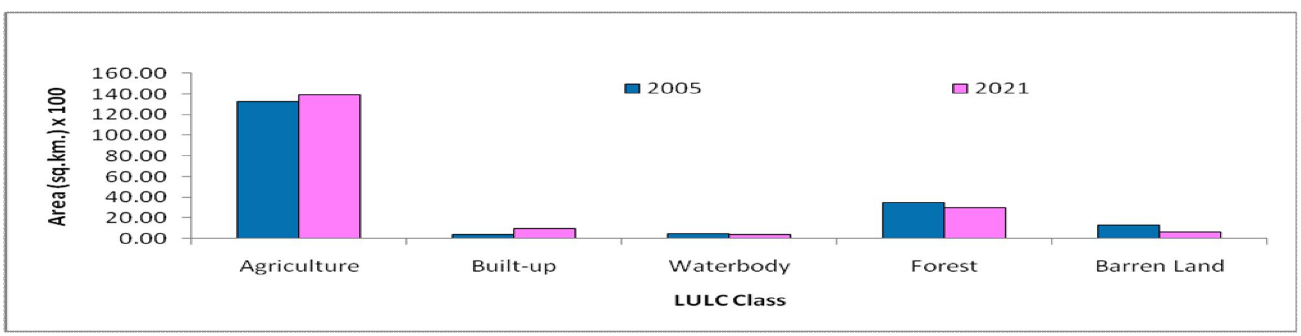

Fig. 4 Transformation of LULC classes from 2005 to 2021

V. DISCUSSION

The findings of the investigation indicate a remarkable transformation in LULC categories of the Betwa River Basin over the period of 2005 to 2021. The increase in agricultural land can be attributed to the growing demand for food and the expansion of agricultural practices in the region. The decrease in forest cover, on the other hand, is due to deforestation, and land-use conversion for agricultural and urban development. The transformation of land use may be linked to the decrease of waterbodies, such as the conversion of wetlands for agriculture, urbanization and infrastructure development.

The rise in urbanization, population, and infrastructure development has resulted in an increase in built-up areas. The growth of built-up areas can lead to various environmental and social challenges, including the loss of natural habitats, air and water pollution, and increased vulnerability to natural disasters such as floods and landslides.

The study provides valuable information that can be used to inform land management policies in the Betwa River Basin. The study's outcomes provide essential information for designing sustainable LULC strategies that balance economic development with environmental conservation. For example, the study highlights the need to protect the remaining forest cover in the region and promote afforestation and reforestation programs. The study also emphasizes the need to promote sustainable agricultural practices that reduce the pressure on natural resources and minimize the environmental impact of agriculture.

VI. CONCLUSION

The results of the study show the efficacy of the remote sensing and GIS approach in analyzing and understanding LULC change in the Betwa River Basin of Madhya Pradesh. The results of the study provide valuable insights into the changes in LULC in the region and their implications for the environment and human activities. The study highlights the need for sustainable land-use practices that balance economic development with environmental conservation. The findings of the study can be used to inform land management policies and aid in sustainable development in the Betwa River Basin of Madhya Pradesh and other similar regions. Further study is necessary to grasp the prolonged enduring effects of land use alterations on the natural environment and human activities in the region.

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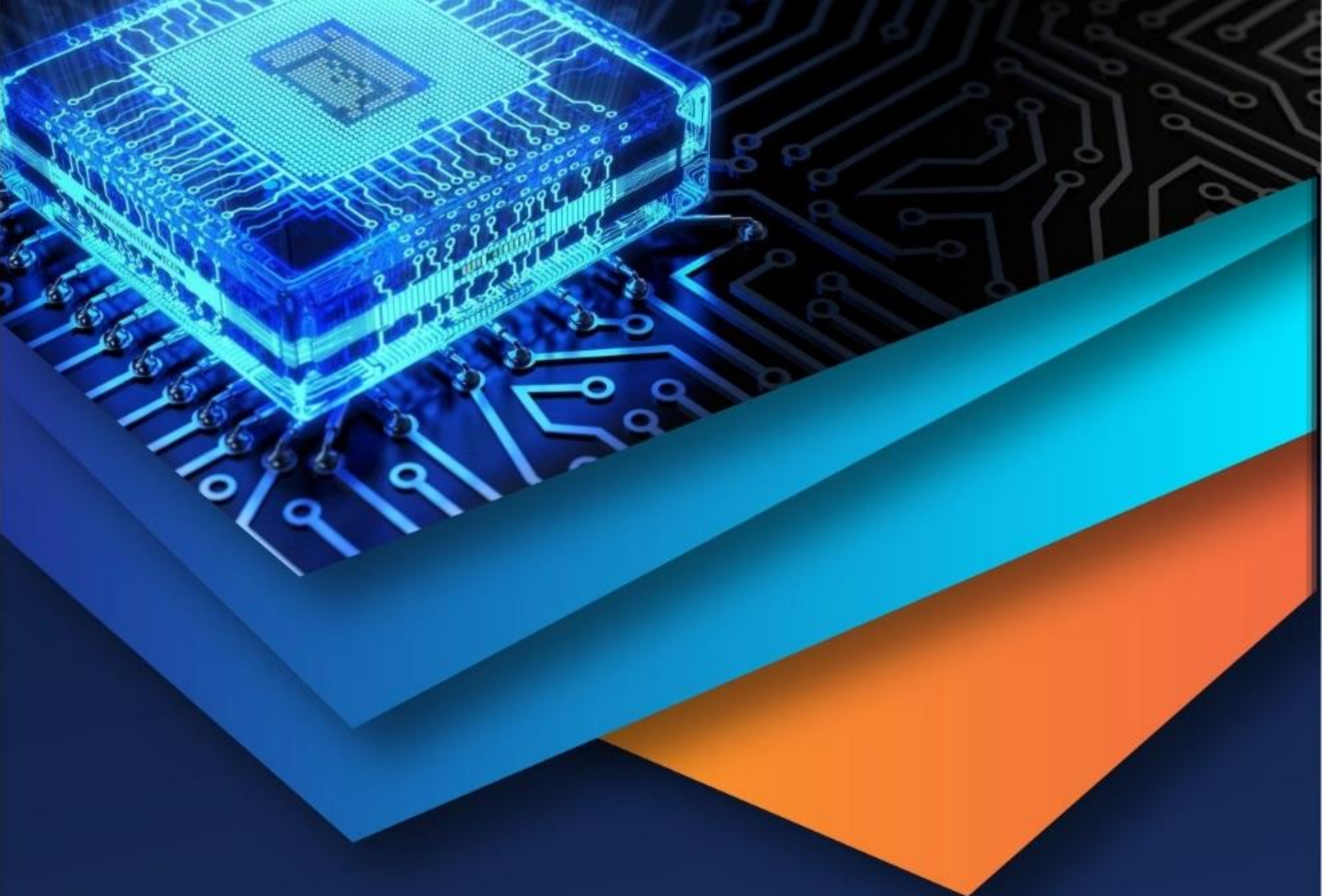

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