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Temporal Analysis of Water Bodies in Mega Cities of India

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Wetlands play an important role in recharging aquifers and stabilizing urban ecosystem. Wetlands attenuate the severe floods by storing water, provides habitat to different kinds of flora and fauna and improves water quality. Thus wetlands play a vital role in urban ecology. In recent years, many of these wetlands are being threatened due to increased land use activities. Thus the study highlights the land use analysis of ten mega cities of India that substantially showed decline in lakes and tanks of the city due to urbanization process. As a result of rapid urbanization, many of the water bodies have been lost and some are totally polluted. Urban sprawl is the major cause for the environmental degradation, makes greater demand on natural resources and hence associated with lose of wetlands. Medium and high-rise buildings have come up on some of these lakes and show the deterioration in the natural catchments flow and degrade the water quality. Unplanned urbanization and development activities have effected tremendously on these wetlands led to substantially decline in the storage capacity of the aquifers. The prime objective of this study is the wetlands dynamics of ten cities using remote sensing dataset and also to understand the rate of change in spatial extent of these wetlands during last four decades. Land use analysis was done to show the changes in four major categories- urban, vegetation, water bodies and others that revealed drastic increase in urban category with sharp decline in the water bodies.

Keywords: Water bodies, wetlands, remote sensing and GIS, urbanization.

1.0 Introduction

Wetlands are areas of land that are covered by water indicating seasonal and perennial variability. Wetlands provides habitat to large varieties of plant and animal species, adapted to seasonal variation of water levels. It meets the essential needs of the human beings such as drinking water, food, energy and stabilizes the climate (Ramachandra and Uttam Kumar, 2008). Wetlands are important source of ecosystem that removes the dissolved nutrients and improves the quality of water. In India, 3.2% of the geographic area constitutes the wetlands and supports the aquatic biodiversity (Prasad et al. 2002). However in recent years, increased populations, industrialization, residential and agricultural development, most of these wetlands have discovered to be disappeared and some are degraded in its quality. As a population spikes, the pressure on the wetlands increases (Rahman, and Begum, 2011). The human induced treats and encroachment for infrastructure development have resulted in the destruction of wetlands (Amezaga, et al., 2002). The major causes for the wetland destruction are due to dam construction, soil erosion, intense fertilizer usage, sewage and industrial waste etc. Due to anthropogenic and climatic changes, these wetlands are getting extinct in time.

There is a need for the preservation of wetlands involving sustainable management that guarantees the maintenance of wetlands for future generations (Amezaga and Santamaria, 2000). As a consequence, the sustainable management of wetlands becomes the one of the critical issues for decision makers (Schuyt, 2005). Watershed management is recognized as ideal approach for sustainable and natural resource management in rain fed areas. Watershed is geographical area, in which water becomes concentrated within particular location, to form rivers, streams, and reservoir etc., and also consists of the region drained by these features. The watershed forms the link between the land and wetlands resources which balances the ecosystem by improving the quality of water, controlling flood, stabilizes the climate, reduces soil erosion etc. Degradation of watershed due to anthropogenic activities as well as natural changes has brought reduction in quantity and quality of water resources. Watershed management aims at providing the sustainable use of natural resources considering both spatial and temporal variability of wetlands (Ramachandra and Uttam Kumar, 2004). Thus sustainable management approaches through the optimal resource planning deals with spatial and temporal mapping of wetlands using remote sensing and GIS (Deka et al., 2011). The satellite data acquired at various spatial and temporal scales provides the variation in spatial extent of wetlands which further helps in planning and monitoring land and water resources for optimal utilization (Navatha, et al., 2011). Remote sensing and GIS offers cost effective method for delineate the wetlands, drainage networks and to manage precise information on wetland characteristics. In recent years, due to increased urbanized process, wetlands are destructed and encroached by human activities. Thus satellite imagery helps in mapping the temporal changes that occurred in wetlands due to landuse activities. Remote sensing data plays a vital role in water management and its conservation and mapping of wetlands enables us to study hydrological process (Ramachandra and Uttam Kumar, 2008).

2.0 Study area

The study area includes the two major cities of India mainly Delhi and Mumbai. Both of these cities facing decrease in wetlands due to increased urbanization.

Delhi is the capital of India and it is the fastest growing city in the country. It is largest metropolis by area and second largest metropolis by population after Mumbai. It is the eighth largest metropolis in the world by population with more than 16.75 million inhabitants in the territory and with nearly 22.2 million residents in the National capital region. It is located at 28.61° north latitude and 77.23° east longitude. It borders the Indian states of Uttar Pradesh to the east and Haryana on the north, west and south and is situated on the banks of the River Yamuna.

Mumbai is the capital of the Indian state of Maharashtra. It is located 18°55'N latitude and 72°50' E longitude and bounded by Arabian Sea to the west. It is the most populous city in India, and the sixth most populous city in the world and it is also considered as the commercial capital of India and serves as an economic hub of India.

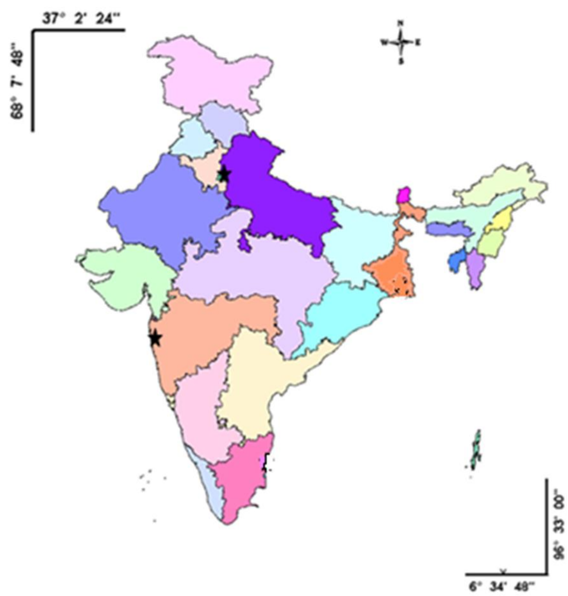


Figure 1: Two mega cities of India- Delhi and Mumbai

3.0 Data acquisition

Landsat satellite images of Delhi, Mumbai, Kolkata and Hyderabad were acquired for different time period from Global Land Cover Facility http://www.glcf.umd.edu/index.shtml (GLCF) and http://www.landcover.org/), United States Geological Survey (USGS) Earth Explorer (http://edcsns17.cr.usgs.gov/NewEarthExplorer/) and Glovis (http://www.glovis.usgs.gov.) websites. Table 1 provides the details of the LANDSAT satellite image that are used in the study. The Digital Elevation Model (DEM) data was obtained from Global Land Cover Facility (http://glcf.umiacs.umd.edu/data/srtm/)

4.0 Methods

Temporal analysis of water bodies using remote sensing data for Delhi and Mumbai was done using the data Landsat series Multispectral scanner (57.3m) and Thematic mapper (28.5). This data were resampled to 28.5m using nearest neighbor interpolation techniques. The base layers were generated from Survey of India (SOI) topo-sheets of 1:50000 and 1:250000 scales. The study area includes the Delhi and Mumbai administrative boundary extended to 10 Km buffer boundary to understand the dynamics at city outskirts due to urbanization process.

Land use analysis was done using maximum likelihood supervised classification technique and classes include: built-up, vegetation, water bodies and others. The excessive noise in the classified images was removed using 3X3 filter.

Digital elevation models are used in the study for extracting drainage network. DEM images were also resampled to 28.5m using nearest neighbor interpolation techniques. The DEM data is elevation data and helps in assessing the terrain characteristics and widely used in hydrological analysis and modelling. Wetlands were extracted from the temporal land use layers, which illustrates the changes during four decades. The wetlands of the Delhi and Mumbai regions are draped on DEM to analyze the impact of urbanization.

Estimation of Land surface temperature: Land surface temperature was calculated from thermal band of Landsat Thematic mapper. Digital number of the band was converted to spectral radiance L_{ETM} using eq (1),

$L_{ETM} = 0.0370588 \times DN + 3.2$ (1),
The black body temperature or at satellite brightness temperature was calculated T_k, eq (2), K1 and K2 are considered as K2 and K2 are pre-launch calibration constants.
$T_k = K2/\ln (K1/ LETM + 1)$ (2)
Surface emissivity is specified for each of the landuse (Snyder et al., 1998).

Landsurface temperature is calculated, using eq (3), where ε is surface emissivity

$$Ts = \frac{Tk}{1+\left(\lambda * \frac{Tk}{p}\right)\ln \varepsilon} \quad (3)$$

5.0 Results and Discussion

Figure 2 provides the land use details for Delhi (1977, 1992, 1998 and 2010) and Mumbai (1973, 1992, 1998 and 2009) and Table 1 shows the accuracy assessment for all the images. Table 2 gives temporal land use details for both cities. Figure 3 shows the Delhi and Mumbai land-use statistics from 1970's to 2010's. The percentage of water bodies have been decreased in Delhi from 1977 to 2010 i.e., 1.7% to 0.58% and for Mumbai 1973 (4.25%) and 2009 (4.06%).

The classified images of Delhi (2010) and Mumbai (2009) are draped on the DEM (SRTM) images to show the urbanization process with respect to terrain. Figure 4 clearly indicates that flat surfaces have major human activities than highly elevated surfaces. The NVIZ module GRASS gis is used to visualize the 3D view of the draped image. Figure 5 represents the extraction of water bodies of four decades for Delhi and Mumbai.

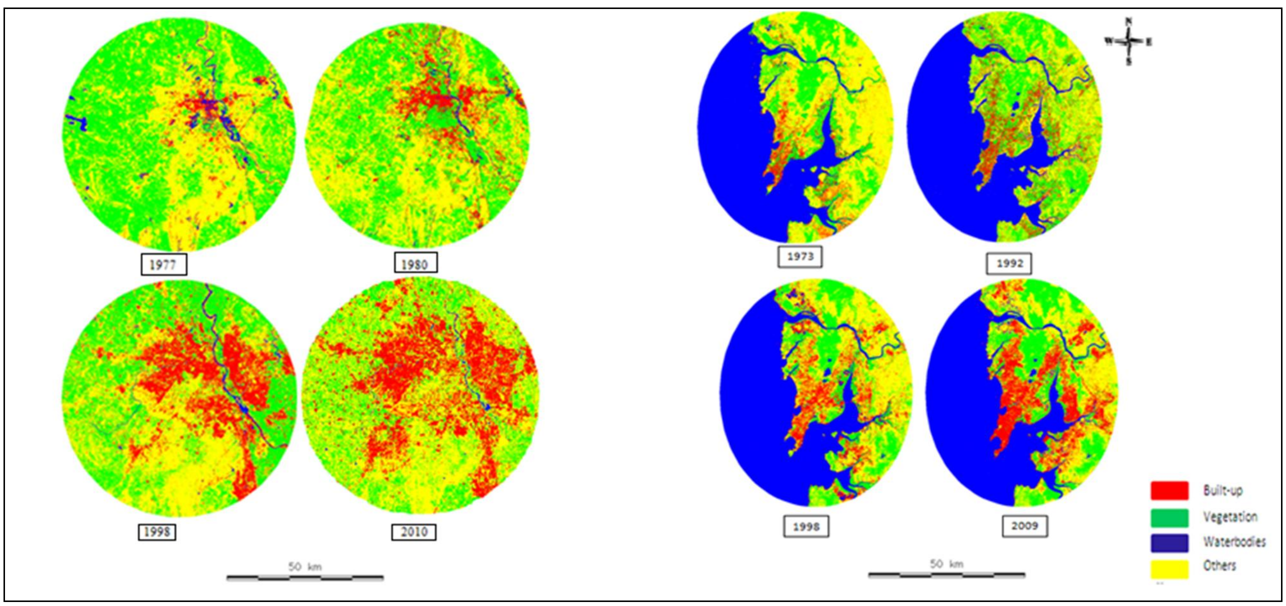


Figure 2: Land use of Delhi (1977, 1980, 1998 and 2010) and Mumbai (1973, 1992, 1998 and 2009).

Cities	1970s		1980s		1990s		2000s	
	OA	$\hat{k}$	OA	$\hat{k}$	OA	$\hat{k}$	OA	$\hat{k}$
Delhi	89	0.9432	99	0.9957	97	0.9887	88	0.7163
Mumbai	73	0.9471	98	0.8115	99	0.8225	99	0.8193

Table 1 Accuracy assessment of classified images

Delhi (year)	*Built-up*		*Vegetation*		*Water bodies*		*Others*	
	Area (sq.km.)	***Area (%)***	***Area (sq.km.)***	***Area (%)***	***Area (sq.km.)***	***Area (%)***	***Area (sq.km.)***	***Area (%)***
1977	105.3	3.60	1120.	38.3	49.7	1.70	1650	56.4
1980	283.3	9.71	1115.	38.2	26.3	0.90	1492	51.1
1998	580.8	19.8	918.6	31.3	43.0	1.47	1383	47.2
2010	733.2	25.0	603.1	20.6	17.0	0.58	1572	53.7

Mumbai (year)	*Built-up*		*Vegetation*		*Water bodies*		*Others*	
	Area (sq.km.)	***Area (%)***	***Area (sq.km.)***	***Area (%)***	***Area (sq.km.)***	***Area (%)***	***Area (sq.km.)***	***Area (%)***
1973	107	5.23	636	31.04	87.1	4.25	1220	59.49
1992	261	12.77	780	38.06	83.9	4.18	924	44.99
1998	327.7	15.98	724	35.3	98	4.8	899	43.87
2009	493	24.06	574	28.01	75.3	4.06	907	43.87

Table3 Land use statistics of Delhi and Mumbai.

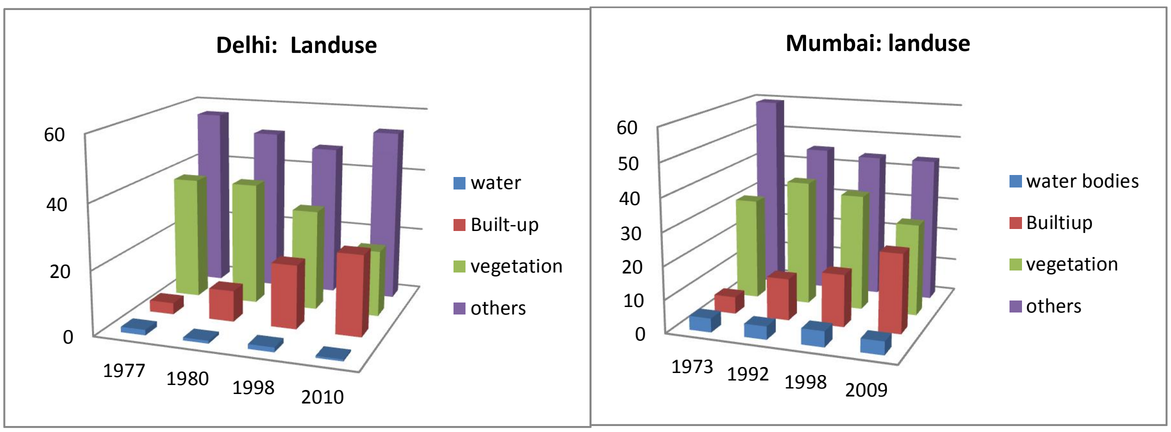


Figure 3 Delhi and Mumbai temporal land uses.

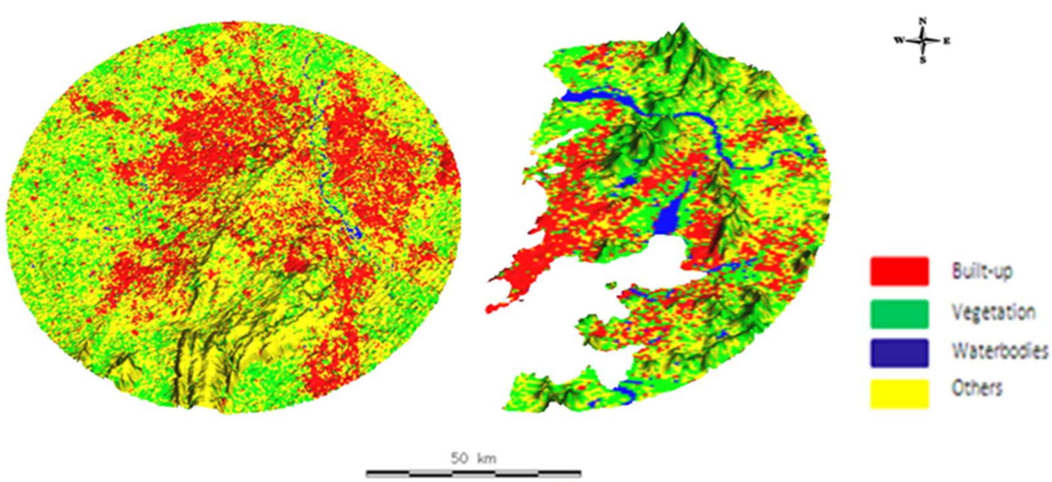
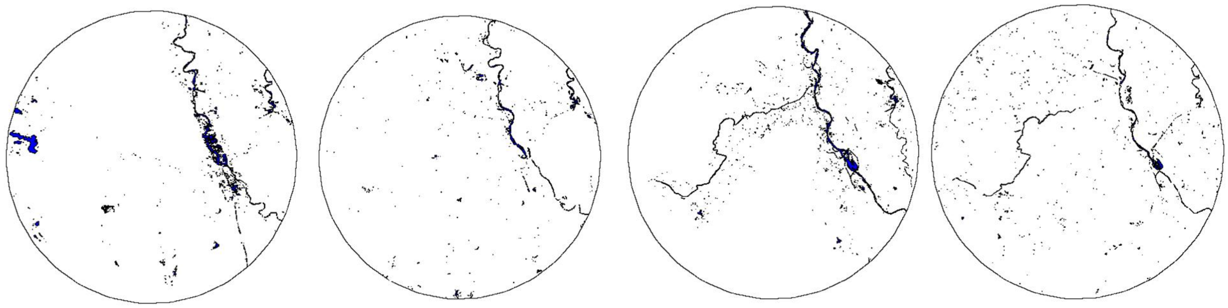
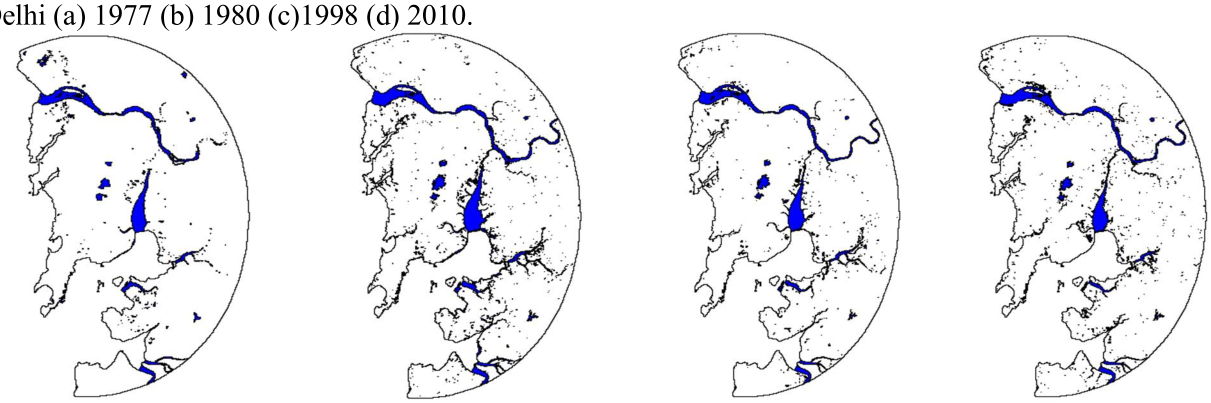


Figure 4: Land use of Delhi (2010) and Mumbai (2009) draped on Digital Elevation model (DEM)



(a) (b) (c) (d)

Delhi (a) 1977 (b) 1980 (c)1998 (d) 2010.



(1) (2) (3) (4)

Mumbai (1) 1973 (2) 1992 (3) 1998 (4) 2009

Figure 5: Extraction of water bodies for Delhi and Mumbai

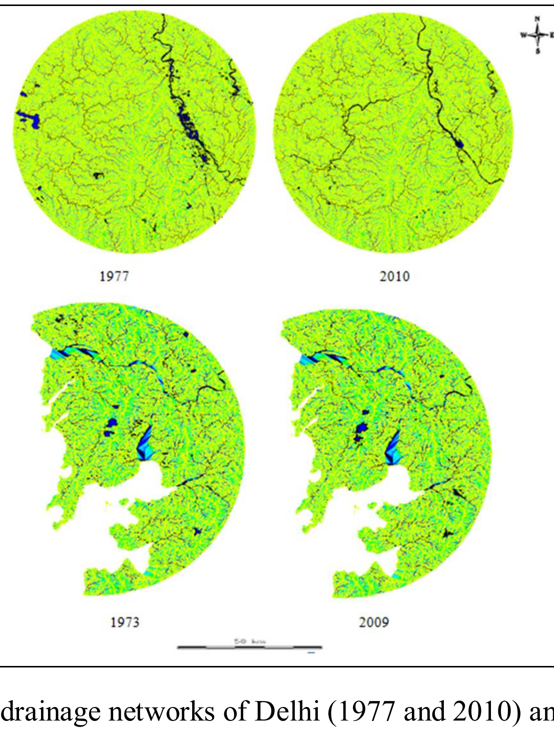


Figure 6: Water bodies with drainage networks of Delhi (1977 and 2010) and Mumbai (1973 and 2009)

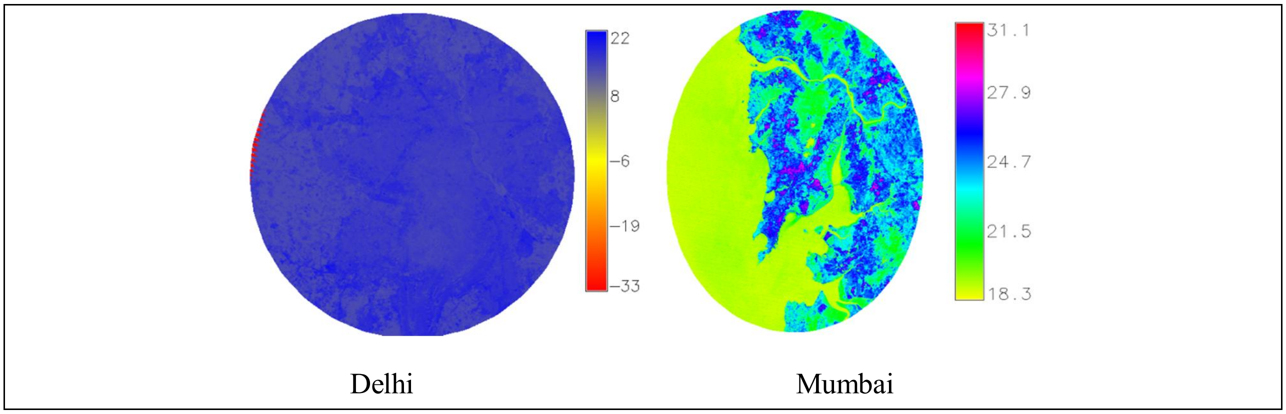


Figure 7: Land surface temperature for Delhi and Mumbai

Watershed analysis helps in assessing the catchment conditions of water bodies which will be useful for conservation of water and natural resources. The DEM image is used to delineate the drainage network. In which elevation values are taken as the input to create the flow direction as well as the flow accumulation map across the landscape. The Yamuna basin covers almost the Delhi region and survives as the major source of water. The fig 6 shows the overlay of water bodies of Delhi (1977 and 2010) and Mumbai (1973 and 2009) on the drainage network extracted from DEM data represents the temporal variation of wetlands.

Estimation of Land surface temperature depicted the Delhi's temperature for urban category 21 ℃, vegetation 15 ℃, water bodies 10 ℃ and others category 22 ℃ . Similarly, Mumbai temperature map showed 30 ℃ for urban category, 21.5 ℃ for vegetation, 18.3 ℃ for water bodies and 27 ℃ for other category as shown in figure 7. Temporal analysis indicates that urbanization process resulting in decline in the water bodies has contributed to enhanced ambient temperatures.

6.0 Conclusion

The temporal remote sensing data showed that urbanization process have reduced the wetlands of Delhi from 1.70% (1977) to 0.58% (2010) and Mumbai from 4.25% (1973) to 4.06% (2009). Comparison of water bodies of Delhi of year 1977 to 2010 and Mumbai of 1973 and 2009 illustrate of conversion of water bodies to other land use categories, mainly built-up category.

7.0 Acknowledgement

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8.0 References

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