VEGETATION DYNAMICS AND LAND USE/LAND COVER CHANGE IN CHONGMING ISLAND OF SHANGHAI, CHINA

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ABSTRACT: Vegetation and land use/land cover change are occurring at rapid rates as human activities induced global climate change increases. Analyzing detailed transition process among various land use/land cover types of Chongming Island of Shanghai, China is important to develop strategies for sustainable development and protection of its ecological settings. Accurate land use/land cover information over the past 30 years (1979-2009) was first extracted based on Landsat MSS, TM, ETM and ALOS and object-oriented classification. Vegetation, land use/land cover dynamics and the mutual conversions among different land use/ land cover classes were analyzed through the calculation of change matrix derived from classified images and application of land use/ land cover transfer model. The results showed that the absolute quantity of vegetation change and associated dynamicity were great in terms of the internal conversion among these main land use classes during the different time interval, although the decrease of vegetation coverage was significant and the ratio of vegetation cover area to the total area of the island had decreased from 71% (1979) to 52% (2009) with the expansion of Chongming Island by 358km^2 from 1979 to 2009. Water body, build-up area and road had stable increasing dynamicity per decade during the past 30 years. The change trend of land use closely related with requirement of social and economic development in given time besides natural evolution factor. The change trajectory of land use/land cover is expected to be a good quantitative measurement for better understanding of the spatio-temporal pattern of land cover change and provide much information for decision-making.

INTRODUCTION

The dynamics of vegetation coverage, land use/land cover (LULC) change and associated driving forces are one of the key issues in global environmental change. Detecting and monitoring of vegetation and LULC is thus essential to obtain a database for decision making in rapidly changing environments. Quantification and mapping of LULC is especially urgent in Chongming Island (121.56°N and 31.75°W) of Shanghai, China, which has been proposed to become an “ecological” island in the near future. This island has grown from a small isolated island to one of the world’s narrowest and longest alluvial island. With rapid economic development and population growth, the land use/land cover changes along with its expansion profoundly altered the ecological environment and sustainability of rural development in the island. It is extremely important to monitor effectively vegetation change and LULC patterns with respect to develop strategies for sustainable development and protection of its ecological settings.

Remote sensing is one of the most important and irreplaceable information sources for deriving land use / land cover information in a timely and cost-effective manner. Considerable progress has been made in the development of monitoring and change detection methods using remote sensing data (George Xian,2005). The expansion characteristics of Chongming Island and associated driving forces have been analyzed from Landsat TM and ALOS images by using object-based classification. The main driving forces behind the changes are identified as rapid economic development and policy orientation besides the natural geographic factor(Shen, 2012). In addition, for the specific location and development orientation of Chongming Island, the landscape ecological security pattern and planning of green space system were often studied with the application of remote sensing data. Qi Ren-hai evaluated the current status & planning of green space system using landscape metrics(Qi Ren-hai， et al. ,2007).Wangliang analyzed the landscape ecological security pattern about Chongming Island in 2007(Wangliang, 2007). Kong Zhenghong investigated community composition and structure of the coastal sheherbelts intending to comprehensively understand the structure and function heterogeneity with the calculation of completeness，pattern metrics and porosities in 2009. These studies are limited in that they focus on the current ecological and green space system themselves, even though the impact of these changes on the environment has been assessed. There are studies concentrated on land use change in general, but not on whole Chongming Island and the issue of long-term change monitoring in land use has attracted little attention from researchers except Zhu Ying(2007),who studied land use change in the eastern part of Chongming Island (about one third of the island) in recent two decades. Land use/land cover change is one of the most sensitive indicators that echo the interactions between human activities and the natural environment and ecosystem (Qiming, 2008). Long-term change monitoring , the spatio-temporal dynamics and conversion of land use /land cover analysis are the primary steps to provide necessary information among researches of assessing of corresponding ecological effects , change modeling and predicting with different scenarios(Jian Peng,2012) .

This study integrated multi-temporal and multi-scale remotely sensed data from various sources (Landsat MSS, TM, ETM and ALOS) including historical and state-of-the-art high-resolution satellite with a monitoring time frame of 30 years (1979-2009), to monitor and map the spatio-temporal dynamics of vegetation coverage and land use in Chongming Island. The objective of the study was to quantify detailed transition process among various land use/land cover types through the calculation of change matrix derived from classified images, and to detect spatio-temporal patterns and trends of vegetation coverage change using statistical methods and transfer model with a focus on the expansion of Chongming Island in different period and its further development as an ecological island.

MATERIALS AND METHODS

Study area and data

Chongming Island (121.56°N and 31.75°W) located in the Yangtze River estuary in Shanghai, China, is one of the world's narrowest and longest alluvial island formed by the Yangtze River's silt (Figure. 1). The island extends over an area of 1411 km^2, and it is 80 km long (from east to west) and 13-18 km wide (north to south). More than 90% of the land is elevated between 3.21-4.20m above sea level with a mean annual temperature of 15.2^{o}C. It has various natural soil types including saline-sodic soil, semi-hydromorphic soil and alfisol distributed mainly to the north, the middle north deflection and the south respectively (Guangrong, 2009). The landscape evolution of Chongming Island has been going on for more than 1300 years. With the continuous expansion of the southeastern side of the island, residential areas have been developed which have a direct consequence to the land-use types, the natural landscape and vegetation cover. Due to its continuous changing terrain and development, the heterogeneity and complexity in the landscape had created a high spectral variation even within the same land-cover classes. In order to measure its growth trend and monitor the changes of natural ecological environment, vegetation, built-up and water body cover were focused on for identifying both spatial and intensity scales of evolution of Chongming Island.

Four multi-temporal remotely sensed images were acquired for change detection in this study, including Landsat MSS (August 1979), TM (August 1989), ETM (August 2000) and ALOS (AVNIR-2 January 2009) multispectral images. In addition, a multispectral 2.5-m resolution ALOS PRISM image was also acquired of September 2009 to be used as reference layers for geometric correction to assist in field investigations and accuracy assessment of the image classification. Imagery selection was driven by the need for high spatial accuracy, as well as by the availability of older remote sensing data especially for those at the time frames of 1979, 1989 and 2000. Images from MSS79, TM89, ETM2000 sensors were first re-projected into UTM/WGS 84. They were then resampled with nearest-neighbor to 10×10 m resolution in accordance with ALOS (AVNIR-2, 2009) in order to be used to dynamic monitoring of land use change. Besides, ALOS PRISM image, other ancillary datasets including road networks, and administrative boundaries were also used.

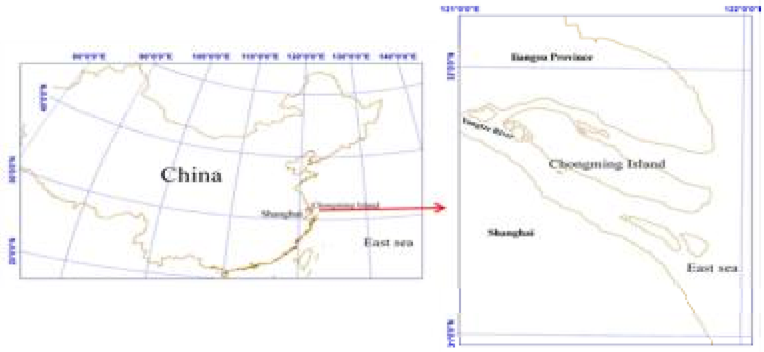

Figure 1: The location of Chongming Island of Shanghai, China.

Image classification

The object-based image analysis software Definiens Developer 7.0 was used for this study. Image of the ground objects in Chongming Island was divided into 6 classes: vegetation, water body, road, building, unused land and wetland based on land resources, use attributes and spectral features of ground objects. Within the general framework of object-based classification, the multi-scale object-specific segmentation and the layers selection for segmentation and classification are of the utmost importance. The multi-resolution or multi-scale segmentation can ensure the different waveband and feature images to contribute to the segmentation and classification process. In this study, the objects of interest for different images were extracted by selecting appropriate features such as NDVI, RNDVI (Ratio normalized difference vegetation index), another vegetation index NDVSI (Normalized difference vegetation structure index) (Yang, et al., 2008, LEE, 2009).

The image segmentation was performed using the multi-resolution segmentation (MRS) algorithm embedded in Definiens Developer 7.0 based on shape and color homogeneity, which is based on the hypothesis that neighboring image pixels belong to the same object. The different input bands can be weighted and their information added to the image objects. A scale parameter, determining the maximum allowed heterogeneity for the image object, influences segment size. In this study, the selection of the appropriate “scale” and “shape / compactness” were achieved by using an iterative “trial-and-error” approach that often employed by others conducting object-based image analysis (DENNIS, 2012, MYINT et al., 2011). The layers used for segmenting different satellite images as well as their corresponding parameters were chosen empirically (Table. 1) based on the interactive visual inspection of the results. The resulting NDVI, RNDVI and NDVSI images which were calculated from MSS, TM and ETM original images were added to the basic image layers involved in the corresponding segmentation and NN(nearest neighbor classification) algorithms classification of the particular satellite imagery. The overall classification accuracies for the TM (1979) and ETM images (1989 and 2000) were 76.2%, 77.3% and 81.6%, respectively.

For ALOS images, the extraction of the vegetation and non-vegetation areas was based on the classification of the NDVI and NDVSI features. Vegetation was first discriminated with a NDVI threshold larger than 0.1. The NN algorithms were then used to eliminate the non-vegetation areas (including the building, road, water body, etc.) from the extracted vegetation areas. The final vegetation polygons were delineated on the rule-based classification and the rule was developed by combination of multiple classifiers such as thresholds and NN algorithms. The overall accuracy was 85.36%. This result indicated that the selected vegetation index based classification scheme for high-resolution images was robust and effective.

Table 1: Parameters used for segmenting the different satellite imagery

Time	Layers	Scale	Weight	Shape	Compact
	MSS(4 wavebands)	20	1	0.1	0.5
1979	RNDVI image		1	0.1	0.5
1989	TM(6 wave bands)	8	1	0.2	0.5
	NDVI image		1	0.2	0.5
2000	ETM(6 wavebands)	10	1	0.2	0.4
	NDVI image		1	0.2	0.4
	RNDVI image		1	0.2	0.4
2009	ALOS(4 wavebands)	8	1	0.3	0.6

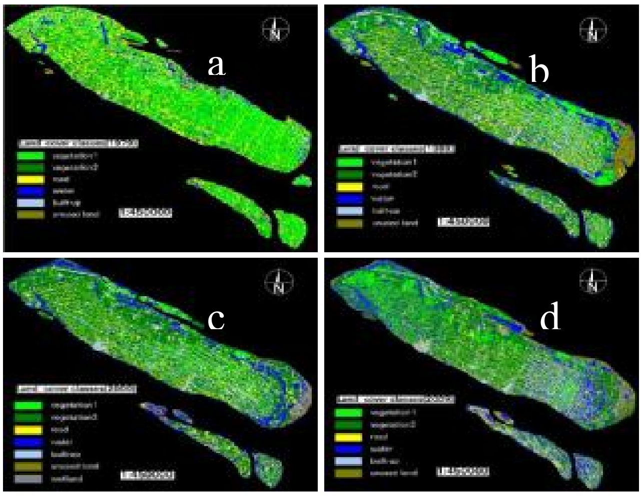

Figure 2: Land use map of Chongming Island, China in 1979(*a*), 1989(*b*), 2000(*c*) and 2009(*d*)

Land use dynamic change analysis

Land use/land cover dynamic change analysis is required to gain better understanding about the conversion of land use/land cover over time and its complexity. In order to reveal the spatio-temporal characteristics of land use change and the trend of vegetation cover change, three land cover change maps between the four study periods were generated. They were statistically analyzed and presented in a tabular form to show the general characteristics of land use/land cover changes. All those land use/land cover patches that had changed their identity during the period were extracted and the corresponding transfer matrixes of land use/land cover change were obtained with the aid of ERDAS 2010 and GIS.

The land use/land cover change in a specific region includes the spatial position conversion and quantitative change of different land use/land cover classes. The position conversion can be modeled as (Fu et al.,2006):

$$S_j = 2 \times \min(P_{j+} - P_{jj}, P_{+j} - P_{jj}) \tag{1}$$

Where S_j represents the area of category j to which spatial position conversion happens. P_{j+} and P_{+j} denote the areas of category j before and after the change, respectively. P_{jj} stands for the area with no change.

Quantitative change refers to the increase and decrease of the balance of areas of different landuse classes after the position conversion (Wang et al., 2000). It can be calculates as (Wang et al., 2000):

$$Q_j = \max(P_{j+} - P_{jj}, P_{+j} - P_{jj}) - \min(P_{j+} - P_{jj}, P_{+j} - P_{jj}) \quad (2)$$

where Q_j stands for quantitative change of area of category j.
Land use dynamicity means the quantitative change speed of land use including single landuse dynamicity and comprehensive landuse dynamicity.
The single land use/land cover dynamicity can be calculated as (Zhu et al., 2001):

$$D = ((P_{+j} - P_{jj})+(P_{j+}- P_{jj}))/(P_{+j}\times T)\times 100\% \quad (3)$$

Where D denotes the dynamicity of one land use type over the given period; T stands for the duration of the study period. If T is set to be multiple years, the value of D will be the annual changing rate of the land use/land cover during the given period. $D < 0$ means that given land use type is in a state of decrease. The larger the absolute value of D, the more intensively given land use type has been decreased. $D> 0$ means just the opposite.

RESULTS & DISCUSSIONS

Dynamic change of vegetation coverage and major cover classes

Classification identified 6 predominant LULC classes: vegetation, water body, road, building, unused land and wetland that were represented the major LULC types of the island in the given time (Figure 2）. Vegetation was denoted as vegetation1 and vegetation2 in thematic maps. They were classified into two types because they had different image features of light green and dark green, respectively. Vegetation2 type included most crop land while vegetation1 represented the forest, natural vegetation and mixed grasslands (with cropland).Bare land was distinguished from unused land when generating conversion matrix after 1989.
The areal extent of the LULC classes, for each time step, was summarized in Table 2. In the late 1970s, human disturbances were limited, most vegetation coverage represented vegetation1 (Figure 2). However, the situation changed since 1980s mainly due to economic development and attention to the construction of ecological island. This was evident from that vegetation2 accounted for over 75% vegetation classes after 1989 (Table 1) while it was 31.90% in 1979. On the other hand, the change of vegetation cover did not follow a proportional growth while the island had been expanding from 1186.76 km^2 of total area in 1979 to 1544.76 km^2 in 2009. The vegetation cover remained almost the constant with a little change in each decade, however, the proportion of vegetation area to the total area of Chongming Island decreased from 71% (1979) to 52% (2009).
In addition, water body had expanded from 47.68 km^{-2} (4.02%) in 1979 to 171.72 km^{-2} (12.18%) in 1989 and build-up area increased from 60.39 km^{-2}(5.09% ,1979)to 167.19 km^{-2}(11.86% ,1989). This expansion continued during the second and third period (from 1989 to 2000, 2000 to 2009, respectively), with water body expanding by about 50 km^{-2} every ten years ,but a little increasing for the proportion of water body to total area over each interval. However, the extent area and proportion of building remained almost unchanged from 1989 to 2000, but expanded from 169.92(2000) to 212.64 km^{-2} (2009) and the percentage of total area increased by about 3% during the last decades. These LULC change tendency over the past 30 year was in accordance with the population change ,which expanded strongly in size during the first decades(from 43.81 to 73.41 ten thousand),then decreased slightly in second period (from 73.41 to 64.98 ten thousand) and increased in recent decades from 64.98 to 87.3 ten thousand (Table2).

Table 2: The 6 landscape level LULC classes and their spatial extent with the observed changes over time

Land use land cover classes	1979		1989		2000		2009	
	area(km^2)	Percent	area(km^2)	Percent	area(km^2)	Percent	area(km^2)	Percent
Vegetation1	576.53	68.10	196.68	24.82	180.79	21.70	174.36	21.85
Vegetation2	270.03	31.90	595.66	75.18	649.91	78.30	623.79	78.15
Vegetation	846.56	71.33	792.34	56.21	830.71	55.75	798.15	51.67
Water body	47.68	4.02	171.72	12.18	222.42	14.93	274.93	17.80
Road	223.22	18.81	212.30	15.06	186.68	12.53	145.92	9.45
Building	60.39	5.09	167.19	11.86	169.92	11.40	212.64	13.77
Unused land	8.90	0.75	65.94	4.68	10.29	0.69	68.89	4.46
Wetland					70.06	4.70	44.21	2.86
total	1186.76		1409.49		1490.08		1544.76	
Population (ten thousand)	43.81		73.41		64.98		87.3	

Transfer changes of land use/land cover

The change transfer matrices of LULC type derived from pixel-based statistical analyses allowed a more rigorous quantitative analysis of LULC trends over time. In this study, class-to-class conversion as well as total gains and losses of specific LULC types in different period were detected in detailed, of which bare land was discriminated from unused land type (except in 1979, for no bare land features then) and vegetation was classified as vegetation1 and vegetation2(as mentioned before)..

The change transfer matrix between 1979 and 1989 (Table 3) showed that half of vegetation1 type in 1979 was converted to vegetation2 (crop land etc.), 37.19% of original water body area, 48.09 % of building and 44.07% of road were converted to vegetation2. Meanwhile, the amount to 38.11% and 28.9% of vegetation were respectively converted to road and building. That may be the cause of vegetation decreased in 1989 although the extent area of vegetaion2 increased then. In addition, the transferring into rate was higher than the transferring from rate of water body, of which 34.01% of unused land was converted to water body during this period, which conversion resulted in the increasing of water body area in 1989. The further analysis based on the classified image and transfer matrix found that water body was also as initially land use type with expansion of island. Thus, the change trajectory of land use/land cover during the first period was as follows: Unused land> Water body (or vegetation2) > vegetation2. These changes better reflected the social and economic requirement and development status when the island starts to be constructed with the recovery of economy resulting from the economic reform in China.

A different tendency was noticed for the period of 1989-2000, where the growth of the island (by81.3 km^2) (Table 2.) was accompanied with an increase of vegetation (by 38.37 km^2). Average transferring into rate of vegetation2 was 39.5% from other land use classes while the transfer ratio of vegetation with water, road and building raised significantly, the total transferring from rate of vegetation (combining vegetation1 and vegetation2) was 26%, 23.3% and 22% to water body, road and building, respectively. Therefore, the proportion of vegetation area to the whole island area remained more or less constant with a small scale expansion of island. Likewise, the conversion rates of building and road kept balance. The increased area of water body can partly attribute to the higher transferring into rate than transferring from rate, an evidently example was as high as 26.52 % unused land converted into water body. During this time interval, land use changed in smooth which kept the same pace with local social and economical developments such as many people went out of work and ecological island construction in a steady state.

In the recent period (2000-2009), the most considerable change that occurred was the reduction of vegetation coverage area although other land use / land cover types showed notable conversion to vegetation2. The highest conversion into rate is 45.92% of bare land; the least is 26.39% of wetland. However, the transferring into rate (40.14%) of vegetation1 was significantly lower than its transferring from rate (88.02%).Which means people paid more attention on the construction and governance the island by converting natural vegetation and other land use (unused land and bare land etc.) into crop land. Meanwhile, the higher conversion into rate of water body and expansion of island resulted in the extent area of water body increase by 52 km^2. The similar change was for building with the area increase of 42.72 km^2 accompanied the population increase during this period .Moreover, land use diversity appeared comparing with the preceding time interval, for instance, wetland, unused land and bare land accounted for more proportion and with certain conversion rate among land use types. These changes just were the reflection of the implementation of ecological island construction policy and structural readjustment of agriculture.

In general, the change trajectory of land use/land cover over the past 30 years was as follows: Unused land (bare land, wetland)> Water body (vegetation1, vegetation2)> vegetation1 (building, road)> vegetation2 (water body, building, road). The most prominent changes in different period were closely related to not only natural evolution of land use but also local economic development and policy orientation.

Table 3: The calculated transfer rate matrix, in percent covers change from 1979 to 1989

		1989						
	LULC classes	**Vegetation 1**	**Vegetation 2**	**Water**	**Road**	**Building**	**Unused land**	**Bare land**
1979	Vegetation1	13.06	51.12	4.81	17.04	13.48	0.07	0.42
	Vegetation 2	8.53	48.39	7.12	21.07	14.45	0.12	0.32
	Water body	11.13	37.19	41.48	4.49	4.61	0.57	0.53
	Road	9.00	44.07	14.05	16.57	15.39	0.25	0.67
	Building	13.40	48.09	11.69	10.24	14.56	0.35	1.68
	Unused land	21.87	24.03	34.01	5.60	12.46	1.30	0.73

Table4: The calculated transfer rate matrix, in percent covers change from 1989 to 2000

		2000							
	LULC classes	**Vegetation 1**	**Vegetation 2**	**Water**	**Road**	**Building**	**Unused land**	**Bare land**	**Wetland**
1989	Vegetation1	16.17	39.50	16.61	10.33	10.66	0.26	3.17	3.29
	Vegetation 2	8.28	54.36	9.45	13.04	11.04	0.12	2.08	1.62
	Water body	8.25	31.89	36.18	9.05	7.85	0.46	2.34	3.97
	Road	9.65	44.63	8.92	17.22	15.70	0.25	1.98	1.64
	Building	11.78	39.21	8.81	15.89	20.04	0.18	2.73	1.37
	Unused land	6.38	28.12	26.52	9.98	5.05	0.80	10.17	12.96
	Bare land	6.17	28.71	12.07	11.43	21.44	0.75	17.29	2.14

Table5: The calculated transfer rate matrix, in percent covers change from 2000 to 2009

		2009							
	LULC classes	**Vegetation 1**	**Vegetation 2**	**Water**	**Road**	**Building**	**Unused land**	**Bare land**	**Wetland**
2000	Vegetation1	11.98	45.90	13.57	10.25	14.75	1.63	0.48	1.44
	Vegetation 2	15.32	51.64	13.34	6.74	8.48	2.12	0.67	1.69
	Water body	3.91	28.14	36.55	9.49	10.78	5.56	1.02	4.54
	Road	5.50	33.41	15.19	17.50	24.67	1.83	0.49	1.41
	Building	5.08	30.17	11.84	18.85	31.17	1.54	0.52	0.84
	Unused land	0.46	29.13	18.50	6.89	9.11	27.18	1.39	7.34

Bare land	6.05	45.92	10.71	12.50	15.26	3.93	2.63	3.00
Wetland	3.81	26.39	16.16	8.55	9.48	18.51	0.40	16.69

CONCLUSIONS

All in this study reveal that Chongming Island of Shanghai ,China are facing a strong land use and land cover change which is very likely intensified by climate change, natural geographic factor and human-impacts.

With the expansion of Chongming Island by 358km^2 from 1979 to 2009, the decrease of vegetation coverage is significant and the ratio of vegetation cover area to the total area of the island had decreased from 71% (1979) to 52% (2009). Of which the percent of crop land(vegetation 2) occupied vegetation had experienced straight up as :31.90%(1979), 75.18%(1989) and 78.30(2000 and 2009) accompanied by the proportion of vegetation1(natural vegetation and mixed grass with crops) decreasing from 68.10%(1979) to 21.85(2009). As dominating land use type, the absolute quantity of vegetation change and associated dynamicity were great in terms of the internal conversion between vegetation1 and vegetation2 and among these main land use classes during the different time interval. This implied it is essential to address corresponding ecological effects of vegetation coverage change in the island in further studies since vegetation coverage is gaining recognitions as a key component of global environmental change and ecosystem safety (Jian Peng, 2012). Furthermore, the extent of dynamic change and conversion of other land use categories have well and truly mirrored the natural evolution and human-impacts. For instance, water body, road and built-up area presented more or less spatial position conversion and quantitatively change during different period, these changes closely related with requirement of social and economic development in given time. Besides unused land, water body owned the higher annual change rate by 15.9%. The similar was for built-up area with annual change rate by 8.9% and also stable dynamicity of 12.9 %(1979-1989) and 14%(the second and third period) during the past 30 years. It is worth noting that annual change rate of vegetation cover is -0.1% while the population of 2009 in the island had been more than twice of that in 1979. Land use change cannot thoroughly represent human activities, however, how to estimate the impact of human activities on the land-use change on earth and evaluate associated ecological effects were need to do in further studies although it is thought that the influence of human activities on vegetation coverage change mainly takes effect through the change of land use system.

In addition, the change trajectory analyses of land use/land cover over the past 30 years based on the 'snapshot' method attempted to infer the drive forces ,which may be need more social and economic information as evidence in future studies and hence to better understand corresponding ecological process. For all that these dynamic changes analysis of land use/land cover was expected to be important for knowledgeable decision-making and policy formulation in regional planning and management to ensure the harmonious evolution of the environment, population and urbanization in accord with Chongming Island ecologic island-oriented construction.

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