

Land Use and Land Cover Change Detection using Remote Sensing and Geographic Information System in Bodri Watershed, Central Java, Indonesia

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Abstract

Remote sensing and GIS technologies are very useful for mapping LULC patterns and detailing the dynamics of a certain area. The utilization of these technologies has been applied to Bodri watershed in Central Java, Indonesia. The aims of this study are to map and detect LULC changes in Bodri watershed over the last two decades (1991-2001 and 2001-2009). Three data sets of Landsat image acquired on June 28, 1991; July 1, 2001 and June 21, 2009 were used for this analysis. Image classification for mapping LULC was performed by supervised classification through the maximum likelihood method. All of the visible and infrared bands (bands 1-5 and 7) were used for the analysis. LULC change processes were then detected through post classification comparison method. Analyzing LULC changes associated to its slope and elevation were performed by overlaying the classified image with slope and elevation maps which had been extracted from digital topographic map (1:25,000). Six LULC categories were classified as forest, tree plantation, dry farming field, paddy field, settlement and water. The results show that in the period of 1991-2001 there were increases in settlement (56.22%), dry farming field (41.77%) and water (32.41%), and decrease in forest (-31.85%), tree plantation (-15.19%) and paddy field (-12.23%). While, between 2001 and 2009 increase occurred in water (34.17%), tree plantation (12.63%) and settlement (7.47%), and decrease in paddy field (-26.01%), forest (-12.33%) and dry farming field (-1.14%). The changes predominantly took place in the gentle slope (0-8%) and the low elevation (0-500 m) areas. These results show that urbanization and agricultural activities have occurred in these areas. The low land and gentle slope were more widely affected by and vulnerable to human and agriculture caused LULC changes than highland and steep slope areas.

1. Introduction

According to the preliminary results of the 2010 National Census (BPS, 2010), 136.61 million people (57.5% of Indonesian's population) reside on the Java's island with an area of 132,187 km² (6.9% of Indonesia's total land area). Thus making Java is the most populous island in the world with an average population density of 1,033 persons per km². In response to this situation, the necessity of land for many purposes resulted in increased pressure on the environment which led to change on land use and land cover (LULC) over a period of time.

LULC change is significant contributor to a range of environmental problem. It has been widely accepted that LULC change in an area is a result of the complex interactions between driving factors (Kelarestaghi and Jeluodar, 2009). Population increase, intensive and extensive of agricultural practices, urbanization, industrialization as well as economic development are

among the forces that cause changes in LULC which lead to sever environmental problems such as floods, drought, landslide, etc (Giri *et al.*, 2003; Agus *et al.*, 2004).

Bodri, as one of the watersheds in Central Java, in recent years has had a large amount of LULC changes, as a result of complex factors. The down part of the watershed frequently experienced flood occurrences which regionally is a part of Kendal regency. Based on investigation conducted by the Ministry of Forestry of Indonesia in 2007, they encountered that many LULC in the upstream of watershed were not properly used. Thus, the Ministry of Forestry of Indonesia categorized Bodri as one of the first priority watersheds that needed to be rehabilitated in Central Java (Departemen Kehutanan, 2009). Dealing with this condition, the up-to-date data on LULC of Bodri are highly important for its sustainable management.

Data on the magnitude, spatial distribution and dynamic of LULC are essential information for monitoring, planning and management of the environment on local, regional and global scales (Wu *et al.*, 2006; Setiawan and Yoshino, 2010; Giri *et al.*, 2003). Remote sensing and geographic information system (GIS) have been widely applied as a valuable means to obtain such information. The application of these technologies is relatively cost effective because it covers large area in the condition of quicker and also more accurate than the conventional ground method (Diallo, *et al.*, 2009)

Many researchers from numerous countries have acknowledged the advantages of remote sensing coupled with GIS in mapping, monitoring and detecting LULC dynamics. For example, Prakasam (2010) analyzed LULC change using Landsat and IRS images data in Kodaikanal Taluk, Tamilnadu and found that forest degraded up to 50% in 2008. Dewan and Yamaguchi (2009) studied land cover change in Dhaka Metropolitan of Bangladesh from 1960 to 2005 using topographic maps, time series data of Landsat imageries and IRS which detected an increase of urban land up to 344%. Mengistu and Salami (2007) studied the application of Landsat imageries in mapping of LULC and detecting its change in a region of south western Nigeria. They revealed that decrease occurred in forests and derived savanna and a corresponding increase in shrub land/farmland complex and settlement/bare surface. Setiawan and Yoshino (2010) analyzed and detected land use change in Java island of Indonesia from 2000 to 2009 based on the change of temporal patterns of the wavelet-filtered MODIS EVI. They found that the large number of change areas occurred in period 2004-2005 and 2005-2006. In West Java, Kaswanto *et al.* (2010) analyzed the impact of land use changes on spatial pattern of landscape during two decades (1989-2009) using Landsat imageries. They found that that the changing of the natural areas (forest and grassland) was due to the conversion into agriculture land and built-up area. Chen *et al.* (2003) observed LULC change in Xilin river basin, Inner Mongolia, China which is dominated by grassland ecosystem using multi-temporal Landsat images. Reis (2008) analyzed LULC changes using Landsat MMS imagery 1976 and Landsat ETM+ 2000 coupled with GIS in Rize, north-east Turkey, an area which characterized by a high steep and rough terrain with a mountainous area of 78%. Their results revealed that severe changes have occurred in agriculture (36.2%), urban (117%), pasture (-72.8%) and forest area (-12.8%) between 1976 and 2000.

In the present study, an effort was made to map and detect the LULC changes over two time periods, 1991-2001 and 2001-2009, in Bodri watershed using Landsat remotely sensed data and GIS technology. The results of this study are expected to provide valuable information for the planners and decision makers to devise sustainable LULC management and the environmental planning policies.

2. Study area and dataset

2.1 Study area

Geographically, Bodri Watershed is situated in the northern Central Java Province, Indonesia between S 7° 23'00" to S 7° 54'08" latitudes and E 109° 52'01" to E 110° 08'06" longitudes (Figure 1). Regionally, Bodri watershed covers four regencies of Central Java which comprise of Kendal, Temanggung, Semarang and Wonosobo. The upper part of the area covers Temanggung, Kendal, Semarang and Wonosobo; the middle part covers Kendal and Temanggung, while the down part covers Kendal. The total area of Bodri is 65,512.89 ha with 49.08% of the area is located in Kendal, 44.94% in Temanggung, 5.73% in Semarang and 0.25% in Wonosobo. Topographically, the area varies from plain, hilly to mountainous with the range of elevation from 0 to 2,600 m above sea level. The soils mainly comprise latosol, grumosol, aluvial, mediteran and regosol. According to Smitch and Ferguson climate type, Bodri watershed belongs to climate type A and type B. The annual rainfall ranges from 2,000 to 3,000 mm. The number of dry months per year is 0-7 months and wet months between 2-12 months.

2.2 Dataset

Three sets digital data of Landsat imagery path 120 and row 65 were utilized as the main data in this study. Landsat Thematic Mapper (TM) imagery dated on June 28, 1991 was obtained from the Ministry of Forestry of Indonesia and Landsat Enhanced Thematic Mapper Plus (ETM+) imageries dated on July 1, 2001 and June 21, 2009 were acquired through the USGS

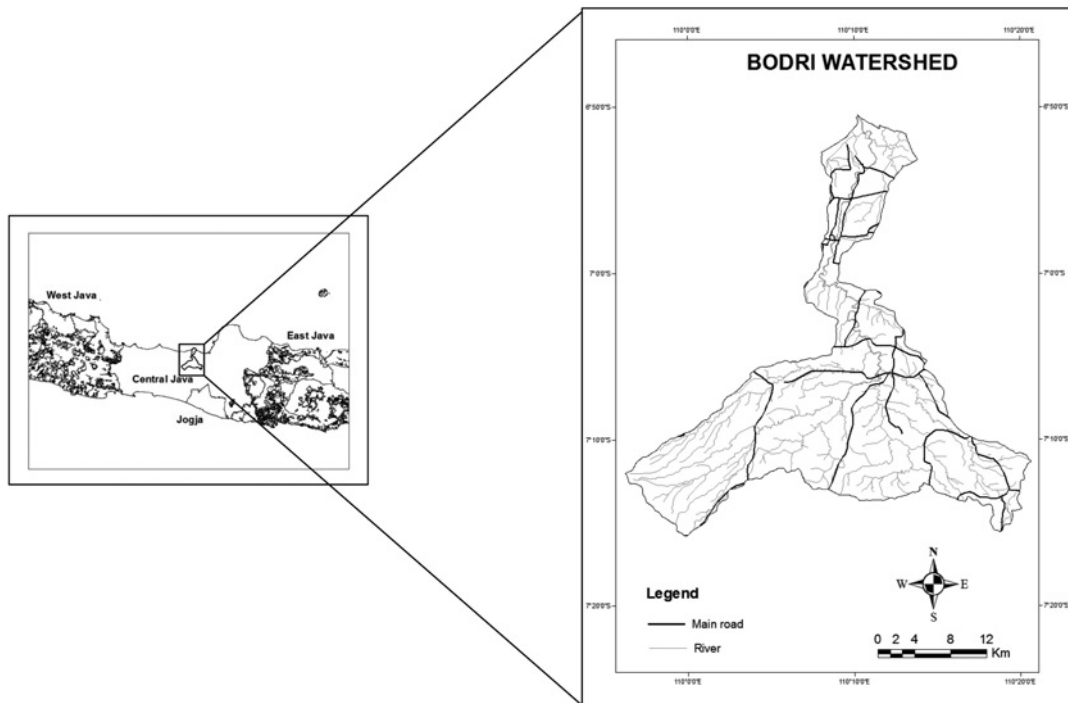


Figure 1. The location of the study area.

(U.S. Geological Survey) GLOVIS (Global Visualization Viewer) website (<http://glovis.usgs.gov/>).

It has been widely known since May 31, 2003 Landsat ETM+ has experienced sensor scan liner corrector (SLC) mechanism fail which resulting gaps manifested as strips near on the edges of image. Therefore, Landsat imagery acquired on June 21, 2009 necessary to perform gap-filling before any other processing could be carried out on the image. This was performed using “frame_and_fill_win32” program which was provided by the National Aeronautics and Space Administration (NASA) (http://landsathandbook.gsfc.nasa.gov/handbook/software/gapfilling_software.html). The 21 June 2009 image was used as the anchor (base) image for the 2009 time-series with the 25 September 2009, 4 May 2009 and 18 June 2008 images as fill scenes 1, 2 and 3, respectively. It is worth to mention that all the fill scenes exhibited almost free cloud cover especially in the area of study.

For supporting image analysis, some ancillary data were used in this study including ground truth data acquired through field survey in October 2010, digital topographic maps 2000 (scale 1:25,000), digital land use map of Java 2000, digital administrative map of Java 2000 which acquired from the National Coordination Agency for Surveys and Mapping of Indonesia (Bakosurtanal), digital forest cover maps of Central Java of 1990, 2000 and 2009, and digital watershed boundary map of Java obtained from the Ministry of Forestry of Indonesia. All of the ancillary data were used to assist the training area selection in image classification and for collecting the reference data in assessing classification accuracy.

3. Methods

Image pre-processing, image classification and change detection were performed using ERDAS Imagine 8.7 (ERDAS, Atlanta), while GIS analysis was carried out using ArcGIS 9.3.1 (ESRI, USA).

3.1 Geometric correction

Geometric correction was required to avoid geometric distortions, by establishing the relationship between the image coordinate system and the geographic coordinate system through calibration data of the sensor, measured data of position and altitude, ground control points, and atmospheric conditions. Image rectification was firstly performed on the Landsat ETM+ 2001 to the digital topographic map 2000 (scale 1:25,000) using the Universal Transverse Mercator (UTM) coordinate system, Datum World Geodetic System (WGS) 1984, zone 49 South. Distinctive features such as road intersections, corners of buildings and permanent landmarks on the image were selected as ground control points. A total number of 10 well distributed

Table 1. Land use and land cover classification scheme and their general descriptions

LULC categories	General description
Forest	An area covered by dense trees with relatively darker green color
Tree plantation	An area cultivating pine, teak, rubber, community forest, mixed garden and smallholder tree crops.
Settlement	An area occupied by housing including road network and other facilities.
Dry farming field	An area cultivating a variety of food crops, vegetable, tobacco, bare land and shrubs.
Paddy field	Rice agriculture cultivation area which determined by inundating of fields.
Water	An area covered by open water such as ocean, rivers, ponds and artificial aquacultures or fishponds.

ground control points were collected through the first-order polynomial rule. Finally, Landsat ETM+ 2001 was resampled to a 30 meters pixel size using the nearest neighborhood algorithm with the resultant root mean square error (RMSE) 0.55 pixels (16.5 meters).

Subsequently, Landsat TM 1991 and Landsat ETM+ 2009 were rectified to Landsat ETM+ 2001 through image to image rectification. All the data was projected to UTM coordinate system, Datum WGS 1984, Zone 49 South. In total 16 and 15 ground control points were collected on the images, respectively, through first-order polynomial rule and all the data was then resampled to 30 m pixel size using the nearest neighborhood method with the resultant of RMSE 0.45 pixels (13.5 m) and 0.50 pixels (15 m), respectively.

Radiometric calibration was also performed on the images through the conversion of DN units into spectral radiance and then further into spectral reflectance units at-sensor. The geometrically corrected images were finally subset to the area of interest of study site.

3.2 Image classification

LULC classification categories were adopted based on LULC modified version of the Ministry of Forestry of Indonesia published in 2000 which had 24 LULC categories. However, generalization was made to several categories in this study in order to obtain consistent LULC categories over the study period. Finally, six separable LULC categories have been identified in the study area as water, paddy field, dry farming field, settlement, tree plantation and forest (Table 1).

All of the visible and infrared bands (bands 1-5 and 7) were used for image analysis. Supervised classification through maximum likelihood algorithm was applied to perform image classification. It was preferred because the prior knowledge of study area was known and the data of the study area were also available. In addition, this classification has been found to be the most commonly and widely used classifier (Diallo *et al.*, 2009; Dewan and Yamaguchi, 2009; Chandola and Vatsavai, 2010). The maximum likelihood classifier assumes that the pixels of unknown category membership have a certain probability of belonging to a particular category (Ismail and Jusoff, 2008). These probabilities are equal for all categories and the input data in each band follows the gaussian (normal) distribution function (Lillesand *et al.*, 2004).

The supervised classification requires training areas for each category. The training areas were used to define spectral reflectance patterns/signature of each LULC category. The signatures would then be used by classifier to group the pixels into a certain category which has the same spectral patterns. Training areas of each category were created with the assistance of visual analysis on the images through displaying RGB combination (bands 543, bands 743 or bands 321) and also supporting by the ancillary information from the digital land use map, forest cover maps, Google Earth and the prior knowledge of the author on the study area which were gained from the field survey. A 3 x 3 majority filter finally was applied to smooth the classified images for reducing the salt and pepper effect (Lillesand and Kiefer, 1999).

3.3 Classification accuracy assessment

LULC maps derived by remote sensing frequently present various errors as result of either one or both factors classification technique or the method of satellite data capturing. Therefore, classification accuracy assessment is an important

step in evaluating image classification. Stratified random sampling was applied to select the classified pixels. Each 250 test pixels from the classified image 1991, 180 pixels from the classified image 2001, and 160 pixels from the classified image 2009 were selected to assess image classification results. The reference data which collected from digital forest cover map 1990 and visual interpretation on the image were used to validate the classified image 1991. The reference data for the classified image 2001 were obtained from digital land use map 2000 and digital forest cover map 2000. Ground truth data and digital forest cover map 2009 were used as reference data to validate the classified image 2009.

An error matrix is the most common and typical method used by researchers to assess classification accuracy of remotely sensed data (Congalton, 1991; Congalton and Green, 1999; Ismail and Jusoff, 2008). It is also sometimes referred to the confusion matrix or contingency table. An error matrix is a square array of numbers set out in rows and columns which represent the number of sample units (i.e., pixels, clusters of pixels, or polygons) assigned to a particular category relative to the actual category as indicated by reference data (Congalton, 1991). The numbers in the rows represent data from the classified image, while the numbers in the columns indicate the reference data. The elements in major diagonal of matrix error are pixels that are correctly classified for each category. In this study, standard criteria of accuracy assessment of the classification such as producer's accuracy, user's accuracy, overall accuracy and the kappa coefficient were computed from the error matrix (Congalton and Green, 1999; Ismail and Jusoff, 2008).

The error matrix of classified images 1991, 2001 and 2009 are depicted in Tables 3, 4 and 5, respectively. The producer's accuracy was computed by dividing the total number of correct pixels in a category to the total number of pixels of that category as derived from the reference data (column total). This statistic values express the probability of reference pixel being correctly classified in the classified image and is a measure of omission error. The producer's accuracy presents how well a certain area can be classified (Jensen, 2005). The user's accuracy was computed by dividing the total number of correct pixels in a category to the total number of pixels that were actually classified in that category (row total). The results of user's accuracy represent the probability or reliability of a pixel classified on the map in a category existing on the ground and is a measure of commission error (Jensen, 2005). The overall accuracy was defined as the total number of correctly classified pixels (sum of the major diagonal) divided by the total number of pixels in the error matrix (Jensen, 2005). The Kappa coefficient was estimated from a *Khat* statistic which was computed as:

$$Khat = \frac{N \sum_{i=1}^r - \sum_{i=1}^r (x_i + *x_{+i})}{N^2 - \sum_{i=1}^r (x_i + *x_{+i})} \quad (1)$$

where r is the number of rows in the error matrix, x_{ij} is the number of observations in row i and column j , x_{i+} and x_{+i} are the marginal totals for row i and column i , respectively, while N is the total number of pixels. The Kappa coefficient value represents on how well remotely sensed classification agrees or is accurate to the reference data (Jensen, 2005). The Kappa coefficient value into three groups: a value is greater than 0.80 represents strong agreement or good classification performance; a value between 0.40 and 0.80 represents moderate agreement or moderate classification performance; and a value less than 0.40 represents poor agreement or poor classification performance (Jensen, 2005).

3.4 Change analysis

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). In this study, LULC change process in the periods of 1991-2001 and 2001-2009 were detected by applying the post-classification comparison method. This method was adopted due to its simplicity and capability to compare two images from different times and sensors (Rahdary *et al.*, 2008; Alphan *et al.*, 2009). In addition it is the most common approach that has been widely used to detect the changes (Dewidar, 2004; Mengistu and Salami, 2007; Guler *et al.*, 2007) with the major advantage of providing "from-to" change information. However the disadvantage of this method is that it depends on the classification of individual images and requires two classifications (Jensen, 2005). In this method, the two images from different dates are classified and labeled independently. The area of change is then calculated through direct comparison of the classified images using ERDAS image 8.7. The results were presented in the form of a change matrix.

In order to analyze LULC changes according to the slope and the elevation, firstly the digital topographic map (1:25,000) was converted into a Triangulated Irregular Network (TIN) and was then transformed into raster DEM format. The generated raster DEM was then used as an input to derive the slope and elevation maps (Figure 2). All of the processes were done using 3D analyst tools in ArcGIS 9.3.1. Subsequently, the LULC change maps in the period of 1991-2001 and 2001-2009 were then converted into shape file extension of ArcGIS. Then, the LULC change maps were overlaid with slope and elevation maps, respectively. The resultant polygon themes were used to determine the extent of the changes.

Tabel 2. Extent and percentage of LULC categories of the classified images in 1991, 2001 and 2009

LULC categories	1991		2001		2009	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Water	1,037.25	1.58	1,373.40	2.10	1,842.75	2.81
Paddy field	12,285.54	18.75	10,782.45	16.46	7,978.41	12.18
Dry farming field	15,354.72	23.44	21,769.11	33.23	21,520.89	32.85
Settlement	2,174.40	3.32	3,396.78	5.18	3,650.40	5.57
Tree plantation	27,421.56	41.86	23,257.26	35.50	26,195.13	39.98
Forest	7,239.42	11.05	4,933.89	7.53	4,325.31	6.60
Total	65,512.89	100.00	65,512.89	100.00	65,512.89	100.00

Tabel 3. Error matrix of the classified image 1991

Classified Image	Reference Data						Row Total	User's Accuracy (%)
	W	PF	DF	S	TP	F		
Water (W)	30	0	0	0	0	0	30	100.00
Paddy field (PF)	3	34	5	1	0	0	43	79.07
Dry farming field (DF)	0	10	36	1	0	0	47	76.60
Settlement (S)	0		4	27	1	0	32	84.38
Tree plantation (TP)	0	0	11	0	46	4	61	75.41
Forest (F)	0	0	1	0	8	28	37	75.68
Column Total	33	44	57	29	55	32	250	Overall Accuracy 80.40 %
Procedure's Accuracy (%)	90.91	77.27	63.16	93.10	83.64	87.50		Kappa coefficient 0.76

Tabel 4. Error matrix of the classified image 2001

Classified Image	Reference Data						Row Total	User's Accuracy (%)
	W	PF	DF	S	TP	F		
Water (W)	19	1	0	0	0	0	20	95.00
Paddy field (PF)	2	25	1	0	2	0	30	83.33
Dry farming field (DF)	0	3	35	1	2	0	41	85.37
Settlement (S)	0	0	0	21	1	0	22	95.45
Tree plantation (TP)	0	2	4	0	36	1	43	83.72
Forest (F)	0	0	1	0	4	19	24	79.17
Column Total	21	31	41	22	45	20	180	Overall Accuracy 86.11 %
Procedure's Accuracy (%)	90.48	80.65	85.37	95.45	80.00	95.00		Kappa coefficient 0.83

Tabel 5. Error matrix of the classified image 2009

Classified Image	Reference Data						Row Total	User's Accuracy (%)
	W	PF	DF	S	TP	F		
Water (W)	20	2	0	0	0	0	22	90.91
Paddy field (PF)	0	23	2	1	0	0	26	88.46
Dry farming field (DF)	0	2	22	0	4	0	28	78.57
Settlement (S)	0	2	1	29	0	0	32	90.63
Tree plantation (TP)	0	1	5	2	20	1	29	68.97
Forest (F)	0	0	1	0	6	14	21	66.67
Column Total	20	30	31	32	30	15	158	Overall Accuracy 81.01 %
Procedure's Accuracy (%)	100.00	76.67	70.97	90.63	66.67	93.33		Kappa coefficient 0.77

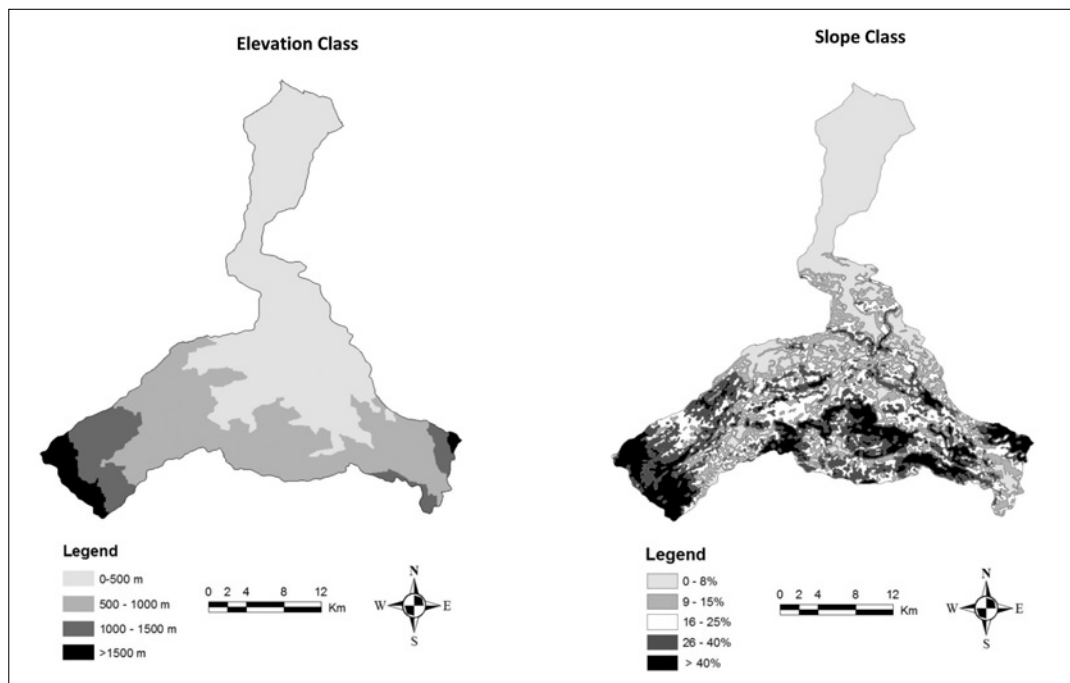


Figure 2. The elevation class and slope class maps of Bodri watershed.

4. Results

4.1 Image classification and analysis

The maximum likelihood supervised classification has been applied successfully to classify land use land cover (LULC) in Bodri watershed. The thematic maps of 1991, 2001 and 2009 derived from the classification are depicted in Figure 3. Six LULC categories were indentified in Bodri watershed as water, paddy field, dry farming field, settlement, tree plantation, and forest. Analyses on the maps show that tree plantations were the most dominant LULC occupied Bodri watershed, followed by dry farming fields and paddy fields throughout the study period. From the maps, it can also be seen that water was mostly distributed in the down part. Aquaculture is one of the important agricultural activities in Bodri which can only be found in the down part. Paddy fields were distributed widely along the down part to the middle part and small portion in the upper part. Irrigated paddy fields were the dominant paddy field in Bodri watershed. It was distributed mostly in the down part, while, non-irrigated paddy fields were distributed in the middle and upper part. A large area of dry farming fields were distributed mostly from the middle to the upper part. Based on the maps, it seems that dry farming field has increased over the study period. Tree plantations as the dominant LULC in Bodri were distributed along the middle part to the upper part. Teak, pine, rubber were the dominant tree plantations in this watershed. Forests were mostly found in the upper part and a few in the middle part. A large portion of settlements were concentrated in the down part which is the capital city of Kendal regency, while others were scattered along the middle to the upper part.

The extent and percentage of each LULC in Bodri watershed over the study period is shown in Table 2. In general more than 35% of the total area was covered by tree plantations, 20% by dry farming fields, 12% by paddy fields, while less than 11% is covered by forest, settlement and water in the three years.

LULC maps derived from remote sensing may contain some errors. Therefore, assessing the accuracy of the classified image is highly important. The aim of the assessment is to determine how accurate the pixels were classified into certain feature categories in the area of investigation. In this study, a stratified random sampling method was applied to evaluate the accuracy of the classified images, resulting 250 sample pixels from 1991, 180 from 2001 and 160 from 2009 selected from the classified image of 1991, 2001 and 2009, respectively. The results show that overall accuracies for 1991, 2001 and 2005 classified images were 80.40%, 86.11% and 81.01% with Kappa coefficient of 0.76, 0.83 and 0.7, respectively (Table 3, 4 and 5). The Kappa coefficients demonstrate that the classified images of 1991 and 2009 were moderate classification performance, while, the classified image of 2001 was good performance classification. The tables also show that the user's accuracy of

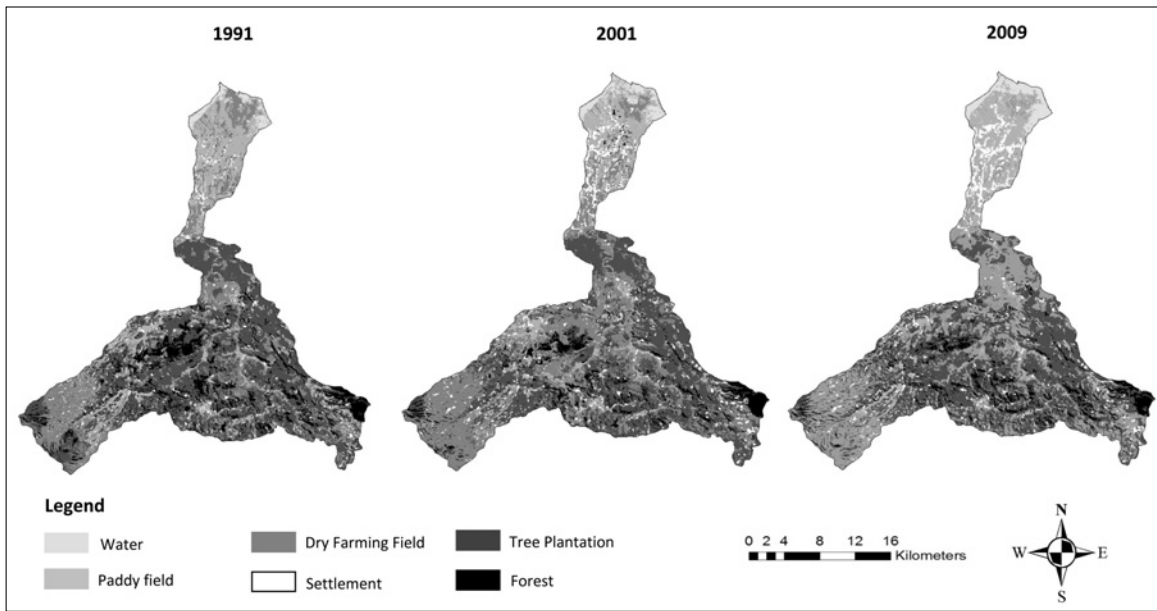


Figure 3. Land use and land cover classification maps of Bodri watershed in 1991, 2001 and 2009.

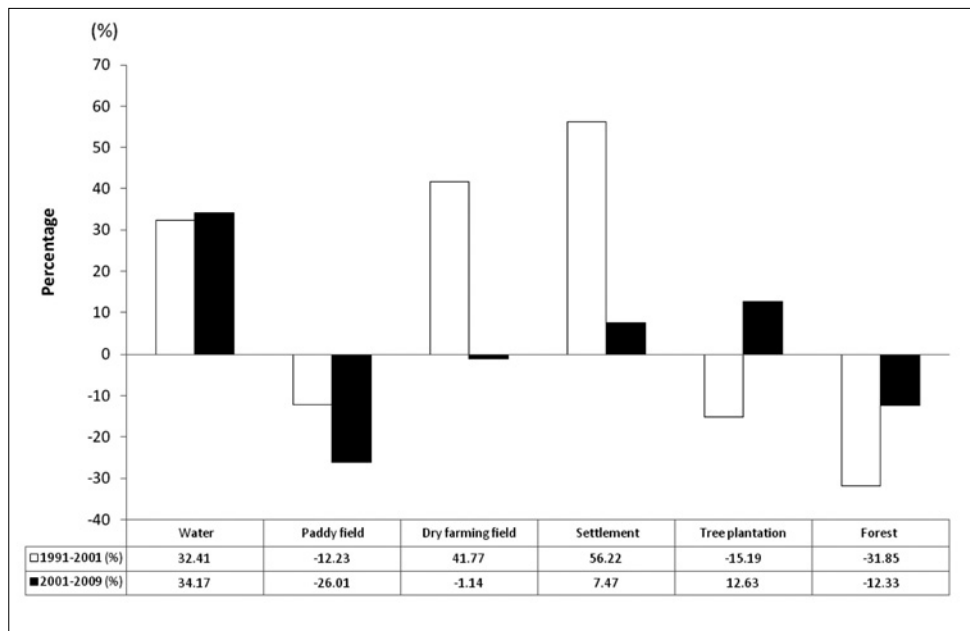


Figure 4. Change percentages of LULC in Bodri watershed in periods 1991-2001 and 2001-2009.

individual category ranged from 66.67% to 100% and the producer’s accuracy ranged from 63% to 100%.

4.2 Land use and land cover changes detection

Post-classification comparison changes detection method revealed that various changes in the different LULC categories took place in Bodri watershed over the study period. The relative changes of each LULC in Bodri watershed within the periods 1991-2001 and 2001-2009 are depicted in Figure 4. Between the years 1991 and 2001, the great increase of LULC occurred in settlement up to 56.22% (1,222.38 ha) followed by dry farming field 41.77% (6,414.39 ha) and water 32.41% (336.15 ha), while, LULC with the large decrease were forest up to 31.85% (2,305.53 ha) followed by tree plantation 15.19% (4,164.3 ha) and paddy field 12.23% (1,503.09 ha).

Table 6. Land use and land cover change matrix in Bodri watershed between 1991 and 2001

Year	LULC categories	2001 (ha)						Total
		Water	Paddy field	Dry farming field	Settlement	Tree plantation	Forest	
1991 (ha)	Water	775.35	229.05	13.32	1.17	5.22	13.14	1,037.25
	Paddy field	411.84	6,245.37	3,420.63	919.26	1,092.15	196.29	12,285.54
	Dry farming field	185.76	1,866.60	10,639.08	483.21	2,110.14	69.93	15,354.72
	Settlement	-	144.90	327.24	1,451.43	231.30	19.53	2,174.40
	Tree plantation	0.36	1,846.62	6,700.05	484.20	17,462.43	927.9	27,421.56
	Forest	0.09	449.91	668.79	57.51	2,356.02	3707.1	7,239.42
Total		1,373.40	10,782.45	21,769.11	3,396.78	23,257.26	4,933.89	65,512.89
Net change 1991-2001		336.15	-1,503.09	6,414.39	1,222.38	-4,164.30	-2,305.53	
Change in %		32.41	-12.23	41.77	56.22	-15.19	-31.85	

Table 7. Land use and land cover change matrix in Bodri watershed between 2001 and 2009

Year	LULC categories	2009 (ha)						Total
		Water	Paddy field	Dry farming field	Settlement	Tree plantation	Forest	
2001 (ha)	Water	1,124.01	209.88	38.16	1.35	-	-	1,373.40
	Paddy field	678.33	5,332.41	1,581.93	434.61	2,561.40	193.77	10,782.45
	Dry farming field	32.49	1,859.40	13,420.89	539.01	5,760.63	156.69	21,769.11
	Settlement	0.18	86.31	416.79	2,507.85	360.54	25.11	3,396.78
	Tree plantation	5.04	355.86	5,879.43	155.34	15,558.66	1,302.93	23,257.26
	Forest	2.70	134.55	183.69	12.24	1,953.90	2,646.81	4,933.89
Total		1,842.75	7,978.41	21,520.89	3,650.40	26,195.13	4,325.31	65,512.89
Net change 2001-2009		469.35	-2,804.04	-248.22	253.62	2,937.87	-608.58	
Change in %		34.17	-26.01	-1.14	7.47	12.63	-12.33	

An important aspect of LULC change detection study is to know the change “from-to” processes information of each category over a certain period (Wu *et al.*, 2006; Mengistu and Salami, 2007; Zhang *et al.*, 2008; Reis, 2008; Alphan *et al.*, 2009) which can be used to clarify the magnitude, location and nature of the actual changes of an area. This information can be derived through change matrix analysis. In this matrix, the diagonal elements represent the area of each class which remains unchanged while the off diagonal elements represent the changes area (Table 6 and Table 7).

Table 6 shows the information of change processes in Bodri watershed from 1991 to 2001. The results revealed that the increase in settlement was largely caused by the conversion of paddy field (919.26 ha), tree plantation (484.20 ha) and dry farming field (483.21 ha). The second largest increase in LULC was dry farming field which gained from the conversion of plantation (6,700.05 ha) and paddy field (3,420.63 ha). At the same time, dry farming field was also converted into plantation (2,110.14 ha) and paddy field (1,866.60 ha). The above conversions processed in dry farming have resulted a net gain of 6,414.39 ha. The last increase of LULC was water which was gained from paddy field (411.84 ha) and dry farming field (185.76 ha).

The largest LULC decrease between 1991 and 2001 was forest with 2,356.02 ha out of 7,239.42 ha converted to tree plantation, 668.79 ha converted to dry farming field and 449.91 ha converted to paddy field. Tree plantation experienced the second largest loss due to the conversion of 6,700.05 ha into dry farming field and a further 1,846.62 ha into paddy field. The third most extensive LULC decrease was paddy field which mainly changed into dry farming field 3,420.63 ha, tree plantation 1,092.15 ha, and settlement 919.26 ha.

Between the period of 2001 and 2009 (Figure 4), the increase of LULC was identified in water, tree plantation and settlement with 34.17% (469.35 ha), 12.63% (2,937.87 ha) and 7.47% (253.62 ha) of the total area, respectively. While, the major LULC losses were observed in paddy field, forest and dry farming field with 26.01% (2,804.04 ha), 12.33% (608.58 ha)

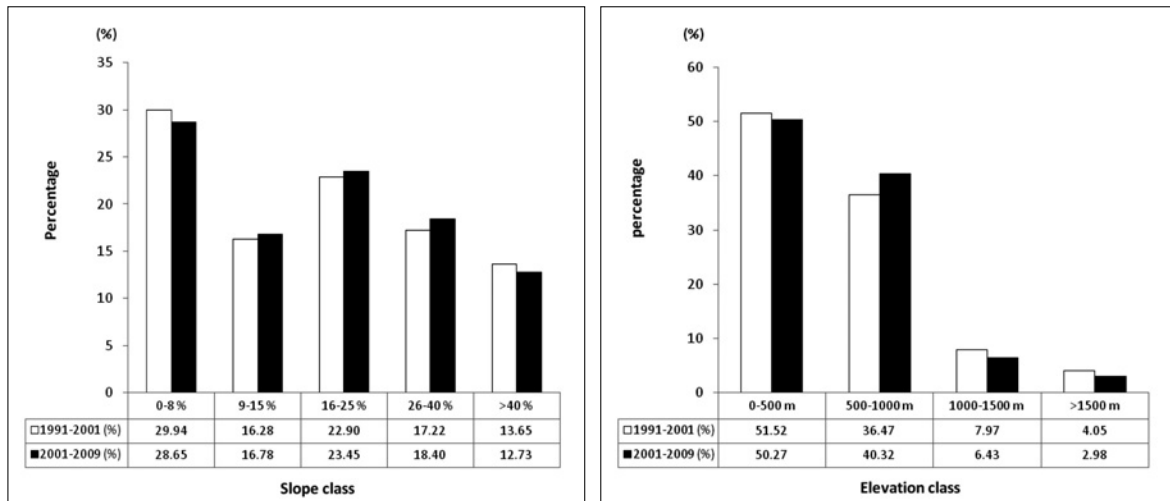


Figure 5. Change percentages of LULC in Bodri watershed associated to slope and elevation.

and 1.14% (248.22 ha) of the total area, respectively.

To better understand the changes “from-to” processes between 2001 and 2009, the detail information is given in Table 7. The table illustrates that the increase in water area by 34.17% in 2009 was largely made up of land conversion from paddy field (678.33 ha). Tree plantation increase its area gained mostly from the conversion of dry farming field (5,760.63 ha), paddy field (2,561.4 ha) and forest (1,953.90 ha). In the same period, large areas of tree plantations were converted to dry farming field (5,879.43 ha) and forest (1,302.93 ha). The escalation of settlement was mostly derived from the conversion of dry farming field and paddy field areas as large as 539.01 ha and 434.61 ha, respectively. At the same time, the lost of paddy field was mainly converted into tree plantation 2,561.4 ha and dry farming field 1,581.93 ha. Forest lost its area mostly to tree plantation 1,953.9 ha. While, the previous dry farming field changed into tree plantation 5,760.63 ha and paddy field 1,859.93 ha.

The results of LULC change analysis associated to slope and elevation are shown in Figure 5. The results implied that most of the changes in the periods of 1991-2001 and 2001-2009 occurred in the low slope (0-8 %) areas calculated as 29.94% and 28.69% of the total changed area, respectively. While, the least change was detected in the steep slope (>40%) both in the period of 1991-2001 and 2001-2009 accounting for 13.65% and 12.70% of the total changed area, respectively. Change analysis further showed that in the transition of 1991-2001 and 2001-2009 changed area predominantly occurred in the low elevation (0-500 m) with 51.52% and 50.35% of the total changed area, respectively. While the lowest portion of the changes took place in the high elevation (>1500 m) areas both in the transition of 1991-2001 and 2001-2009 at 4.05% and 2.96%, respectively.

5. Discussion

In this study, LULC changes in Bodri watershed were successfully detected using the combination of remotely sensed data and GIS technology. The results revealed that dynamic changes occurred in the different LULC categories over the study period. Figure 4 demonstrates that the area of settlement and water consistently increased, while the area of paddy field and forest consistently decreased in the whole study period. The area of dry farming field and tree plantation experienced both increases and decreases over the study period.

Active aquaculture was found in Bodri watershed. An increase of water in the period of 1991 to 2001 was caused by the establishment of artificial aquaculture (fishpond) areas in the downstream which encroached dry farming field and paddy field areas. While in the transition of 2001 and 2009, the larger increase in water was caused more apparently by misclassification, where some inundated paddy field being prepared for cultivation may be classified as water. It is reasonable because the spectral reflectance of water and inundated paddy fields are almost similar to each other.

Urbanization was detected in this area especially in the period of 1991 to 2001 which is indicated from the escalation of settlement area by 56.22%. The land was converted mostly from paddy field (919.26 ha), tree plantation (484.20 ha) and dry farming field (483.21 ha) (Table 6). The increase of the settlement then continued in the period between 2001 and 2009 (Table 7) by a lower percentage (7.47%) that came from the conversion of dry farming field (539.01 ha) and paddy field (434.61 ha). In this regards, there is an indication that the areas mostly converted into settlements in Bodri watershed were the productive

agriculture lands including paddy field and dry farming field. This conforms to the results of Wahyunto *et al.* (2001) in Java (Citarik sub-watershed) where the development of industrial and settlement mostly took place in highly productive paddy fields and other agriculture lands. It can be seen from Figure 4 that paddy field in this watershed has been on the decrease continuously following the increase in settlement over the study period. This may result greater risk of flood occurrence in the downstream. As the finding of Agus *et al.* (2004) and Watung *et al.* (2005) revealed that paddy field has the ability to retain water and to filter the sediment in a landscape which contributes to flood mitigation.

Urbanization processes in Java frequently attribute by population growth which then resulted change in LULC. It seems that rapid increase of settlements in Bodri watershed might be caused by the increase of the population especially in the down part which covers Kendal regency. Based on the data obtained from BPS of Kendal regency, the population of Kendal regency increased from 803,008 in 1991 (Kantor Statistik Kabupaten Kendal, 1992) to 882,929 in 2001 (BPS Kabupaten Kendal, 2001) and increased further to 951,388 in 2008 (BPS Kabupaten Kendal, 2008). Kaswanto *et al.* (2010) also found that population growth had significant affect on land use change in West Java region during two decades (1989-2009). They revealed that land degradation during the two decades is triggered by the population growth and urbanization. Verburg *et al.* (1999) noted that a long history of increases in population pressure in Java Island has caused agricultural land use to expand and intensify. Present land use changes caused the conversion of prime agricultural land into residential and industrial areas.

The dynamic changes of dry farming field were associated with the changes in tree plantation and paddy field, and vice versa in this area. This is could be happened due to the rotation system in the traditional cultivation mostly applied in the study area. As shown in Tables 6 and 7, the increases of dry farming fields were mainly a result of the conversion of tree plantations and paddy fields. At the same time, the decrease of dry farming field increased tree plantation and paddy field which resulting a net gain by 6,414.39 ha in the period of 1991 to 2001 and net loss by 248.22 ha in the period of 2001 to 2009. The increase of dry farming field from tree plantation may have occurred when some teak trees and pine trees were harvested and some rubbers trees were regenerated. In addition, the people who live surrounding teak and pine plantations may have cultivated food crops such as cassava, maize, beans, potatoes or vegetable crops by intercropping between rows of direct-seeded tree plantation which resembles mix-agriculture. This mix-agriculture system is known as *taungya* or *tumpang Sari* which has existed for a long period of time in Java Island. These practices exist widely in Bodri watershed especially in the state-owned forest lands. In this system the peasants were allowed to cultivate the land usually for 2 years before the canopy closes. After that, the peasants must leave the areas to let the seedling grow. While the increase dry farming field from the conversion of paddy field could be due to the farmer's frequently rotated cultivation system in the paddy field area especially when the area was prepared for the next rice cultivation season.

Deforestation is not found to be severe in this area. It conforms to the finding of Prasetyo *et al.* (2009) that Central Java has the lowest deforestation rate compared to other provinces in Java Island, because the forest area is located at high altitudes and on steep slopes, hence it has less opportunity to be converted. However, the similar spectral reflectance of the tree plantation and forest category has led to the misclassification, therefore a large number of forest conversions to tree plantation took place in this area as indicated in Tables 6 and 7. In addition, another source of error could be due to the closeness of many other tree plantations, such as pine, community forest, and mix-garden, to the forest area that often technically classified as forest. Similar problem of misclassification due to the similarities of spectral reflectance was also revealed by Munoz-Viller and Lopez-Blanco (2008), where agro-forestry system and tropical forest being mistakenly classified as coffee plantation.

Further analysis revealed that gentle slope (0-8%) and low elevation (0-500 m) areas were more susceptible to changes than steep slope (>40%) and high elevation areas (Figure 5). The findings of this study affirm the prediction by Verburg *et al.* (1999) which showed that the most intensive land use change in Java predominantly occurs in the lowland areas, either directly through construction or indirectly through the demand for higher values crops, while the upland areas will stay primarily rural. In gentle slope (0-8%) and low elevation (0-500 m) areas, settlement, paddy field and dry farming field had the most changes. While, in the steep slope (>40%) and high elevation (>1500 m), forest experienced the most change.

Another problem observed in this area during the field survey was the annual upland crop system in the steep slopes. The annual upland crop system in general is a rotation or a relay planting of food crops such as cassava, maize, peanuts, soybean, vegetables or high marketable crops such as tobacco which leaves these areas to be very prone to erosion, thus contributes to flood occurrence in the downstream.

6. Conclusion

Information on the LULC pattern dynamics over a period is vital to the effective management of an area. This study has shown the effectiveness of the use of remote sensing and GIS integration for mapping and detecting LULC changes in Bodri

watershed. The overall accuracies for the classified images of 1991, 2001 and 2009 were 80.40%, 86.11% and 81.01% with kappa coefficients of 0.76, 0.83 and 0.77, respectively. User's accuracy of individual classes ranged from 66.67% to 100% and producer's accuracy ranged from 63% to 100%. The Kappa coefficients demonstrate that the classified images of 1991 and 2009 had a moderate classification performance, while, the classified image of 2001 had a good performance classification.

Change detection analysis revealed that dynamic changes have occurred in Bodri watershed over the period of the study. In the period 1991-2001, there were net increases in size for the following areas: settlement (56.22%), dry farming field (41.77%) and water (32.41%), while there were decreases in the area for forest (-31.85%), tree plantation (-15.19%) and paddy field (-12.23%). Between 2001 and 2009, there were net increases in area for water (34.17%), tree plantation (12.63%) and settlement (7.47%), while decreases in areas of paddy field (-26.01%), forest (-12.33%) and dry farming field (-1.14%). The majority of changes over the entire study period occurred in the low slope (0-8%) and low elevation (0-500 m) areas. Urbanization and agricultural activities were detected to be the principle reasons for land use and land cover change in Bodri watershed.

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