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The Analysis of The Land cover Change Effect to Soil Erosion Using Spatial Modeling And Analysis (As A Key For Land Use Planning In Telaga Warna Catchment Area)

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ABSTRACT

Lake Telaga Warna is situated at upper stream of Ciliwung River. The lake contains freshwater supporting a rich ecosystem, promoting the lives of three primate species of Java and play important role hydrological function. Considering to its function, the national government established its status as Nature Reserve in 1981 through Ministry of Forestry Regulation No. 481/Kpts/Um/6/1981. Unfortunately, the lake is subject to land cover changes due to agricultural, settlement encroachment & other infrastructure development. The objectives of the research are (a) To provide accurate information of critical land / land degradation map for land use planning, (b) To analyze potential soil erosion due to land cover change in Telaga Warna Nature Reserve. Remote Sensing and GIS Technology couple with hydrological modeling (USLE) were applied.

Forest areas have been decreasing since 1991 of about 13.66% (1.315 Ha) or almost 1% per year. In the other hand settlement areas have been increasing. Meanwhile agricultural land was fluctuated depend on the season. Due to the land cover changes, distribution pattern of potential soil loss /erosion also changed. The area were classified into very heavy soil erosion were increase, which are situated mostly at bare land & agricultural areas.

Key words : Telaga Warna, GIS, Remote Sensing, USLE, soil erosion, soil loss

1. INTRODUCTION

1.1. Background

Telaga Warna is a shallow basin lake, situated at 25 km southeast of Bogor. This lake contains freshwater supporting a rich ecosystem, promoting the lives of three primate species of Java. Considering to its function, the national government established its status as Nature Reserve in 1981 through Ministry of Forestry Regulation No. 481/Kpts/Um/6/1981.

Sustainable land use is a complex problem which containing several issues in different fields and then need to be solved by integrating the information from different field studies. It requires not only the information come from relation of natural condition and natural process such as land cover change and soil erosion, but also the information from analysis of socio-economic condition of the catchments area. It aims to prevent even a small part of land losing their function or degraded. Lack of information about the condition of land is one of important problem to know why most of soil in mountainous area is degraded (Tuan, 2004). To comprehend such issue, many aspects and levels using information from history to present needs to be considered (Mannaerts 1993). One of the major factors that affect sustainable land use is soil erosion.

The relationship between land cover and soil erosion is obvious. The change of land cover tends to affect the quantity of soil erosion. Hence, the information of soil erosion through land cover change assessment can be used to design sustainable land use planning. Under some limitation, the result of this study is expected to facilitate the design of land use especially its natural condition (land cover) which minimize soil erosion in "Telaga Warna" catchments area.

1.2. Objectives of the Research

The objectives of the research are as follows:

1. To provide accurate information of critical land / land degradation map for land use planning.
2. To analyze potential soil erosion due to land cover change in Telaga Warna Nature Reserve using USLE model

2. MATERIALS AND METHOD

2.1. Time and Location of Study

The study area is situated in the Puncak, Bogor District, about 25 km southeast from Bogor (Figures 1). Study area is situated between 106,99° –

107,01° E longitude and 6,68° - 6,70° S latitude. The altitude range of the study area is about 1250 - 2000 meters a.s.l.

2.2. Data

The data is classified into two types, i.e. digital satellite imagery and vector data. Landsat TM and Landsat ETM+ are the satellite imagery used for land cover extraction and further for land cover change analysis. IKONOS imagery is used to help the identification of land cover types. Data used in this study are Landsat TM (Path: 122, Row: 65, year 1991, 1994, and 1997), Landsat ETM+ (Path: 122, Row: 65, year 2001, 2004, and 2006) and Ikonos taken in 2002.

Digital vector data used are topographic and soil map. Contour feature from topographic map was used to generate Digital Elevation Model (DEM) data. DEM, geological and soil map is used in the analysis of soil erosion.

2.3. Methodology

A. Data Preprocessing

The aims of data preprocessing are to improve the quality of the images and to produce the intermediate data which will be used in further processing.

1) **Geometric Correction**

Topographic map (especially road map) and Ground Control Point Data were used as reference data to rectify IKONOS and Landsat data. Polynomial order was used for developing transformation model and the used re-sampling method was cubic convolution.

2) **Atmospheric Correction**

The atmospheric condition may unique on each features but the reflectance value of features is always constant. Therefore, to compare and process multi-date images data, the images should radiometrically corrected in such that each feature has a similar reflectance value (digital number) throughout the images.In this research, relative radiometric normalization was used to improve the radiometric quality of multi images efficiently. Another atmospheric correction method used is haze removal.

3) **Radiometric Normalization**

Relative radiometric normalization (*RRN*) comprises of many methods, such as pseudo-invariant features, radiometric control set, image regression, no-change set determined from scattergrams, and histogram matching (Yang and Lo, 2000). Image regression (*IR*) based on pseudo-invariant features (*PIF*) is preferred consider that it is used to reduce variability throughout image other than land cover changes (Phua and Tsuyuki, 2006) and possible to know the uncertainty level of developed model. It works by using one image as reference and adjust the brightness of the rest image to match the reference.

The dark object method was carried out upon Landsat images 2006 which is assigned as referenced data of normalization. Even the image was suffered from striping caused by Scan Line Corrector (SLC) failure,

4) **DEM (Digital Elevation Model) Generation**

DEM was generated through surfacing process by using non-linear rubber sheeting method. In order to have same in resolution of data, DEM produced have a resolution as same as LANDSAT data, that is 30 m x 30 m. In further step of analysis in this study, the DEM was converted to a slope map and then used as a one factor for estimate soil erosion.

B. Data Processing

There are three kinds of data processing are carried out to prepare the data for the main analysis in the study (that is soil erosion analysis), comprise of image classification, watershed delineation, and slope classes and length generation.

1) **Watershed Delineation**

The watershed delineation tool uses *AVSWAT-2000* (version 1.0), the extension for ArcView and Spatial Analysis. It is used to perform watershed delineation based on *SWAT* (*Soil and Water Assessment Tool*) model. SWAT is a model developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watershed with varying soils, land use, and management conditions over long period of time (Arnold *et al*., 1998). The delineation process requires a Digital Elevation Model (DEM) in ArcInfo grid format.

2) **Slope Classes and Length Generation**

The length and the gradient of the slope have a major influence on the amount of soil erosion that can be occurred. The DEM was generated using surfacing method used to produce length and gradient of the slope.

3) **Classification Accuracy Analysis**

The accuracy parameters involve in building error matrix, estimating accuracy parameters such as total accuracy, user's accuracy, and producer's accuracy (Congalton and Green, 1999), *KHAT* statistic (*Kappa* estimator) and its variance.

4) **Land Cover Change Analysis**

The method used for analyzing land cover change per year was Boolean method. Subsequently, the descriptive statistics in the tabular and graphic format was used to expose the change of each class in sequential years. The analysis was carried out by using MS Excel.

5) **Soil erosion analysis**

The erosion is estimated by using USLE (*Universal Soil Loss Equation*) model (Wischmeier dan Smith, 1978). The model is ordered several factors which presumed affected land erosion, which mathematically describe by the equation below:

$$A = R \times K \times LS \times C \times P$$

A : Maximum soil erosion rate (ton/ha/year),
R : Rain erosivity factor
K : Soil erodibility factor ,
LS : Slope and length factor index,
C : Plant management factor index,
P : Soil conservation techniques factor index

1. Erosivity Factor

Erosivity factor is estimated by considering monthly rainfall intensity (*r*), rainy days (*D*), and maximum rainfall intensity (*M*) in 24 hours. The equation is given below (Bols, 1978):

$$EI_{30} = 6,119 .r^{1,21}.D^{-0,47}. M^{0,53}$$

2. Erodibility Factor

Soil erodibility is estimated based on soil sensitivity on erosion, which influenced by the nature of soil texture, structure, permeability and contained bio-organic matters.

$$100\ K = 1.292\ [2.1\ M^{1.14}\ (10^{-4})\ (12-a)] + 3.25\ (b-2) + 2.5\ (c-3)$$

where:

M : (% sand + % dust) x (100 - % clay), a : soil organic matter concentration (%)

b : soil structure codes, c : soil permeability classes

3. Slope and length factor

The length slope (*LS*) is estimated by the following equation below (Ardis and Booth, 2004):

$$LS = [0.065 + 0.0456.slope + 0.00654.slope^2] \times \left(\frac{slope\_length}{const}\right)^{NN}$$

Where:

slope : slope steepness (%), *slope_length* : length of slope (meter),

const : a constant, i.e.: 22.1, *NN* : constant determined from Table 1.

Table 1. Slope Range and *NN* Exponent Constants (Arsyad, 1989)

No.	Slope	*NN*
1	< 1%	0.2
2	1% < *slope* < 3%	0.3
3	3% < *slope* < 5%	0.4
4	< 5%	0.5

4. *C* and *P* Factor

C and *P* factor is determined by referring to the investigation of Arsyad (1989) and Wischmeier and Smith (1979 *in* Arsyad, 1989) and the information obtained from ground check data and image interpretation.

3. RESULTS AND DISCUSSION

3.1. Topographic Normalization of Landsat Image

The area study is a mountainous area which certain parts have a significant variation of topography. In turn, it affects the result of classification. Therefore, topographic correction has to be done, before conducting classification. Topographic slope, aspect, calculated incidence, and angle existence were merged with the multi-spectral Landsat response for TM/ETM bands. In order to fit a generalized photometric function, Minnaert method, a member of non-Lambertian model in which utilizing regression analysis, was applied. Generally, the effect of topography was reduced. Previously, at the area which has a high slope and aspect in line with solar radiation is darker than others, even they has a same land cover type (Figure 4.1). Minnaert method was able to correct such error, although it was overestimated for a small area which slopes more than 50° (Figure 2).

3.2. Land Cover Changes

Based on Landsat data there are 10 classes of land cover can be identified, which are forest, bush/scrub, mix garden, built up, paddy field, upland, tea plantation, bare land, grass and water. The Overall Classification Accuracy is 87.83% and Kappa Coefficient equal to 0.8525 which is represents strong agreement. In total 9629.23 ha of study area were evaluated for land cover changes. Table 2 presents about land cover changes from 1991 until 2006.

Table 2. Land cover changes from 1991 until 2006

	1991	1994	1997	2001	2004	2006
			(hectare)			
Forest	3315.51	3162.60	2978.64	2726.73	2474.19	2000.340
Bush	1043.46	1027.62	1286.10	1171.62	1677.87	1393.660
Mix garden	574.74	898.47	422.64	804.78	409.06	824.490
Built up	133.11	255.06	352.35	457.65	743.76	1058.580
Paddy field	30.24	38.88	29.70	137.61	126.36	60.750
Upland	1172.25	904.32	1373.22	1215.99	977.13	920.250
Tea plantation	562.41	968.31	749.79	663.75	923.61	748.290
Bare land	763.83	318.42	301.68	124.29	224.56	582.22
Grass	8.46	29.88	111.24	310.77	53.01	21.24
Water	0.54	0.90	11.25	2.43	1.53	1.26
Cloud	4.14	4.14	4.14	4.14	4.14	4.14
Shadow	8.01	8.01	8.01	8.01	8.01	8.01

Based on result of classification, forest, bush, upland and bare land has decreased between 1991 and 1994. However, upland and bare land fluctuate in next year. Its fluctuating happened depends on a season and planting time. Decreasing forest cover happened consistently until 2006, opposite with increasing in built up (settlement) cover. Degradation of ecologically valuable land caused by forest cover decreasing between 1991 until 2006 affects more than 13.66 % of the total land area (over 1.315 ha). Moreover, 9.61 % of the built up/settlement (over 925 ha) and 9.48 % of cultivated land always in fluctuated depends on a seasons and planting time (over 912 ha).

Between 1991 until 2006, bush, mix garden, built up, paddy field, tea plantation, and grass increased per year by 0.24 %, 0.17 %, 0.64 %, 0.02 %, 0.13 % and 0.01 %, respectively. Forest cover decreased by 1,315 ha representing decrease of 0.91 % per year. Areas of upland and bare land also decreased between 1991 until 2006 by 0.17 % and 0.13 % per year, respectively.

Figure **1**. shows that catchments area in upper Ciliwung, Cigundul and Cibeet has different trend of forest and built up/settlement cover changes. Forest cover of upper Ciliwung watershed has curve decrease stepper than Cigundul and Cibeet watershed. During 5 years, built up cover in upper Cigundul watershed increased significantly.

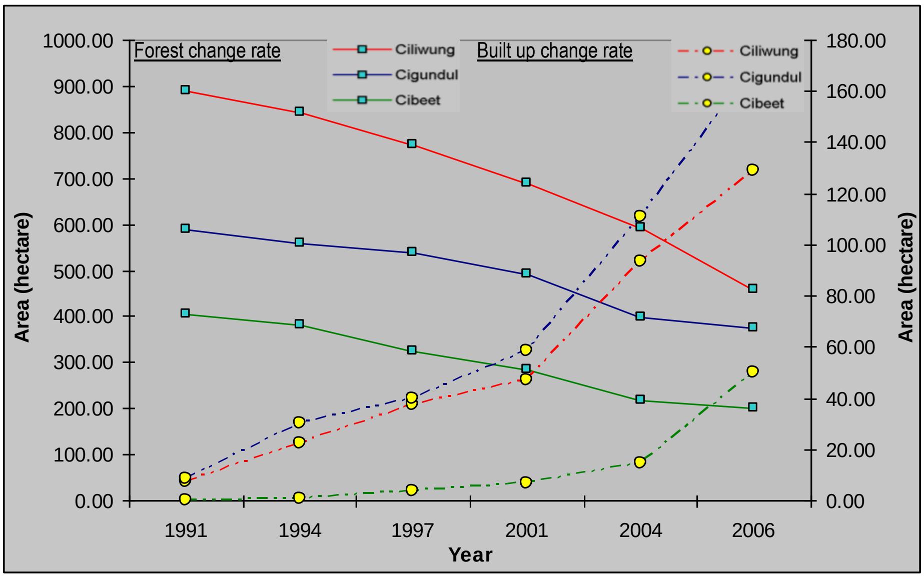

Figure 1. Trend of forest and built up cover change in three catchments area

3.3. Trend of Soil Erosion

Soil erosion in the whole watershed was estimated with GIS Remote Sensing based on USLE. The rainfall factor R was assumed a constant value in the whole study area, because study area not too wide, and no enough rainfall data available, which accurate to determined rainfall map in detail scale. So, soil erosion rate in this study represented by soil loss risk. The result of calculation of soil erosion (soil loss risk) between 1991, 1994, 1997, 2001, 2004 and 2006 are given in Table 3 .

Table 3. Calculation of soil erosion from 1991 until 2006

No	Class of soil erosion	1991	1994	1997	2001	2004	2006
		Area (hectare)					
1	Very low	4921.47	5082.48	4814.82	4721.67	4467.78	3914.19
2	Low	1235.97	1267.38	1251.81	1257.57	1282.77	1366.65
3	Moderate	1278.90	1194.21	1416.24	1481.31	1721.61	1965.78
4	Heavy	149.13	100.17	149.13	164.52	147.24	259.11
5	Very heavy	**111.78**	53.01	65.25	72.18	77.85	**191.52**

Based on spatial analysis about showed that most areas with soil erosion rate in very heavy class happened if land cover change to bare land, up land, mix garden and built up, although that location not in steep of slope (more than 40 %). Very heavy class of soil erosion happened in bare land, mix garden, up land, built up and grass (Table 4).

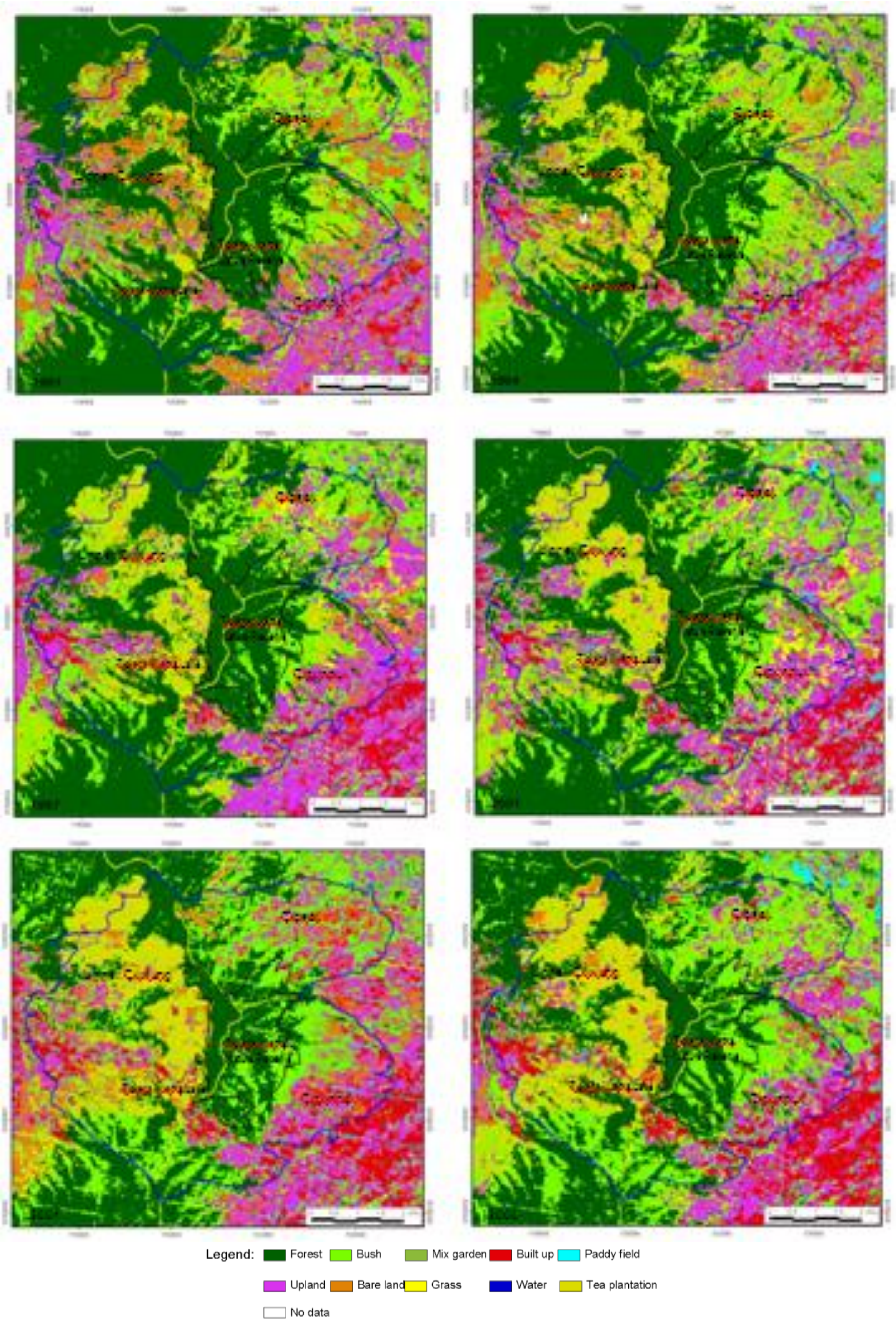

Figure 2. Distributions of Land cover from 1991 until 2006

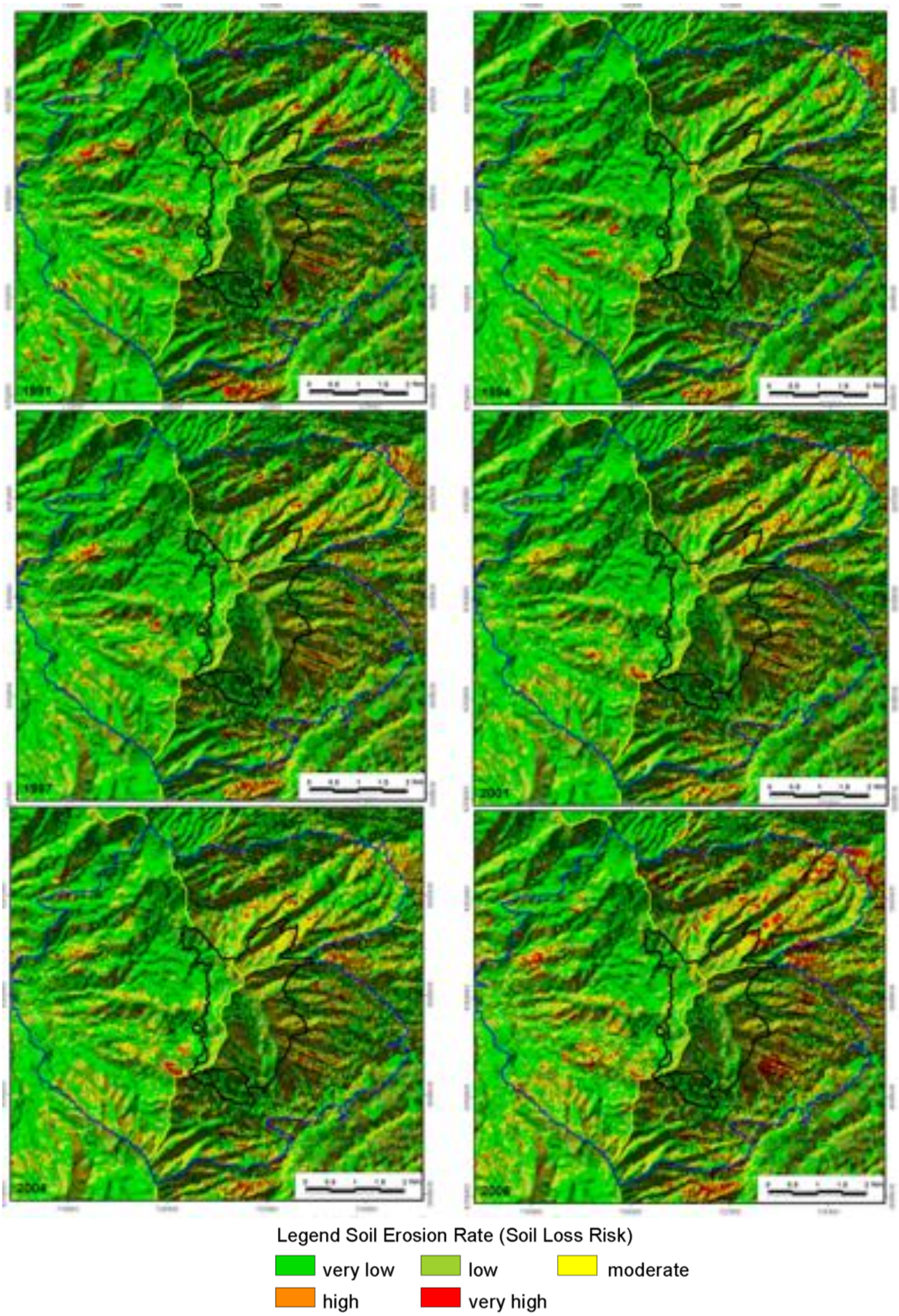

Figure 3. Distribution of soil erosion rate from 1991 until 2006

Table 4. Relation landcover change and very heavy class of soil erosion

No	Type of land cover	91-94	94-97	97-2001	2001-2004	2004-2006
		Area (hectare)				
1	Mix garden	2.07	1.44	6.66	0.99	5.22
2	Built up	0.72	1.71	5.22	10.98	28.53
3	Upland	3.96	20.70	24.21	13.32	21.60
4	Bare land	27.99	26.19	14.58	19.44	96.21
5	Grass	0.18	0.00	0.09	0.00	0.00

4. CONCLUSION

Based on result of classification, decreasing forest cover happened consistently until 2006, opposite with increasing in built up (settlement) cover. Cultivated area always in fluctuated depends on a seasons and planting time. However, land preservation of area Telaga Warna Nature Reserve is currently good.

The result of analysis about effect of land cover changes to soil erosion in pattern has showed that most areas with soil erosion rate in very heavy class happened if land cover change to bare land, up land, mix garden and built up, although that location not in steep of slope (more than 40 %). Very heavy class of soil erosion happened in bare land, mix garden, up land, built up and grass.

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