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Dynamic Patterns and Socioeconomic Driving forces of land use and land cover change in Humid Tropical Watersheds: A Case Study of Batang Merao watershed, Indonesia

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Abstract

Batang Merao watershed, a representative of the little known land change in humid tropical regions in Indonesia, is one of the key regions of this land use and land cover (LULC) research and has essential functions in maintaining the conservation function of the Kerinci Seblat National Parks and the socioeconomic function of Jambi Province, Indonesia. The implementation of regional autonomy started in Indonesia in 2000, and as the consequence, land has rapidly changed. This research aimed to investigate dynamic patterns and socioeconomic driving forces of LULC, and population pressure from 2006 to 2011. The dynamic patterns were investigated with GIS and Remote Sensing techniques while the socioeconomic driving forces were analyzed with multiple regressions, and the population pressure was quantified with Population Pressure Index (PPI) method. The results indicated that the dynamics of LULC showed an increase in agricultural area (mix plantation and agri-land) from 49.25% in 2006 to 56.71% in 2011, with primarily at the detriment of forest area. On the contrary, forest area decreased from 24.20% in 2006 to 18.13% in 2011 respectively. Annual rate of LULC change clearly showed the dynamics of different LULC classes over the study periods. The proximate socioeconomic driving factors significantly involved in the dynamic of LULC change were population growth/pressure, number of farmers, GDRP agriculture, GDRP total, and Human Development Index (HDI). The study is expected to be able to give useful contribution in providing essential information for natural resources conservation and sustainable land management in humid tropical watersheds.

Keywords: Conservation, humid tropical watershed, land change, land management, population pressure.

Introduction

Indonesia is a developing country in a humid tropical region where population has grown rapidly in the last decades, from 218.9 million (2005) to future 273.2 million (2025)[1], which placed Indonesia in the fourth most populous country in the world. Unfortunately, this mega biodiversity country is now under environmental pressure that Indonesia is also often seen as a country of environmental ruin whose biodiversity degradation is in alarming rates[1]. Among tropical regions, Indonesia exemplifies this critical situation and experiences one of the highest rates of deforestation due to land change such as agricultural expansion, deforestation, and habitat fragmentation. The predominance of Indonesia in humid tropical forest clearing accounts for 12.8% of the total forest loss[2]. Other previous studies about LULC issues at national level in Indonesia reported that the causes of deforestation at national scale are becoming more complex, and cover various aspects of inappropriate policy implementation, socioeconomic, and political issues[3].

The awareness about the importance of LULC change study among global issues has risen for its nexus on global human security and quality of the environment. Furthermore, LULC change is a critical issue due to its great influence on land degradation[4], biodiversity loss[5], water quality[6], eco-hydrological effects[7], and human life[8]. Analyzing the land cover changes and understanding the subsequent trends of change contribute to present complex dynamics of LULC and are important for planning and policy making[9] and sustainable management of resources[10].

Comprehension of landchange requires a rigorous understanding of the underlying processes[11] and a full range of methods from the natural and social sciences[12]. One of the fundamental theories in land change study is the force that observes land change usually called “driving force”[13]. It is generally accepted that there are two main driving forces of land change namely biophysical forces[14] and socioeconomic or anthropogenic drivers[15]. Some studies disclosed that the relationship between land change and its causative factors is complex and dynamic[16], strongly related to socioeconomic factors[17], and may occur at various temporal and spatial scales[18]. As a consequence of complex interactions between biophysical and socioeconomic conditions[18], it constantly changes in response to the dynamic interaction between underlying drivers (indirect or root) and proximate causes (direct)[14]. In tropical regions, LULC change is associated with population growth[19], population pressure[20], agricultural expansion[21], and deforestation[22].

Located in the Midwest part of Sumatera Island, the Batang Merao watershed can be regarded as a typical case of the complex dynamics of humid tropical watersheds in Indonesia. The watershed is primarily based on agriculture, and hence an adequate and sustainable agricultural production depends on the appropriate land resource management. It is also considered as the most important buffer zone of Kerinci Seblat Park, a UNESCO’s world heritage site in tropical rain forests. In addition, the watershed serves as the source of water resource, fresh water, and many important river systems in this region. In recent decades, however, the increasing of pressure on LULC gives significant impacts on the environment, particularly forest, soil, and water. Unfortunately, there is a lack of information about the dynamic change of LULC in this tropical watershed. Therefore, this paper aims at investigating dynamic patterns and socioeconomic driving forces of LULC change, and population pressure in the watershed. The final hope is that this research will give useful contribution in providing essential information for natural resources conservation, land use planning, and sustainable land management in humid tropical watersheds.

Methodology

Study area: Batang Merao watershed is located in the Kerinci Regency, a region in the western part of Jambi Province and in the middle of Sumatera Island, Indonesia. It lies between the latitude of 01°42’19”S and 02°08’14”S and longitude between 101°13’11”E and 101°32’20”E, as described in figure 1. The watershed covers an area about 67,874.48 ha and consists of 10 sub regencies including 124 villages. The altitude ranges from 767 to 3,266 m above sea level. The watershed falls within the humid tropical zone characterized by dry and rainy seasons with an estimated annual mean precipitation of 2,495 mm.y^{-1}over the last 20 years and annual mean temperature of 23.1^{0}C over the last 10 years. It plays an important role in serving regional economic development of Kerinci Regency and Jambi Province and is predominantly dependent on agriculture and tourism. Since it is a buffer zone of a UNESCO tropical rainforest heritage site in Kerinci Seblat National Park, maintenance of the protected area around the watershed is also an essential requirement for the regional economic and environmental development. Agriculture is the principal occupation of the people of Batang Merao watershed who are mainly engaged in cultivation of Tea (*Camellia sinensis L*), Paddy (*Oryza sativa*), Potato (*Solanum tuberosum*), Cassiavera (*Cinnamomum burmannii*), and local tropical fruits such as Orange (*Citrus sp*), Mangosteen (*Garcinia mangostana L*), Mango (*Mangifera indica*), etc. Issues of environmental degradation such as deforestation, land degradation, and illegal logging are now among great concerns of the local government Jambi Province.

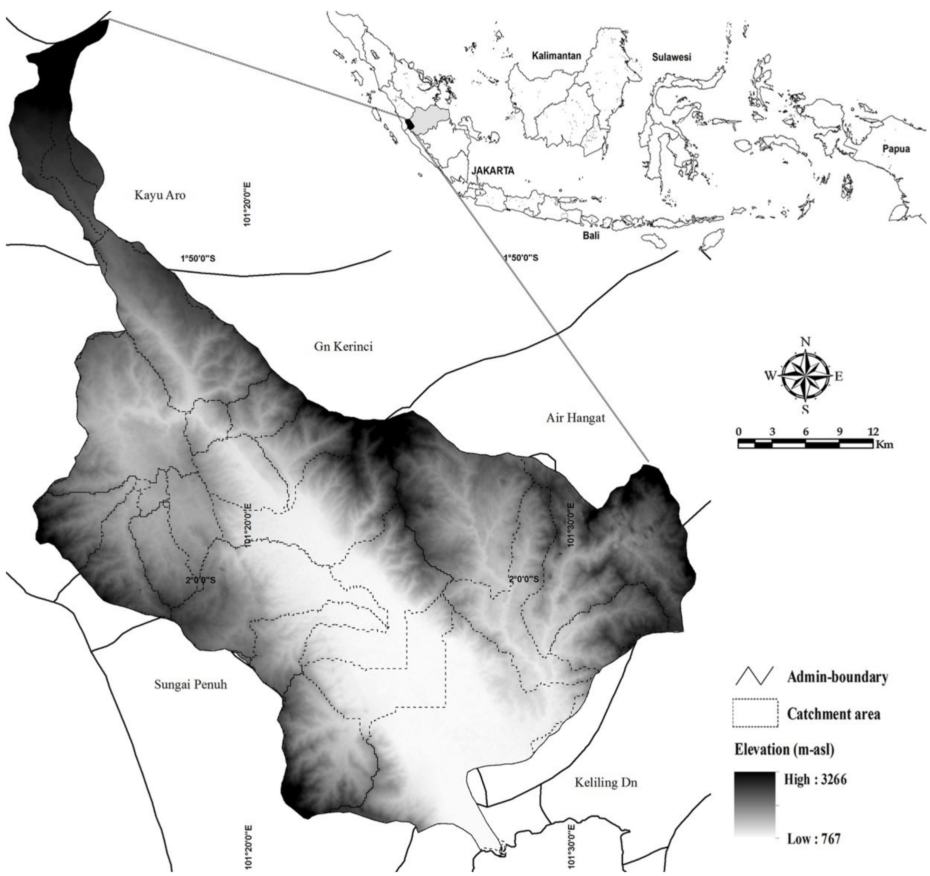

Figure-1
Map of Batang Merao watershed, Indonesia

Data collection: The details of data sets are described in table 1. The data used for studying LULC change included historical Landsat satellite images covering Batang Merao watershed for the year of 2006-2011 (path 126/row 61) retrieved from the USGS Earth Resource Observation System (http://glovis.usgs.gov). For supporting image analysis some ancillary data were used including ground truth data (83 samplings) acquired through the field survey (September 10-15, 2011), digital administrative map of Jambi Province provided by the Geo-spatial Information Agency of Indonesia, and digital watershed boundary map of Jambi Province published by the Ministry of Forestry of Indonesia. All the ancillary data were used to assist the training area in image classification and to collect the reference data in accuracy assessment.

Socioeconomic data were collected by primary survey of respondents in the study area. Semi-structured interviews with a total of 248 representative local people (2 respondents per village) were conducted in order to analyze population pressure to the LULC. Furthermore, relevant secondary socioeconomic data such as demographic and gross domestic regional product (GDRP) data were collected from the statistical yearbooks provided by the statistical offices at all administrative levels.

Table-1
Data collection and its description

Data	Description	Source
Landsat ETM	Path 126 / row 61 May 30, 2006 May 28, 2011	http://glovis.usgs.gov/
Administrative	Jambi Province Kerinci Regency Watershed Boundary	- Geospatial Information Agency of Indonesia (BIG) - Planning Agency of Jambi - Forestry office of Batanghari (BPDAS)
Demography	Population, statistics	Statistics of Kerinci Regency
Socioeconomic	Basic need, land-hold, income	Primary survey (248 respondents)
Ground truth	Ground truth for LULC classification Sept 10-15, 2011	Field survey (83 points)

Data analysis: Classification and accuracy assessment of LULC: In order to prepare the multitemporal satellite images for accurate change analysis, the Landsat images were pre-processed using standard procedures including Geo-referencing and geometric correction[23] while the WGS datum 1984 was used as the coordinate system. Subsets of Landsat satellite images were rectified using orthophotos with UTM projection Zone 48 S using first order polynomial methods and nearest neighbor image re-sampling algorithm. A total of 25 Ground Control Points (GCPs) were functioned to note the Landsat image with the data rectification error of less than 1 pixel (0.165 of RMS Errors).

A total of six LULC categories were considered in this study namely forest, mix plantation, tea plantation, shrub/bush, agricultural land, and settlement. This classification was modified from LULC categories of Indonesian National Standar No. 7645:2010 by National Standard Agency of Indonesia referring to the FAO's land cover classification system and ISO 19144-1[24]. Supervised classification, the most popular method for assesing remote sensing images[25], was used to classify images. An accuracy assessment or confusion contingency matrix was implemented for evaluating the accuracy of the classified images. The error matrix functions to compare a relationship between the known reference data (ground truth) and the conforming outputs of image classification[26]. The kappa coefficient, the value for an estimation of how well remotely sensed classification accuracies to the reference data, was used for accuracy assessment[23]. The Kappa (***Khat***) statistics[26] was guided by the equation below:

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

where r is the number of rows, $x_i$is the number of observations in row i and column i, x_{i+} and x_{+i} are the marginal totals of row and column, and N is the total number of observed pixels[26]. The value greater than 0.80 represents strong or good classification; the value between 0.40 and 0.80 means moderate classfication and the value less than 0.40 represents poor classification or agreement[23]. Furthermore, all LULC data were analyzed in ERDAS version 8.7 and Arc GIS version 10.1.

Relationship between LULC and socioeconomic factors: In order to investigate the socioeconomic driving forces which were significantly related to LULC change, a number of statistical tests were then performed with the LULC and socioeconomic data. A number of socioeconomic factors from the statistical yearbooks were selected for the analysis including total population, number of farmers, GDRP agriculture, GDRP construction, total GDRP, average expenses, and Human Development Index (HDI). These variables were initially computed for annual change rates, and subsequently the outputs were merged with derived LULC. A correlation matrix among the considered variables was firstly tested employing Pearson's correlationcoefficient through bivariate analysis with statistically significance at $p< 0.05$. For further analysis of the relationship, the stepwise multiple regression analyses with forest, a major concern of LULC change, as dependent variable, was carried out to measure the relationship among LULC compositions in each part of the watershed. All of the statistical tests were performed in SPSS version 18.0 for Windows.

Analysis of population pressure: The conceptual framework of population pressure has frequently been used for describing relationship amongst land change, environmental degradation, and human activity. It assumes that population density will lead to greater competition for resources, and it will thus decrease land or even outright resource shortage. Among its growing theories, the population pressure level was determined by using the PPI method[27,28]. The index of population pressure is calculated as follows:

$$PPI = Z(1-\alpha)\frac{fPo\,(1+r)^t}{L} \qquad (2)$$

where PPI is the population pressure index, ***Z*** is the minimum agriculture land-hold for proper life of each farmer (equal with rice 650 $kgyear^{-1}$), ***α*** is the non-agricultural income, ***f*** is the proportion of farmer in population, ***P*** is the population, ***r*** is the population growth, ***t*** is time, and ***L*** is the total of agriculture area (ha). If the PPI index is less than one, it means there is no population pressure on land and that land can still accommodate agricultural activities.

Results and Discussion

Distribution and dynamic pattern of LULC: The accuracy of LULC change along with the overall accuracy and the Khat coefficient are briefly explained in table 2. The table shows that the user's accuracy of individual category was from 50% to 100%, and the producer's accuracy was from 68% to 100%. The overall accuracy of image classification was 81.93%, and the Kappa coefficient was 0.776. The Kappa coefficients indicated that the classified images showed moderate classification performance or moderate agreement.

The distribution of LULC and its changes for 2006 and 2011 is summarized in table 3. Through the study period, there were substantial changes in several LULC categories including settlement, agricultural land, and mix plantation: agricultural land increased from 13,454.08 ha in 2006 to 14,457.84 ha in 2011; settlement areas increased from 1,514.62 ha in 2006 to 1,634.8; and mix plantation, the biggest change in the study period, increased from 19,977.76 ha in 2006 to 24,034.57 ha in 2011. Contrarily, forest decreased from 16,425.48 ha in 2006 to 12,304.79 ha in 2011.

Furthermore, the dynamic patterns of LULC change are also represented in figure 2. It appears that forested land has changed into another LULC type. Its change to mix plantation and agriculture could be the indication of a trend and need of agricultural market and regional economic development.

Table-2
Accuracy assessment for supervised classification of LULC

LULC Classification	Reference Data							User's Accuracy (%)
	F	**MP**	**TP**	**SB**	**AL**	**S**	**Total**	
Forest (**F**)	**19**	-	-	-	-	-	19	100.00
Mix Plantation (**MP**)	1	**17**	-	1	1	-	20	85.00
Tea Plantation (**TP**)	-	1	**8**	-	-	-	9	88.89
Shrub/Bush (**SB**)	-	2	-	**7**	1	-	10	70.00
Agricultural Land (**AL**)	-	2	-	1	**12**	-	15	80.00
Settlement (**S**)	-	3	-	1	1	**5**	10	50.00
Total	20	25	8	10	15	5	**83**	**Overall Accuray** ***81.93%***
Producer's Accuray (%)	95.00	68.00	100.00	70.00	80.00	100.00		**Kappa coefficient** ***0.776***

Table-3
Summary of LULC change and annual rate of change

LULC Classification	2006		2011		Change 2006-2011	Annual rate of change
	ha	%	ha	%	ha	%
Forest	16,425.48	24.20	12,304.79	18.13	-4,120.69	-5.02
Mixed plantation	19,977.76	29.43	24,034.57	35.41	4,056.81	4.06
Tea plantation	1,070.08	1.58	989.68	1.46	-80.39	-1.50
Shrub/bush	15,432.46	22.74	14,452.70	21.29	-979.76	-1.27
Agricultural land	13,454.08	19.82	14,457.84	21.30	1,003.76	1.49
Settlement	1,514.62	2.23	1,634.89	2.41	120.27	1.59
	67,874.48		**67,874.48**			

In general, the patterns showed a tendency towards more land being brought under mix plantation and agricultural land. These given data expressly stated that the increase in cultivated function resulted in deforestation, meaning that some forest areas (protected areas) were removed and converted to cultivated areas, such as mix plantation, paddy-field, and potato plantation.

Socioeconomic driving forces of LULC: Annual socioeconomic change rates were summarized in table 4. The result of Pearson's correlation matrix analysis indicated that the forest land was significantly correlated with five of seven socioeconomic factors namely total population, number of farmer, GDRP agriculture, total GDRP, and HDI. Meanwhile, GDRP Construction and total expenses were not related with forest land conversion.

As summarized in table 5, the output of multiple regression analyses confirmed that the forest land changes were contributed by five proximate driving forces. The GDRP, which is considered as an indicator used for measuring the size of the regional economy, indicated its coefficient at a high record of +2.65 supported by GDRP agriculture score of +0.51.

The rapid regional economic growth was parallel with forest degradation and agricultural expansion, as represented in figure 3. Therefore, due to the high deforestation rate in the watershed, it is necessary to give more attention about the ecological impacts of LULC change in order to achieve sustainability for both society and environment.

Population pressure in Batang Merao watershed: In order to better understand the population pressure on land, the population pressure index year 2006 and 2011 were examined and summarized in table 6. The data indicated that Batang Merao watershed was in high population pressure. The lowest PPI was Sungai Penuh sub Regency with the value of 0.46 (2006) and 0.89 (2011), and the highest PPI was Kayu Aro sub-regency at the value of 1.26 (2006) and 1.89 (2011), respectively. Accordingly, the average PPI level increased from 0.72 in 2006 to 1.30 in 2011. This result means that agricultural carrying capacity of the watershed could support the population of 189,444 in 2006; on the contrary, it could not accommodate the population of 229,089 in 2011; thus, there was an ecological overshoot in the watershed in 2011. This result was not too different with the previous study on the PPI level at provincial level and regional level in which the average PPI level in Jambi Province was 0.95 (2006) and 1.02 (2010)[29] respectively. Furthermore, the findings of this research agreed that the consequent high pressure on resources are feared to have adverse effects on the existing natural resources of the area as the demand for food and other necessities would increase. Among the major causes, demographic factors, especially an increase in local population including household structure and land-hold, play a significant role in LULC change[30].

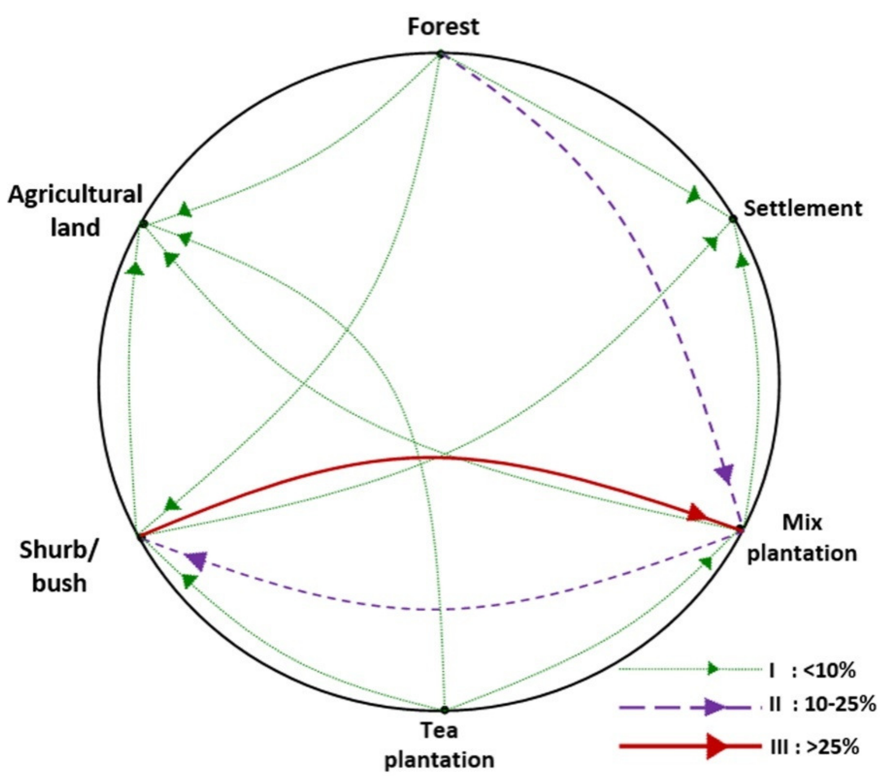

Figure-2
The dynamic patterns of LULC in the period of 2006 - 2011

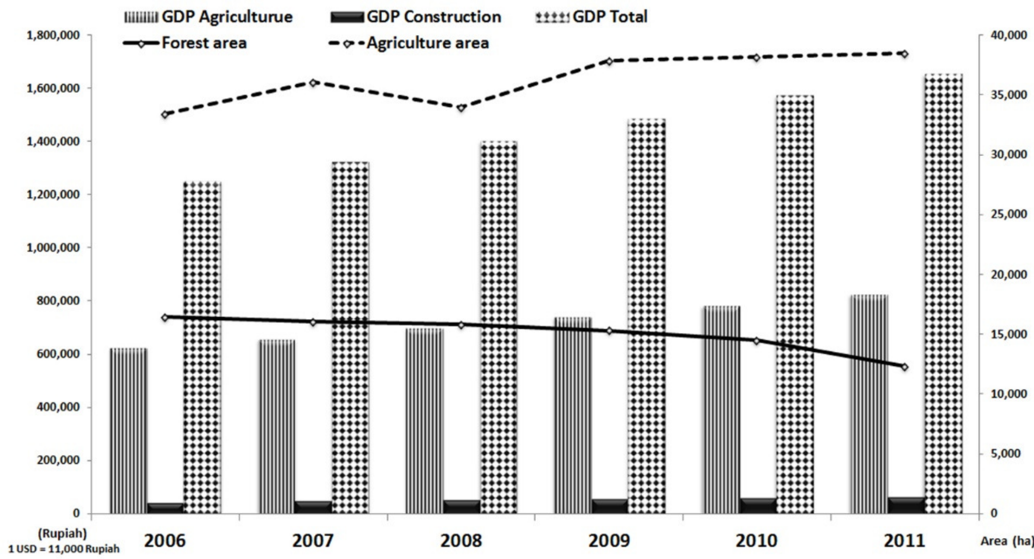

Figure-3
Changes and trends in the regional economic sharing and LULC areas

Table-4
Annual socioeconomic driving forces

Driving forces	2006	2011	Change rate
Total population (person)	183,033	229,089	5.03
Number of farmers (person)	76,546	100,424	6.24
GDRP agriculture (Rupiah)	625,435	826,590	6.43
GDRP Construction (Rupiah)	45,181	64,572	8.58
GDRP Total (Rupiah)	1,253,561	1,655,197	6.41
Total Expenses (Rupiah)	619,000	635,000	0.50
HDI	72.20	74.26	0.57
Note: 1 USD = ± 11,000 Rupiah (Indonesian Currency)			

Table-5
Regression analysis of socioeconomic driving forces of LULC change

Parameter	Coefficient	t-statistic	Sig.
Intercept	-2.79	-428.44	<.05
Total population	-0.37	-166.27	<.05
Number of farmers	-0.22	-148.98	.05
GDRP Agriculture	-0.61	-199.99	<.05
GDRP Total	1.05	224.23	<.05
HDI	0.12	205.05	.05
R^2 = .938 Adjusted R^2 = .917			

Table-6
Population pressure level in Batang Merao watershed

Year	**Category**		**Population Pressure Index**		
	No Pressure	**Under pressure**	**The lowest index**	**The highest index**	**Average**
2006	4 sub-regencies	3 sub-regencies	0.46 Sungai Penuh	1.26 Kayu Aro	0.72
2011	2 sub-regencies	5 sub-regencies	0.89 Sungai Penuh	1.89 Kayu Aro	1.30

Conclusion

The structural pattern of LULC in Batang Merao watershed, according to the distribution pattern, was forest (35.41%), agricultural land (21.30%), shrub/bush (21.29%), forest (18.13%), settlement (2.41%), and tea plantation (1.46%), respectively. Meanwhile, the dynamic pattern of LULC of forest was mix plantation, shrub/bush, agricultural land, and settlement.

The driving forces of LULC from the proximate factors included GDRP total, GDRP agriculture, total population, number of farmers, and HDI. The results suggested that changes in LULC and its dynamics were closely associated with human activities in the region such as the expansion of agricultural area (mix plantation and paddy field).

The growing population pressure and its associated problems, such as the increasing demand for land and agricultural products, limited land-hold shares, and the lack of non-agricultural income, had been the major driving forces of LULC. Hence, attention should be given to the introduction of wise land resource uses and management practices and secure land tenure systems.

Currently, the Batang Merao watershed, which might be the representative of many other watersheds in the humid tropical areas, reflected a critical dynamic change of LULC due to driving forces and population pressure. In regard to sustainable land management, conservation strategies for natural, agricultural, and pro-environment local economic activities, should be a priority for land managers and relevant stakeholders.

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References

1. Ministry of Environment of Indonesia, Fourth national report the convention on biological diversity, Jakarta **(2009)**
2. Hansen M., Stehman S., Potapov P., Loveland T., Townshend J., Defries R., Pittman K., Arunarwati B., Stolle F., Steininger M., Carroll M. and Dimiceli C., Humid tropical forest clearing from 2000 to 2005 quantified by using multitemporal and multiresolution remotely sensed data, *PNAS.*, **105(27)**, 9439–9444 **(2008)**
3. Resosudarmo B., Nawir A., Resosudarmo I. and Subiman N., Forest land use dynamics in Indonesia, WP No.2012/01, **(2012)**
4. Symeonakis E., Calvo-Cases A. and Arnau-Rosalen E., Land use change and land degradation in Southeastern Mediterranean Spain, *Environ Manage.,***40(1)**, 80–94 **(2007)**
5. de Baan L., Alkemade R. and Koellner T., Land use impacts on biodiversity in LCA: a global approach, *Int J Life Cycle Assess.*, **18(6)**, 1216–1230 **(2012)**
6. Uriarte M., Yackulic C., Lim Y. and Arce-Nazario J., Influence of land use on water quality in a tropical landscape: a multi-scale analysis, *Landscape Ecol*., **26(8)**, 1151–1164 **(2011)**
7. Fu B., Zhao W., Chen L., Liu Z. and Lü Y., Eco-hydrological effects of landscape pattern change, *Landscape Ecol Eng*., **1(1)**, 25–32 **(2005)**
8. Maitima J., Olson J., Mugatha S., Mugiisha S. and Mutie I., Land use changes, impacts and options for sustaining productivity and livelihoods in the Basin of Lake Victoria, *J. Sustain. Dev. Africa*., **12(3)**, 189–206 **(2010)**
9. Reddy T. B. and Gebreselassie M. A., Analyses of land cover changes and major driving forces assessment in middle highland Tigray, Ethiopia: the case of areas around Laelay-Koraro, *J. Biodivers. Environ. Sci*., **1(6)**, 22–29 **(2011)**
10. Turner B., Lambin E. and Reenberg A., The emergence of land change science for global environmental change and sustainability, *PNAS*, **104(52)**, 20666–20671 **(2007)**
11. Pena J., Bonet A., Bellot J., Sanchez J., Eisenhuth D., Hallett S. and Aledo A., Driving forces of land-use chang in a cultural landscape of Spain: preliminary assessment of the human-mediated influences, Springer, Netherlands, 97–116, **(2007)**
12. Ellis E., Land-use and land-cover change, *The Encyclopedia of Earth*, http://www.eoearth.org/view/article/154143/ [online accessed: Sept 10, 2013] **(2010)**
13. Bürgi M., Hersperger A. and Schneeberger N., Driving forces of landscape change – current and new directions, *Landscape Ecology*., **19**, 857–868 **(2004)**
14. Lambin E., Geist H. and Lepers E., Dynamics of land-use and land-cover change in tropical regions, *Annu. Rev. Environ. Resour*., **28**, 205–241 **(2003)**
15. Su C., Fu B., Lu Y., Lu N., Zeng Y., He A. and Lamparski H., Land use change and anthropogenic driving forces: a case study in Yanhe River Basin, *Chin Geogra. Sci*., **21(5)**, 587–599 **(2011)**
16. Minale A. S., Retrospective analysis of land cover and use dynamics in Gilgel Abbay watershed by using GIS and

Remote Sensing techniques, Northwestern Ethiopia, *International Journal of Geosciences*, **4**, 1003–1008 **(2013)**

17. Long H., Tang G., Li X. and Heilig G., Socio-economic driving forces of land-use change in Kunshan, the Yangtze River Delta economic area of China, *J. Environ. Manage*., **83(3)**, 351–364 **(2007)**

18. Reid R. S., Kruska R. L., Muthui N., Taye A., Wotton S., Wilson C. J. and Mulatu W., Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: the case of Southwestern Ethiopia, *Landscape Ecology*., **15**, 339–355 **(2000)**

19. Ningal T., Hartemink A. E. and Bregt A. K., Land use change and population growth in the Morobe Province of Papua New Guinea between 1975 and 2000, *J. Environ. Manage*., **87(1)**, 117–24 **(2008)**

20. Dhas A. C., Population pressure on land use changes in Southeast Asian countries: recent evidences, MPRA No.9570, 1–14 **(2008)**

21. Etter A., McAlpine C., Wilson K., Phinn S. and Possingham H., Regional patterns of agricultural land use and deforestation in Colombia, *Agric. Ecosyst. Environ*., **114**, 369–386 **(2006)**

22. Walker R., Theorizing land-cover and land-Use change: the case of tropical deforestation, *Int. Reg. Sci. Rev*., **27(3)**, 247–270 **(2004)**

23. Jensen J., Introductory digital image processing: a remote sensing perspective (3rd ed.), Prentice-Hall, New Jersey, **(2004)**

24. BSN - National Standarization Agency of Indonesia, Klasifikasi penutup lahan - Land cover classification (in Bahasa Indonesia), SNI 7645, **(2010)**

25. Perumal K. and Bhaskaran R., Supervised classification performance of multispectral images, *Journal of Computing*, **2(2)**, 124–129 **(2010)**

26. Congalton R., A review of assessing the accuracy of classifications of remotely sensed data, *Remote Sens. Environ*., **37**, 35–46 **(1991)**

27. Soemarwoto O., A quantitative model of population pressure and its potential use in development planning, *Majalah Demografi Indonesia*., **12(24)**, 1–15 **(1985)**

28. Ministry of Forestry., Technical regulation for critical land data management in Indonesia (in Bahasa Indonesia), No. P.4/V-SET/2013, **(2013)**

29. Rusli S., Widiono S. and Indriana H., Population pressure, ecological overshoot of Sumatera Island, and its recovery (In Bahasa Indonesia), *J. Sodality*, **04(01)**, 59–90 **(2010)**

30. Lambin E. and Geist H., Causes of land-use and land-cover change, *The Encyclopedia of Earth*, http://www.eoearth.org/view/article/150964/ [online accessed: Sept 10, 2013] **(2007)**