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LAND USE CHANGE ASSESSMENT AND ITS DEMAND PROJECTION IN BATANGHARI RIVER BASIN, SUMATERA, INDONESIA

Nurya Utami[a], Asep Sapei[b], and Apip[c,d]

[a]*Master of science in Information Technology for Natural Resources Management, IPB*
[b]*Geomatic Engineering, Department of Civil and Environmental Engineering, IPB*
[c]*Research Center Limnology-LIPI*
[d]*Asia Pacific Centre for Ecohydrology (APCE), Category II Centre under the Auspice of UNESCO*

Email : nurya.utami@gmail.com

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ABSTRAK

Studi ini meliputi analisis perubahan penggunaan lahan di wilayah DAS Batanghari. Peta tutupan lahan berasal dari klasifikasi citra satelit LANDSAT MS/ETM/OLI dengan menggunakan metode klasifikasi terbimbing. Citra dikategorikan menjadi enam kelas yaitu yaitu badan air, pemukiman, pertanian, semak, lahan terbuka dan hutan. Validasi untuk hasil klasifikasi dihitung menggunakan statistik Kappa dengan hasil rata-rata 85% -95%. Berdasarkan hasil klasifikasi, tingkat perubahan penutupan lahan yang paling banyak ditemui adalah kawasan hutan menjadi daerah pertanian. Perubahan pada area jenis tutupan lahan lebih spesifikasi dapat dilihat pada matriks deteksi perubahan. Data historis dari penutupan lahan ini (1990, 1997, 2005 dan 2015) digunakan untuk menghasilkan proyeksi kebutuhan lahan dari tahun 2016 sampai 2040. Hasil proyeksi menunjukkan bahwa pada tahun 2040, lahan pertanian merupakan lahan yang mendominasi area DAS Batanghari. Penambahan luas lahan pertanian mencapai 22 % dari tahun 2015sampai dengan 2040 yaitu sekitar 3.148.100 ha. Sebaliknya kawasan hutan menurun hingga hampir 50 % pada masa mendatang.

Kata kunci: Perubahan penggunaan lahan, klasifikasi terbimbing, penutupan lahan

ABSTRACT

This study covers land use change in the region of Batanghari River Basin. Land use maps were derived from supervised classification of LANDSAT MS/ETM/OLI satellite imagery. The objectives of this study were to observe and analyse the changes of land use and project the temporal demand for each land use. Classification of images was categorized into six classes, namely water body, settlement, agriculture, bush, open land and forest. The validation for classification result using Kappa statistics with average accuracy of 85% -95%. Based on the classification results, the largest extent of land cover change is forest areas into agricultural areas. Changes in the area of certain types of land cover can be seen in the change detection matrix. This change was formulated for land use demands from recent past to near future, generating a dominant land use type of agriculture. The expansion of agriculture areas area about 22% (2015-2040), around 3.148.100 ha. On the contrary, forest areas decrease almost 50% (ha).

Keywords: Land use change, supervised classification, land demands

INTRODUCTION

Batanghari river basin is the second largest basin in Indonesia with an area of approximately 4.5 million hectares. This watershed is located mostly in Jambi Province and only 18 % of total area is in West Sumatera. High sedimentation and extreme fluctuation of water discharge between wet season and dry season are the main indicators recorded. Water discharge during rainy season becomes extremely high resulting in flooding in the midle to low areas of basin. Meanwhile in dry season, several areas are in droughts state because the water discharge is very low.

Conversion of forest land into residential areas at both upstream and downstream is one of main contributors that causes Batanghari River basin becomes critical. Due to rampant land clearing for rubber and oil palm plantations as a primary commodity, turns into a devastating effect in the short term. In the regulations, river border area should not be planted or converted.

Land use/land cover changes will lead to several environmental problems, such as landslide and floods. Generally, it caused by mismanagement of agricultural, urban, and forestlands (Reis 2008). Land use change analysis and predictions in the future is very important to know. The use of satellite imagery with suitable resolutions and multi-temporal time coverage for zoning, characterization, adaptation and mitigation of land use change is necessary. Therefore, available data on land use changes can provide critical insights in the decision making process in relation to environmental management and future planning.

Remote sensing data have a long history of being used for deriving land cover maps. Malupattu *et al.* (2013) have used remote sensing as the tool to analyse land use/land cover in urban area in Tirupati. Weng (2000) also use remote sensing as the primary data to model land use change in Zhujiang delta by using markov model. Butt *et al.* (2015) have examined land use change using remote sensing and GIS (Geographic Information System) in Simly Watershed, Pakistan with the overall result of classification accuracy is around 95%.

Previous research about land use changes in Batanghari river basin was done by Tarigan (2016). The study focused on how to distinguish secondary forest, primary forest, oil palm growth phase, and another vegetation cover. The land cover of Landsat images were classified using Carnegie Landsat Analysis System-Lite (CLASlite) module. There are also another study about land use changes in Jambi Province but in small region. Sari *et al.* (2014) studied about deforestation specifically in Muaro Jambi district. Nurwanda *et al.* (2015) analysed land cover changes and lanscape fragmentation only in Batanghari Regency, followed by Achmad *et al*. (2016) who analysed land use change and its affecting factor in Berbak National Park Jambi Province. However, no previous researches in Batanghari River basin were conducted by using more than two series of present land use data and considering its future demand projection.

Considering the above previous research results, this research was intended: (1) to detect a long-term spatio-temporal land use change by utilizing four data series of Landsat images and; (2) to project the temporal land use demand for near future in the study area. Therefore, compared to Tarigan (2016) that only using two time series of images, profile of land use changes will be more visible obtained by this research. In addition, temporal demand projection from 1990 to 2040 was included in the study.

Batanghari river basin as the study area is included in a very large scale. This study was analysed the whole basin area because it will be used for the analysis of flood simulation in basin area under climate and land use changes.

METHODS

Study area

The study area focused on a large scale of Batanghari River Basin. Geographically, Batanghari River Basin located between 0˚43’ – 2˚46’ S and 100˚45’ – 104˚25’ E. It is surrounded by several mountains and a strait. In record, Batanghari is the second largest river basin in Indonesia, covers an area of 4.5 million hectares. It consists of 14 district; Batanghari, Kota Jambi, Merangin, Bungo, Tebo, Sarolangun, Muaro Jambi, Tanjung Jabung Timur, Kerinci, Kota Sungai Penuh, Dharmasraya, Sijunjung, Solok, Solok Selatan Districts. The study area was selected as a case study because of a less research on the projection of land use in the area. In addition, flood disaster also becomes more intensive in the Batanghari River basin recently. The whole areas include a large scale region because the results of this study will be used for the analysis of the risk of flooding in the next research.

The additional data includes ground truth data for the land use/land cover classes in 2015. The ground truth data collected using Geographical Positioning System (GPS) in 2015.

Image pre-processing and image classification

The Landsat images were already corrected geometrically by USGS Earth Resource Observation System Data Center (EROS). All of the images were orthorectified to a UTM 48 S projection. Images then classified using maximum likelihood algorithm, which is one of the most commonly used as a supervised

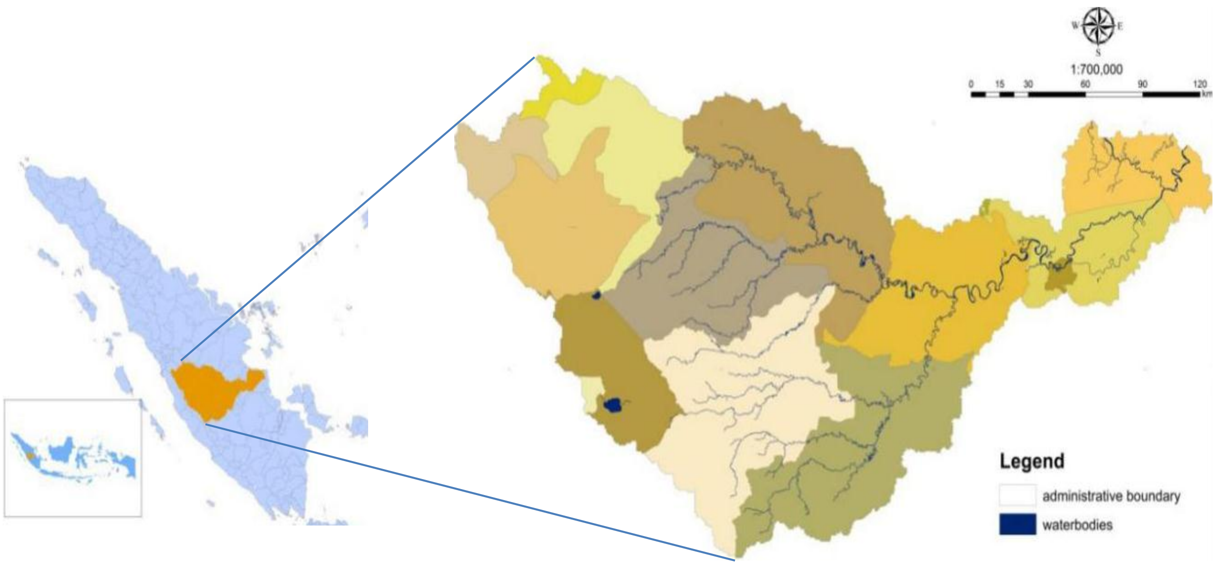


Figure 1. Study area, Batanghari River basin located in West Sumatera and Jambi Provinces.

Materials and Methods

The primary data used in this study were Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper + (ETM+) and Landsat 8 Operational Land Imager (OLI) with spatial resolution of 30 m. The satellite data was collected from year 1990, 1997, 2005 and 2015. Those data were obtained from USGS (United States Geological Survey). The boundary of Batanghari River Basin in aerial imagery, as a study case, consist of 5 scenes (path/row; 125/61, 125/62, 126/61, 126/62, and 127/61).

classification technique (Catur *et al.* 2015; Juniarno 1997; Sampurno & Thoriq 2016; Devi & Baboo 2011). This technique requires several training samples from the imagery data for each classes. Each pixel is assigned to the class that has the highest probability. The advantage of the maximum likelihood classification is that it examining variance and the covariance in the class distribution and for the normal distributed data, the maximum likelihood performs a better classification than the other classification methods. There were six classes differentiate inside the boundary area, as describes in Table 1.

Table 1. Classification of land use types.

No	Land Use	Description
1	Water body 	River and lakes
2	Settlement 	Residential area, industrial area, transportaion and facilities
3	Agricultural land  	Paddy field, dry land plantation includes rubber and oil palm plantation
4	Bush 	Bush, shrub
5	Openland 	Open land, abandoned land which exposed soil
6	Forest 	National parks, mangrove forest, mixed forest

Accuracy assessment

The ground data in the form of reference data points was used to validate the classification result in landuse year 2015. Because the ground truth data does not distribute evenly, the accuracy point was added with 100 of random point in each scene. The value of accuracy is expressed by overall accuracy and kappa statistics as the level of agreement. This asessment was calculated automatically in the ERDAS tools, by using Kappa Statistic equation (Senseman 1995).:

$$K = \frac{N\sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r}(X_{i+}, X_{+i})}{N^2 - \sum_{i=1}^{r}(X_{i+}, X_{+i})} \qquad (1)$$

where N is number of sites in the matrix, R is number of rows in the matrix, X_{ii} is number in row i and column i, X_{i+} is total for row i, and X_{+i} is total for column i.

Land use demand

Six different land use types with land requirements scenarios have been created for the period 1990 to 2040. A scenario was derived from trend extrapolation from 1990 to 2015. In this scenario, the area that has been designated as a national park forest, was used as the minimum limit of the forest area change. Hence, if the forest area is less than an area of a national park, then the land use will stop changing.

Analysis of land use projections were simply carried out by using extrapolation of trends in land use change of 1990, 1997, 2005 and 2015 that was divided into three intervals of year; 1990-1997, 1997-2005, and 2005-2015. Simple linear regression was used as the equation in every interval. The equation was then used to predict how much land demands in 1990-2005. The prediction of the following year (2016-2040) was carried out using the formulation in 2005-2015, assuming that the change of land remains for up to 30 years.

RESULTS AND DISCUSSION

Land use change detection and analysis

Land use changes analysis in the Batanghari river basin starts from 1990 to

2015. Based on the delineation, Batanghari River Basin has total area of 4,402,825 ha. In this study, land use/ land cover types were divided into six classes; water body, settlement, agriculture, bush, open land and forest. The results in Figure 2, illustrates the land use change of 26 years history and the distribution of the changes for each classes.

Figure 3 reveal that in 1990, about 59% area was under forest area. Periodically, there is an increasing demand for basic needs due to increasing population density. As a result, the land clearing of forest area into agricultural land cannot be circumvented. Forest areas decline up to 33% of the initial area in 2015. Until now, the extent of the forest area

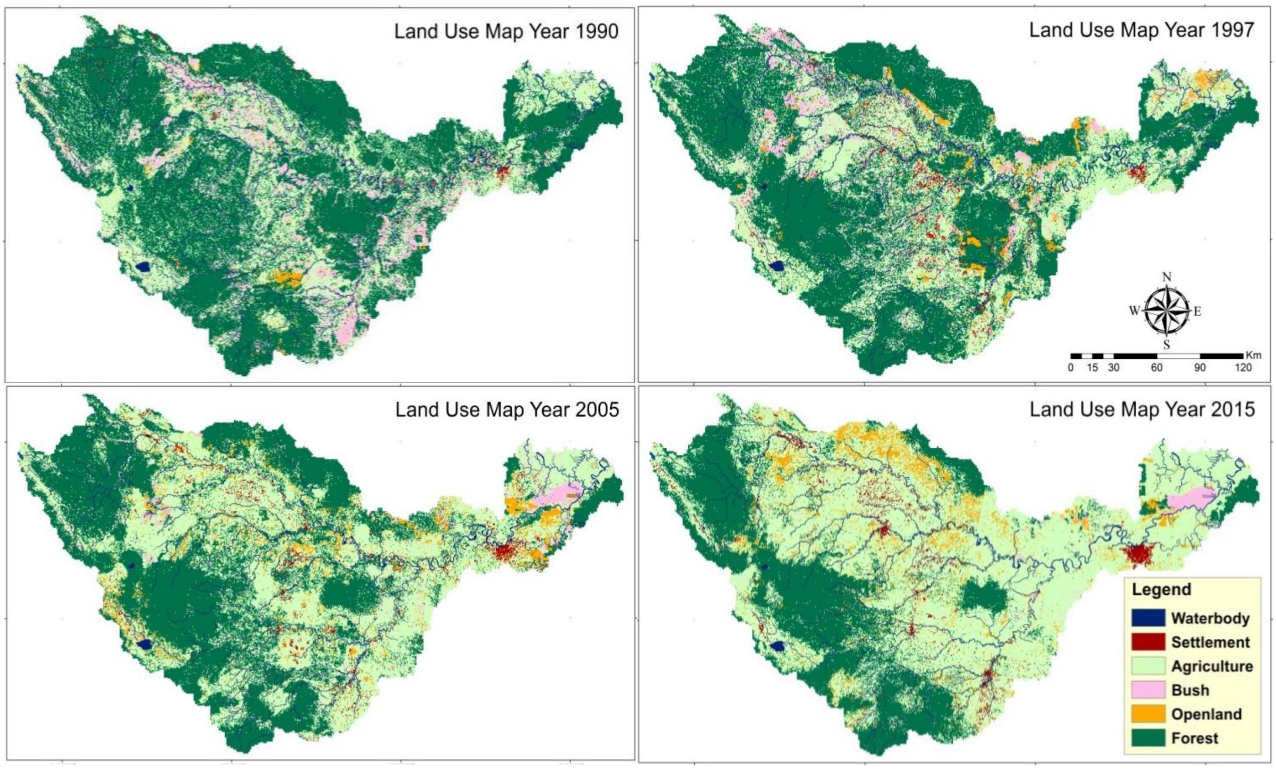
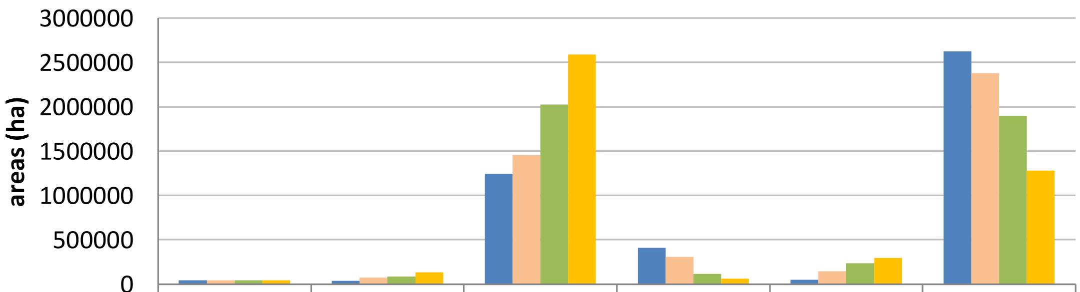


Figure 2. Delineated land use map from satellite imagery classification in 1990, 1997, 2005 and 2015.

The accuracy was calculated automatically in ERDAS imagine tools. The overall accuracy for the four land use (1990, 1997, 2005, 2015) maps each scene produced automatically in ERDAS Imagine tools, between 80% - 90%. The minimum values to be considered as a good accuracy interpretation in the identification of land use/land cover is 85% (Araya & Cabral 2010). This result is good enough to consider as representation of actual land use. Meanwhile, Kappa statistic for those land use classifications generated a fairly high accuracy that varies between 0.75-0.85 each scene.

Visually, the changes in land-use can be seen in Figure 2, which is clear that forest area decreases from year to year. The data in Batanghari River Basin included the national park only reached 29% (1,280,500 ha) of total area. According to Tarigan (2016), in the period of 1990-2013, about 1 million ha forest areas were converted into other land use types.

Jambi province has small population compare to other provinces. However, the growth rate is relatively high that reached 2.55 % annually in the period of 2000-2010 (Hardiani, 2014). Based on statistical data, Dharmasraya and Solok Selatan have the highest population growth rate of 2.96% and 1.92%, respectively. However, the increase of settlement areas inside the watershed was not significant. In 1990, this area occupied only 0.9 % of total basin and then increased three times to 3 % in 2015.



	Water	Settlement	Agriculture	Bush	Open	Forest
1990	42325	39575	1242450	407525	48750	2622200
1997	42325	73775	1452475	309700	144150	2380400
2005	42325	86800	2024950	112650	237675	1898425
2015	42325	135450	2586525	63025	295000	1280500

Figure 3. Trends of land use change 1990-2015 for each classes.

In the year of 2015, agriculture area was dramatically expanded from 28% to 57 % of total area. Most of the conversion was from forest area followed by bush land use type. Agriculture area was dominated by dry land plantation. Rubber and oil palm plantation are two competitive commodity in Jambi. Rubber is the oldest agricultural crops in Jambi. Recently, rubber production began to decline because it was replaced by oil palm plantations (Busyra, 2014). Currently, rubber plantation areas are 588.000 ha and oil palm plantations area reaches about 688.000 ha. Another agriculture lands that exist are rice field, coconut farm, coffee agroforestry, and crops.

Land conversion is not only triggered by migration of people into Jambi region, but also considered the entry of large oil palm companies and other industrial plantations. The needs of industry and oil palm exports created forest policy to support the issuance of these commodities through the conversion of forest land on a large scale (Widawati *et al.* 2012).

During the period of 1990 – 2015, the percentage area covered by bush decreased by 7 %, while open land area increased by 6 %. Usually, open land areas, especially surrounded by agriculture area, is only temporarily. Because it will be conversed to another land use type. Sometimes it abandoned by the owner and in long time period become bush area. The increase in the bare soil area was due to rapid deforestation (Butt *et al.*, 2015).

Waterbody is assumed as unchanged area. Considering that the imageries used were varies from rainy, dry and transitions period, sometimes the image shows Batanghari river a bit dry and it will be fully charged again when rainy season. A positive value indicates an increase and a negative value indicates a decrease in area.

A positive value (Table 2) indicates an increase and a negative value indicates a decrease in area. Historical land use describe that the highest rate of agriculture land during period 1997-2005. Agricultural expansion reached 39 % from 1990. Otherwise, the greatest deforestation rate occurred in the period 2005-2015. Supported by increased population, land clearing is used for commercial and tourism purposes.

Table 2. Land use change percentage for each type.

Land use	Land use change (%)		
	1990-1997	1997-2005	2005-2015
Settlement	86	18	56
Agricultural land	17	39	28
Bush	-24	-64	-44
Openland	196	65	24
Forest	- 9	- 20	- 33

The change detection matrix for the time period of 1990-2015 was generated using pixel by pixel method. As discussed before, the lands converted into agriculture area was mostly from forest area of about 1.2 million ha. Deforestation will continue if the area belongs to industrial timber plantations companies. There are slightly odd data shown in Table 3, where settlement areas changes into another land use. As a matter of fact, it is unlikely that settlement area to be converted into forest area or another land use type. This is likely due to error/miss-classification of residential areas. Meanwhile, conversion from agriculture area into forest area might occur due to reforestation.

Land use demand projection

Figure 4 shows linear equations for land use projections. Figure 5 is the result of the calculation of land use demand up to 2045. Land use demand was generated each year for every land use type. The smallest increase of land use changes was open land with areas of 352.325 ha, followed by agricultural land which increase 22% in 2040 (3.148.100 ha) and settlement areas increases about 36 % from 2015 (184.100 ha).

Table 3. Changes matrix of land use area (ha) in 1990 to 2015 (ha).

		2015						Total
		0	1	2	3	4	5	
1990	0	42325						42325
	1		9150	23400	500	2100	4425	39575
	2		64675	932500	11425	72250	161600	1242450
	3		33975	313050	4100	18850	37550	407525
	4		2550	35225	175	2300	8500	48750
	5		25100	1282350	46825	199500	1068425	2622200
Total		42325	135450	2586525	63025	295000	1280500	4402825

Information : 0 = water body, 1= settlemnt, 2 = agriculture, 3 = bush, 4= open land, 5 = forest

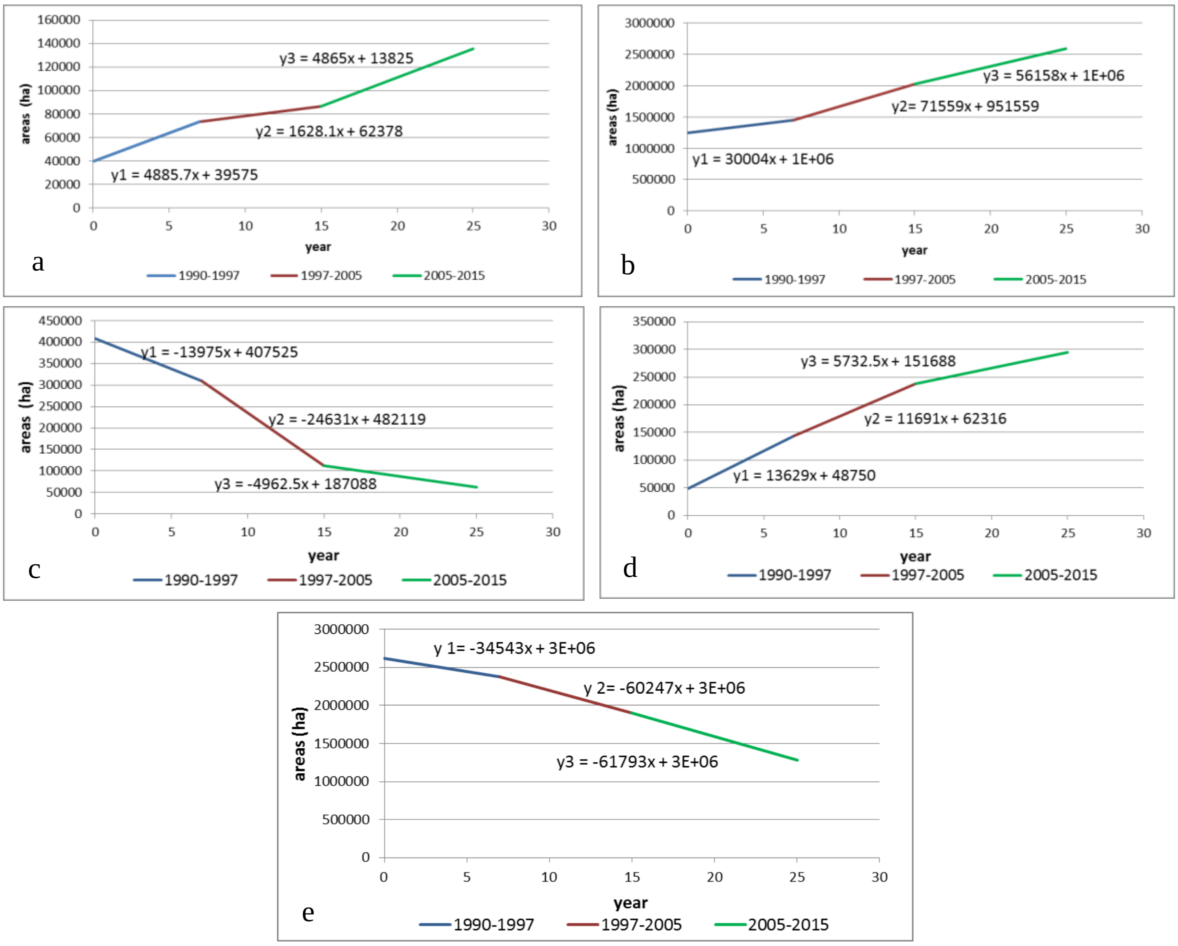


Figure 4. Linear equation for land use projections ; (a) settlement, (b) agriculture, (c) bush, (d) open land, and (e) forest.

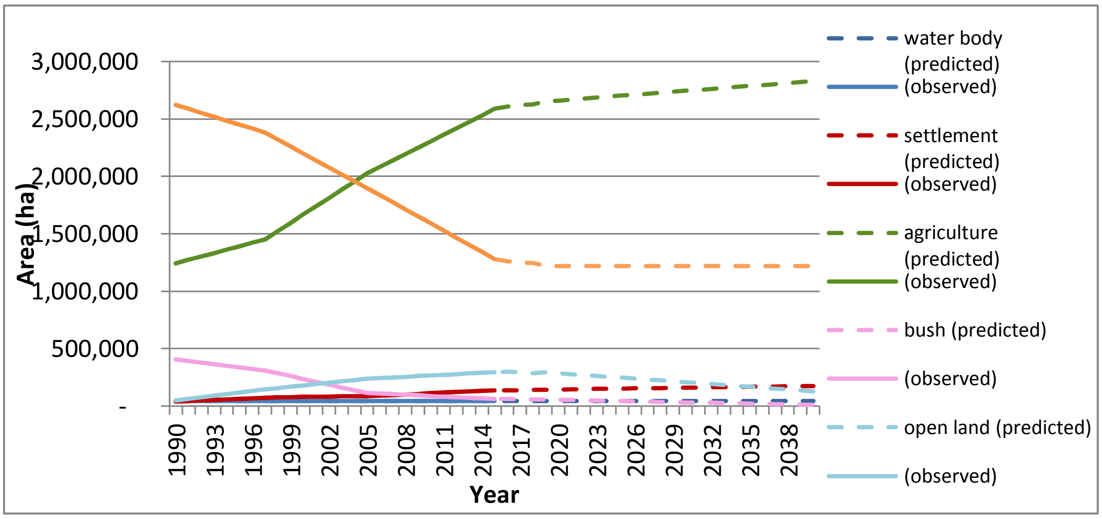


Figure 5. Past, present, and projected land use demand for each type.

This land use demand will be used as one of the input to project land use change based on historical data and driving factor. The actual land use projection involves many factors including social and economic factors. Therefore, the result of land use projections in this paper is a preliminary result for the next research.

CONCLUSION

Based on the analysis, the greatest land conversion in Batanghari river basin was forest area into agriculture area. Forest area is predicted to decline continously until the next 30 years. While agricultural lands always expand along with the increasing population. Bush and open land area also mostly converted into agriculture land. Currently, Batanghari river basin is dominated by agriculture land use type. Bush and open land area that turned into forest was likely occurs as a result of abandoned land in a very long time. Settlement expansion generally from bush and forest area. Based on land requirements, settlement, open land and agriculture area always increases while bush and forest area always decreases.

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