Analysis of Changes in Land Cover to Support The Management of Gunung Leuser National Park

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Abstract. *Gunung Leuser National Park (GLNP) in Aceh and North Sumatra, Indonesia was allocated to protect and preserve its local biodiversity. GLNP implements a national park management policy that adopts a zoning system which includes core, wilderness, rehabilitation, traditional use, utilization and other zones. Population growth causes land cover changes in GLNP and in its buffer zone. One of the approaches to assessing rapid land cover changes is by employing a remote sensing approach. The purposes of this study are: (1) to analyze land cover change between the periods of 1996, 2005 and 2014; (2) to analyze the relationship between the population pressure index and land cover changes; and (3) to propose a guidance and recommendations for a better management of land cover changes in GLNP. The results showed that the main land cover classes at GLNP and its buffer zone in the period between 1996 and 2014 were forests, grass/shrubs, and cropland. Compared with the proposed zoning and the provincial master plan, there were land cover mismatches in 2014, especially in Southeast Aceh Regency. The land cover changes analysis indicated a significant decrease of forest land cover from 1996 to 2014. In the period between 1996 and 2005, the analysis showed the highest increase for cropland whilst in the period between 2005 and 2014, the highest increase was observed for plantations.*

Keywords: *Gunung Leuser National Park, land use/land cover change, population pressure index.*

Abstrak. *Fungsi utama dari Taman Nasional Gunung Leuser (GLNP), sebagai salah satu dari kawasan konservasi yang ada di Provinsi Aceh dan Provinsi Sumatera Utara, adalah untuk melindungi dan melestarikan sumberdaya keanekaragaman hayati yang terdapat di dalamnya. Sebagai Taman Nasional, GLNP memiliki kebijakan pengelolaan yang harus didasarkan pada sistem zonasi yang terdiri dari zona inti, rimba, rehabilitasi, penggunaan tradisional, pemanfaatan dan zona- zona lainnya. Peningkatan jumlah penduduk menyebabkan perubahan penutupan lahan di kawasan GLNP dan zona penyangganya. Salah satu pendekatan yang dapat dilakukan untuk mengetahui perubahan penggunaan lahan secara cepat adalah menggunakan teknik penginderaan jauh. Untuk itu, tujuan dari penelitian ini adalah: (1) Untuk menganalisis perubahan penutupan lahan pada tahun 1996, 2005 dan 2014; (2) Untuk menganalisis hubungan antara indeks tekanan penduduk dengan perubahan penutupan lahan; dan (3) Untuk menyusun arahan dan rekomendasi pengendalian perubahan penutupan lahan yang mendukung*

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pengelolaan GLNP. Hasil penelitian menunjukkan bahwa bentuk penutupan lahan paling besar di GLNP dan zona penyangga pada periode 1996-2014 adalah hutan, rumput/semak belukar dan pertanian lahan kering. Terdapat ketidaksesuaian penutupan lahan tahun 2014 dengan peta zonasi yang telah dibuat dan juga ketidaksesuaian penutupan lahan tahun 2014 dengan Rencana Tata Ruang Wilayah (RTRW) Provinsi Aceh dan Sumatera Utara terutama di Kabupaten Aceh Tenggara. Hasil analisis perubahan penutupan lahan menunjukkan penyusutan penutupan lahan paling tinggi terjadi pada hutan pada periode tahun 1996-2005 dan periode 2005-2014. Pada periode tahun 1996-2005 peningkatan penutupan lahan paling tinggi terjadi pada pertanian lahan kering sedangkan untuk periode tahun 2005-2014 peningkatan penutupan lahan paling tinggi terjadi pada perkebunan.

Kata kunci*: indeks tekanan penduduk, perubahan penutupan lahan, Taman Nasional Gunung Leuser.*

Introduction

Gunung Leuser National Park (GLNP) is one of the conservation forests with a status as a national park with a native ecosystem that is managed with a zoning system and is used for research, science, education, supporting cultivation, tourism and recreation purposes. The national park is located in two provinces i.e. Aceh and North Sumatra and is one of 52 national parks in Indonesia with a size of 1,094,692 hectares (Decree of the Minister of Forestry No. 276/Kpts-II/1997), see in Figure 1.

Figure 1. Study Location

The main function of GLNP, like other national parks, is as a life support system with a management focus on maintaining the unique Leuser Ecosystem that has a high biodiversity and is a critical habitat for several flagship species. Endangered and protected animals found in GLNP include the Sumatran orangutan *(Pongo abelii),* siamang *(Hylobates syndactylus),* Sumatran elephant *(Elephas maximus sumatranus),* Sumatran rhinoceros *(Dicherorhinus sumatrensis sumatrensis),* Sumatran tiger (*Panthera tigris sumatrae),* Sumatran serow *(Capricornis sumatrensis),* and many others. GLNP is acknowledged as having an important international value for its high biodiversity and as important habitat for several flagship species. This recognition is seen from GLNP's status as ASEAN Heritage Park, World Heritage Site and Biosphere Reserve (Tim Pokja Penanganan Perambahan Ditjen PHKA, 2010).

The size of the national park, also its high biodiversity and functions are an important resource asset. Beukering et al., (2003) have calculated the accumulated total economic value from GLNP and its buffer zone, known as the Leuser Ecosystem, for the period of 2000-2030 using a dynamic simulation model with 3 scenarios. The accumulated total economic value in the "deforestation scenario" amounted to US $7.0 billion, the "conversion scenario" of US $9.5 billion, and the "selective usage scenario" of US $9.1 billion.

GLNP is highly vulnerable to land cover disruptions due to its size. This is because the surrounding community is dependent on the area and because protecting the area requires a lot of human resources and funds. Verburg et al., (2002) state that the causes of changes in land use consist of driving factors such as demographics (population pressure), economic, technological, institutional, cultural, and biophysical factors. Warlina (2007) points out demographic (population pressure), economic (economic growth), technological, policy, institutional, cultural and biophysical factors.

Land cover in GLNP is different from its original condition. These changes have occurred since the conflict between the Government of the Republic of Indonesia and the Free Aceh Movement (Gerakan Aceh Merdeka, GAM), which in 1999 resulted in the displacement of people from conflict areas into GLNP. Over time, the people entering the region are increasing in number and diversity. As activities of the local population become more and more widespread, slowly the need for land for settlements, agriculture and plantations increases. This causes changes in land cover that will likely reduce or even eliminate GLNP's natural function as a conservation area. The extent of damage to GLNP is listed in Table 1.

Table 1. Total Damage in GLNP

No	National Park Management Region (BPTN)	National Park Management Section (SPTN)	Area (ha)	Extent of Damage (ha)
1.	I / Tapak Tuan	I (Blang Pidie)	71,218	67
2.	I / Tapak Tuan	II (North Kluet)	175,584	1,504
3.	II / Kutacane	III (Blangkejeren)	247,673	3,030
4.	II / Kutacane	IV (Badar)	388,281	10,289
5.	III / Stabat	V (Bahorok)	86,107	985
6.	III / Stabat	VI (Besitang)	125,829	3,894
	Total area		**1,094,692**	**19,769**

Source: Damaged/cleared land area based on a calculation of forest cover change 1990 - 2000 (WCS 2007 *in* Wiratno, 2007).

The management and various parties who care about GLNP have made various efforts to preserve the sustainability and function of the area, ranging from persuasive to repressive efforts. However, these efforts have not overcome all problems. A study by Subhan (2010) shows that until 2009 the extent of GLNP forest destruction in National Park Management Section (SPTN) IV Besitang increased to 7,435 ha. Other National Park Management Sections are also indicated to experience similar increases. Changes in land cover also lead to damage and loss of biodiversity in GLNP. Changes in land cover increasingly lead to conflicts between humans and wildlife exiting GLNP. These conflicts harm both humans and the wildlife itself.

Based on the above, it is necessary to analyze the existing land cover in GLNP and recent land cover changes. In addition, population pressure needs to be analyzed as one of the driving factors of land cover change. The analysis can then be used to develop guidelines and recommendations to support the management of GLNP.

The objective of this study is to 1) analyze changes and patterns of land cover change in 1996, 2005 and 2014; 2) analyze the relationship between population pressure index and the change of land cover/use occurring; and 3) to prepare guidelines and recommendations for controlling land cover changes that support the management of GLNP.

Research Methods

This research was conducted in GLNP and in its buffer zone in Aceh and North Sumatera. GLNP has a size of 1,094,692 ha with ± 867,789 ha located in Aceh and ± 226,903 ha in North Sumatra (Forestry Ministerial Decree No 276/1997). The total study location of GLNP and its buffer zone comprises ± 1,252,810 ha. The research lasted eight months between April and December 2015, starting from preparation, data collection in the field, data processing and analysis and writing the thesis.

The study uses Landsat images recorded in 1995, 1996, 1997, 2003, 2005 and 2014 on scene path 129 row 57, path 129 row 58, path 130 row 57 and path 130 row 58. In addition, the study uses the following maps: Rupa Bumi Indonesia (RBI) map with scale 1:25.000; map of administration boundaries with scale 1: 25.000; a geological map, slope map, elevation map, and provincial spatial planning maps (RTRW) for Aceh and North Sumatra with scale 1: 250,000. The study further uses data from the Gunung Leuser National Park Management Plan (RPTN) and Village Potential (PODES) data. The tools used are 1) a GPS receiver 2) a computer equipped with ArcGIS, Google Earth, and Microsoft Office.

Analysis of Land Cover in GLNP and Its Buffer Zones

Land cover is interpreted visually by looking at elements of color gradient (the color/gray scale of objects), texture (the frequency of changes in color gradient), pattern (the spatial arrangement of objects), the size, shape (the general shape, configuration or framework of single objects), shadow, and site (the location of an object in relation to other objects). The combination of Landsat images provides the best information on the land cover classification, in this case using a combination of 5-4-3 and 6-5-4 RGB composite bands. The coordinate system used is WGS 1984 UTM with 47N zone. The classification of land cover is done by screen digitizing as is commonly done by the Ministry of Environment and Forestry.

The data used to analyze changes in land cover consist of multi temporal satellite images of four scenes per coverage year. This is because the study location is very large and is covered in four

scene satellite images. To illustrate the land cover in 1996 Landsat 5 images of 1995, 1996, and 1997 are used. This is done because the image at the study location was incomplete; therefore, the images closest to 1996 were used.

To illustrate the land cover in 2005 Landsat 7 images of 2005 were used, patched with Landsat images of 2003 on the same scene path and row. The Landsat 7 image of 2005 needed to be patched due to stripping issues because the Landsat 7 satellite sensor was broken. Out of 4 image scenes of 2005, 3 images had stripes. To illustrate the land cover in 2014 Landsat 8 OLI TIRS images of 2014 were used.

An accuracy test of the land cover classification used 100 test points with a stratified random sampling distribution. The results were confirmed by field observations (ground truth) and with a high-resolution image (Google Earth).

Analysis of Land Cover Changes in GLNP and Its Buffer Areas

The interpretation resulted in land cover maps of 1996, 2005 and 2014, which were supported by checks in the field. Land cover maps of each year were then overlaid which resulted in the land cover transformation matrix.

This transformation matrix will show the classes of land cover that decreased or increased in size. In addition, it shows a pattern of changes in land cover between 1996, 2005 and 2014 in the study location. This pattern provides information on the tendency of a land cover to transform into certain other types of land cover.

Population Pressure Analysis

One of the causes of population pressure on protected areas such as national parks is because agricultural land in the area is insufficient to support the population adequately, causing the population search additional land (UML, 2005).

The Population Pressure Index (PPI) is calculated using the Population Pressure Index equation with the village as analysis unit (Soemarwoto, 1985). A population pressure index value >1 in this equation means the population pressure will affect the environment. The equation is as follows:

$$PP_t = Z_t \frac{f_t P_0 (1+r)^t}{L_t}$$

where:

PP_t = Population Pressure Index
Z_t = Minimum land area per farmer to make a living (ha/person)
P_0 = Population at t_0
F_t = Proportion of farmers in the population
r = Average population growth rate per year
t = Time span in years
L_t = Total size of agricultural land (ha)

The Directorate of Population Impact Analysis of the National Population and Family Planning Board (*BKKBN*) (2011) lists several impacts of high population pressure, i.e. (1) the population

will expand existing agricultural land or seek new agricultural land for their survival or to reach a desired standard of living; (2) Residents will excessively exploit natural and environmental resources which negatively affects the carrying capacity and assimilative capacity of the environment; (3) This results in a low level of welfare for most farmers in the area; and (4) the possibility of the workforce to transfer from the agricultural sector to business fields in the non-agricultural sector; (5) This not only impacts the rural agricultural area, but through the mobility of the population, also leads to increased urbanization which will have an impact on urban areas. Thus, GLNP will likely experience similar impacts if the population pressure of the villagers around GLNP becomes too high.

Guidelines and Recommendations

Guidelines and recommendations for controlling changes in land cover to support the management of GLNP consider land cover, land cover change, population pressure, spatial patterns in the Provincial Spatial Plan, maps of GLNP spatial arrangement, and GLNP management zones. The guidelines and recommendations must also comply with applicable laws and regulations. It is hoped that the guidelines and recommendations will help to control inappropriate land cover changes and will support effective GLNP management. The recommendations and guidelines consist of designating target villages as Conservation Village Model (MDK), revision of GLNP management zoning, and GLNP ecosystem recovery. Villages around GLNP with a population pressure index > 1 are a priority for Conservation Village Model activities. These villages are selected since they can endanger the existence and safety of GLNP. The guidelines for the revision of GLNP management zoning use the applicable criteria for national park zones. The guidelines for GLNP ecosystem recovery are developed by differentiating activities of rehabilitation/restoration and natural mechanisms. The distinction is made by looking at the land cover/land use conditions in 2014. At locations where land cover is significantly different from the original condition, rehabilitation/restoration should be carried out, while natural mechanisms apply for areas where land cover did not change too much.

Results and Discussion

Land cover in GLNP and buffer zones

Land cover in GLNP and its buffer zones consists of eight classes, i.e. forests, plantations, settlements, cropland, grass/shrubs, paddy fields, Open Area and water bodies. Grasslands and shrubs are combined into one class due to the limitations of interpreting Landsat's imagery in discerning differences between grasslands and shrubs.

The accuracy test for the land cover classification in 2014, through the analysis of the error matrix, results in an Overall Accuracy and Kappa Accuracy value of respectively of 91% and 74%. This means that the accuracy value is in very good agreement. Thus, the land use classification can be used to analyze changes in land use.

In 1996, land cover in GLNP and its buffer was dominated by forest (90.86%), grass/shrubs (4.70%) and cropland (2.84%). Forrest is the most extensive in Southeast Aceh Regency, Gayo Lues Regency, and Langkat Regency. Grass/shrubs are most widely found in the regencies of Gayo Lues, Southeast Aceh, and Langkat. Meanwhile, cropland is most extensive in Langkat, Southeast Aceh, and South Aceh Regencies. Langkat Regency, Southeast Aceh Regency, and Gayo Lues Regency are the areas of GLNP and its buffer with the greatest human intervention

when land cover other than forests and water bodies is classified as lands with human interference.

In 2005, land cover is still dominated by forest (89.29%), grass/shrubs (5.37%), and cropland (3.75%). Forest is the most extensive in the regencies of Southeast Aceh, Gayo Lues, and Langkat. Grass/shrubs are most widely found in Gayo Lues Regency, Southeast Aceh Regency, and South Aceh Regency. Cropland is the most extensive in the regencies of Langkat, Southeast Aceh, and South Aceh. In 2005, Langkat, Southeast Aceh, and Gayo Lues Regencies still showed the highest rate of human interference of GLNP and its buffer zones.

Table 2. Land cover in 1996, 2005 and 2014 in GLNP and buffer zone

No	Type of Land Cover 1996	In National Park (Ha)	Buffer (Ha)	Total Area (Ha)	%
1	Forest	1,040,708	97,623	1,138,331	90.86
2	Plantation	92	7,392	7,484	0.60
3	Settlement	44	322	366	0.03
4	Cropland	7,255	28,278	35,533	2.84
5	Grass/Shrub	31,253	27,690	58,943	4.70
6	Paddy fields	426	5,968	6,394	0.51
7	Open Area	2,769	1,319	4,088	0.33
8	Water body	767	902	1,669	0.13
	Total	**1,083,314**	**169,494**	**1,252,808**	**100**
No	Type of Land Cover 2005	In National Park (Ha)	Buffer (Ha)	Total Area (Ha)	%
1	Forest	1,025,772	92,832	1,118,604	89.29
2	Plantation	632	8,990	9,622	0.77
3	Settlement	44	356	400	0.03
4	Cropland	11,295	33,479	44,774	3.57
5	Grass/Shrubs	41,137	26,150	67,287	5.37
6	Paddy fields	99	5,949	6,048	0.48
7	Open Area	3,572	845	4,417	0.35
8	Water body	765	893	1,658	0.13
	Total	**1,083,316**	**169,494**	**1,252,810**	**100**
No	Type of Land Cover 2014	In National Park (Ha)	Buffer (Ha)	Total Area (Ha)	%
1	Forest	1,005,591	90,212	1,095,803	87.47
2	Plantation	3,523	14,584	18,107	1.45
3	Settlement	107	732	839	0.07
4	Cropland	19,452	22,816	42,268	3.37
5	Grass/Shrubs	45,645	29,054	74,699	5.96
6	Paddy fields	920	8,110	9,030	0.72
7	Open Area	7,319	3.130	10,449	0.83
8	Water body	759	856	1,615	0.13
	Total	**1,083,316**	**169,494**	**1,252,810**	**100**

In 2014, land cover is still dominated by forest (87.47%), grass/shrubs (4.98%), and cropland (3.37%). There was a large increase in plantations reaching a land cover of 1.45%. Forest is the most extensive in Southeast Aceh Regency, Gayo Lues Regency, and Langkat Regency.

Grass/shrubs are most widely found in the regencies of Gayo Lues, Langkat and Southeast Aceh. Cropland is the most extensive in Southeast Aceh, Langkat and South Aceh Regencies. In 2014, Southeast Aceh Regency, Langkat Regency, and Gayo Lues are still the regencies of GLNP and its buffer zone with the greatest human interference.
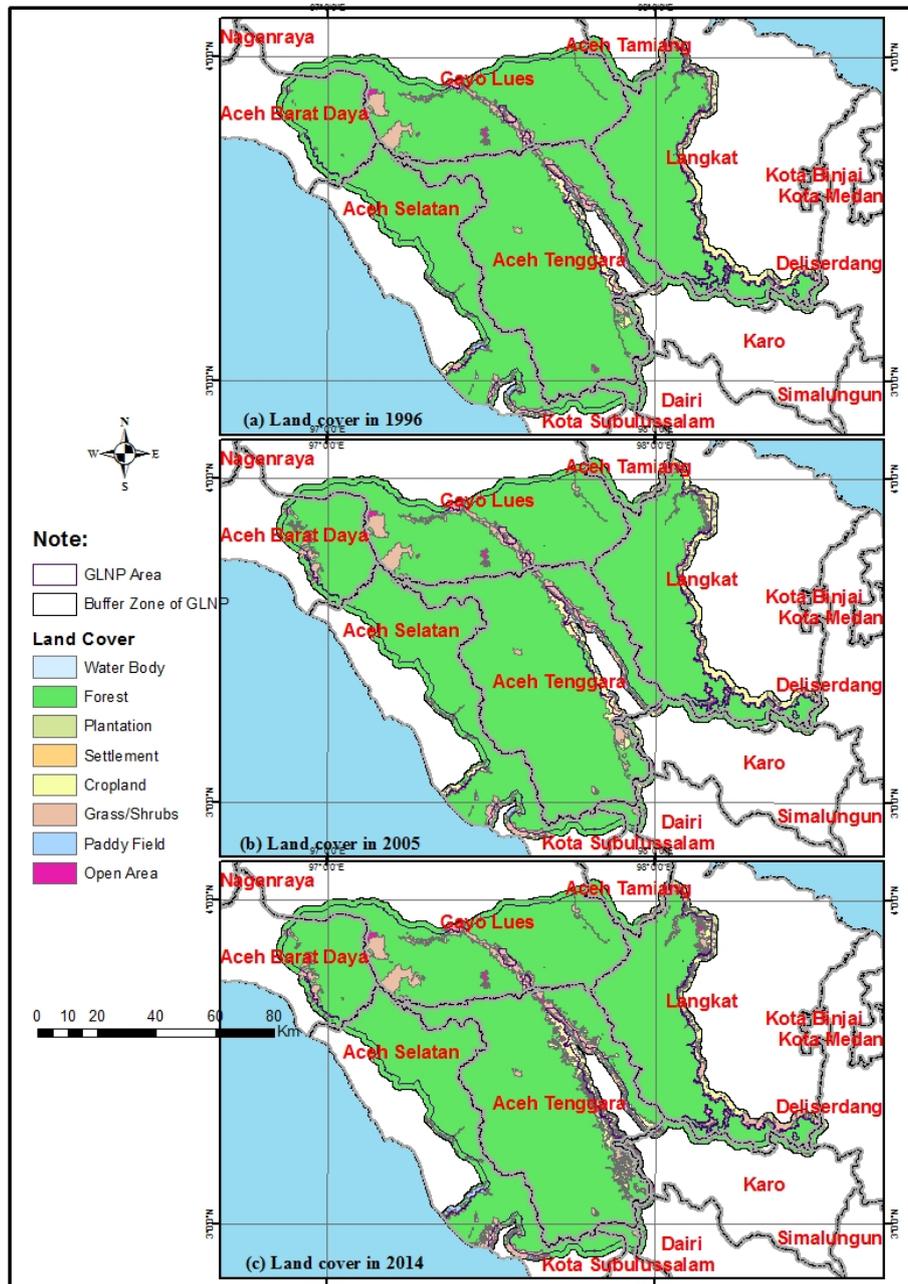

Figure 2. Land Cover Map

The table of land covers in GLNP and its buffer zone in 1996, 2005 and 2014 indicates inappropriate land cover in GLNP (Table 2). This can be seen from the column of land cover in the national park. As an area with a status as a national park, land cover types such as plantations, settlements, cropland and paddy fields should not exist. Referring to the definition

of a national park as a natural conservation area with a native ecosystem, GLNP no longer has a native ecosystem. In addition, national parks may only be used for research, science, education, supporting cultivation, tourism and recreation rather than for agricultural production Figure 2.

Land Cover Changes in GLNP and Buffer Areas

Rustiadi et al., (2011) emphasize the importance of evaluating the existing space utilization that includes land use and land cover to illustrate the real physical condition of a region. According to Liu et al. (2009), changes in land use and land cover always have ecological consequences, such as a loss of biodiversity and a decrease in ecological carrying capacity.

Table 3. Changes in Land Cover Year 1996-2005

No	Types of Land Cover	Year				Change in Size	
		1996		2005			
		Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
1	Forest	1,138,331	90.86	1,118,604	89.29	-19,727	49.11
2	Plantation	7,484	0.60	9,622	0.77	2,138	5.32
3	Settlement	366	0.03	400	0.03	34	0.08
4	Cropland	35,533	2.84	44,774	3.57	9,241	23.00
5	Grass/Shrubs	58,943	4.70	67,287	5.37	8,344	20.78
6	Paddy fields	6,394	0.51	6,048	0.48	-346	0.86
7	Open Area	4,088	0.33	4,417	0.35	329	0.82
8	Water body	1,669	0.13	1,658	0.13	-11	0.03
	Total	**1,252,808**	**100**	**1,252,810**	**100**	**40,170**	**100**

Changes in land use in GLNP and its buffer in the 1996 - 2005 period occurred in an area of 40,170 ha (3.21% of the total area), as can be seen in Table 3. Forests, paddy fields, and water bodies show a widespread decrease in size, while plantations, settlements, cropland, grass/shrubs and Open Area increases. Forests are the type of land cover experiencing the strongest decrease, while cropland increases most.

Table 4. Matrix of Changes in Land Cover in the 1996 – 2005 Period

		Land Use 2005								
		BA	**Ht**	**Pkb**	**Pkm**	**PLK**	**RSB**	**Sw**	**Tt**	**TOTAL**
	BA	1.585,11	27,69	0,51	-	21,42	21,90	9,88	2,76	**1.669,27**
	Ht	25,69	1.118.200,00	146,21	-	3.601,74	14.796,20	-	1.558,78	**1.138.328,61**
	Pkb	1,80	1,60	7.389,73	-	2,55	83,21	-	5,40	**7.484,30**
	Pkm	-	-	-	366,60	-	-	-	-	**366,60**
Land Use 1996	**PLK**	17,76	-	336,63	-	34.439,90	-	739,61	-	**35.533,90**
	RSB	7,73	281,37	1.332,64	14,34	5.653,36	51.452,50	11,35	189,18	**58.942,48**
	Sw	19,63	0,09	-	18,89	1.021,39	46,50	5.287,26	-	**6.393,76**
	Tt	0,00	90,77	416,38	-	33,08	886,89	-	2.660,61	**4.087,74**
	TOTAL	1.657,72	1.118.601,51	9.622,10	399,84	44.773,44	67.287,20	6.048,11	4.416,74	1.252.806,66

Note: BA (Water Body); Ht (Forest); Pkb (Plantation); Pkm (Settlement); PLK (Cropland); RSB (Grass/Shrub); Sw (Paddy field); Tt (Open Area)

The change matrix shows that forest, the type of land cover that decreased most, becomes grass/shrubs and cropland (Table 4). This change is most prevalent in Southwest Aceh Regency, Langkat Regency, and Southeast Aceh Regency. Cropland, the type of land cover that increased in size most, was developed in favor of land cover types such as grass/shrubs and forests. The addition of cropland is most prevalent in the regencies of Langkat, Southeast Aceh, and South Aceh.

Table 5 shows that for the 2005 - 2014 period, changes occur on an area of 50,700 ha (4.05% of the total area). Types of land cover that experience widespread shrinkage are forests, cropland, and water bodies while plantations, settlements, grass/shrubs, paddy fields and Open Area increase in size. Forests are the type of land cover with the greatest decrease, while plantations increase most in size.

Table 5. Changes in Land Cover 2005 - 2014

| No | Types of Land cover | Year | | | | Change in Size | |
| | | 2005 | | 2014 | | | |
		Area(Ha)	%	Area (Ha)	%	Area (Ha)	%
1	Forest	1,118,604	89.29	1,095,803	87.47	-22,801	44.97
2	Plantation	9,622	0.77	18,107	1.45	8,485	16,74
3	Settlement	400	0.03	839	0.07	439	0.87
4	Cropland	44,774	3.57	42,268	3.37	-2,506	4.94
5	Grass/Shrubs	67,287	5.37	74,699	5.96	7,412	14.62
6	Paddy fields	6,048	0.48	9,030	0.72	2,982	5.88
7	Open Area	4,417	0.35	10,449	0.83	6,032	11.90
8	Water body	1,658	0.13	1,615	0.13	-43	0.08
	Total	**1,252,810**	**100**	**1,252,810**	**100**	**50,700**	**100**

Table 6. Matrix of Land Cover Changes in the 2005-2014 Period

| | | Land Use 2014 | | | | | | | | |
		BA	Ht	Pkb	Pkm	PLK	RSB	Sw	Tt	TOTAL
	BA	1.451,09	34,56	17,22	0,39	104,06	21,16	20,97	6,93	**1.656,38**
	Ht	34,25	1.090.975,23	1.331,81	21,27	12.645,77	7.877,55	296,40	5.422,14	**1.118.604,42**
	Pkb	-	1.280,81	7.788,37	21,37	10,51	364,43	-	159,78	**9.625,26**
Land Use 2005	**Pkm**	-	-	24,82	374,95	0,04	0,10	0,04	-	**399,95**
	PLK	66,66	955,00	5.983,83	129,44	27.968,46	6.208,96	2.783,38	668,42	**44.764,14**
	RSB	31,44	2.328,98	2.409,01	163,59	1.168,16	59.461,94	465,25	1.264,12	**67.292,50**
	Sw	13,68	67,36	365,57	111,68	183,56	40,99	5.267,64	1,96	**6.052,44**
	Tt	18,01	163,67	186,48	15,99	187,78	723,59	196,03	2.925,94	**4.417,49**
	TOTAL	**1.615,14**	**1.095.805,60**	**18.107,12**	**838,67**	**42.268,33**	**74.698,74**	**9.029,70**	**10.449,29**	**1.252.812,58**

Note: BA (Water Body); Ht (Forest); Pkb (Plantation); Pkm (Settlement); PLK (Cropland); RSB (Grass/Shrub); Sw (Paddy field); Tt (Open Area)

The matrix of land cover change for the period of 2005 – 2014 shows that forest, the type of land cover with the greatest shrinkage, becomes cropland and grass/shrubs (Table 6). This reduction is most prevalent in the regencies of Southeast Aceh, Gayo Lues, and Langkat. Meanwhile, plantations increase most in size using up land cover types such as cropland and

grass/shrubs. The increase in the size of plantations is most prevalent in Southeast Aceh Regency, Langkat Regency, and South Aceh Regency.

Changes in land cover were observed in two periods namely between 1996-2005 and 2005-2014. This done to see if there is a difference in land cover changes between the two periods. These observations show both a similar and a different pattern. Forest is the type of land cover that decreases most in both periods. However, a different pattern can be observed for the type of land cover that increased. Namely, in the 1996-2005 period cropland increased most, whereas in the 2005-2014 periods, the highest increase was in plantation area. This changed pattern may be because it has become more attractive for the community to clear land for plantations, especially palm oil plantations.

Population Pressure on GLNP

An overlay of the map of village administration boundaries with GLNP maps shows the villages in and around GLNP. Villages directly bordering or fully within GLNP are identified as villages likely to exert population pressures on the GLNP. The population pressure index of these villages was calculated with data from following sources. The population size and the proportion of farmers in the population use Village Potential (PODES) 2008 data. Data on the minimum land area per farmer to live is based on Leuser Management Unit (UML) (2005) that states that the minimum area a farmer requires to make a living is 0.75 Ha. The population growth rate data is based on the population growth rate per province for Aceh and North Sumatera. The amount of potential land available for agricultural land is obtained by overlaying villages with GLNP areas, where the size of villages located outside GLNP is considered potential agricultural land. Villages located partly or entirely within GLNP are automatically considered to have no potential as agricultural land due to their location in a national park (Figure 3).

Figure 3. Population Pressure on GLNP

Out of 366 villages located in the vicinity or within GLNP 228 villages have a Population Pressure Index (PPI) > 1. Based on the possible impacts mentioned by the Directorate of Population Impact Analysis of the National Population and Family Planning Board (*BKKBN*), the population of these 228 villages will possibly expand their land, excessively exploit and negatively impact natural resources and the environment, and cause other effects. An overlay is used to compare land use/land cover in 2014 with the population pressure index. This comparison showed that 210 of 228 villages with a population pressure index > 1 have a land cover that is dominated by plantations, cropland, and paddy fields. This indicates that the land use/land cover of villages with a population pressure index > 1 will be dominated by plantations, cropland, and paddy fields.

Southeast Aceh Regency contains 213 villages located around and inside GLNP and 197 villages with a population pressure index above 1. South Aceh Regency has 46 villages located around and inside GLNP, 10 of which have a population pressure index above 1. In Langkat Regency, 28 villages are located around and inside GLNP and five villages have a population pressure index above 1.

Guidelines and Recommendations

Law No. 5/1990 defines the National Park as a nature conservation area with a native ecosystem, managed with a zoning system, which is utilized for research, science, education, supporting cultivation, tourism, and recreation. Zoning is used to adjust area allotment and to manage the region effectively considering the biophysical conditions of the area, future regional planning targets, and the outcome of public consultation with the community around the national park and provincial governments. Similarly, for the National Park Management Plan (RTPN), which is a planned and measurable framework for managers and stakeholders for optimal management of GLNP. The National Park Management Plan contains a zoning map as a framework and optimal performance. The National Park Technical Management Unit is responsible for drafting the National Park Management Plan by making an inventory of regional potential, regional planning and preparing a management plan.

The following Table 7 shows land cover zoning in GLNP based on an overlay of the GLNP Zoning Map 2009 - 2014 with land cover in 2014.

Table 7. Land Cover per GLNP Zoning (Ha)

No	Zoning	Land Cover Class of 2014								Total Size
		BA	Ht	PKB	pkm	PLK	RSB	Sw	Tt	
1	Gray	24	412	622	14	832	695	9	130	2,738
2	Core	110	827,289	60	-	1,345	16,865	2	2,894	848,565
3	Special	37	9	-	8	9	1,246	-	7	1,316
4	Utilization	180	9,272	147	15	557	2,174	1	318	12,664
5	Rehabilitation	351	96,804	2,698	65	16,404	23,005	908	3,547	143,782
6	Religion	-	73	-	-	-	-	-	-	73
7	Wilderness	4	61,547	-	5	317	1,564	-	386	63,823
8	Traditional	54	10,234	-	-	-	102	-	37	10,427
	Total Size	**760**	**1,005,640**	**3,527**	**107**	**19,464**	**45,651**	**920**	**7,319**	**1,083,388**

Note: BA (Water Body); Ht (Forest); Pkb (Plantation); Pkm (Settlement); PLK (Cropland); RSB (Grass/Shrub); Sw (Paddy field); Tt (Open Area).

Current zoning allotment is no longer compatible with the zoning criteria in the Regulation of the Minister of Environment and Forestry No. 76/2015, which mentions a core zone, wilderness zone, and rehabilitation zone. According to this regulation, the core zone and wilderness zone are areas with good natural conditions, with original biota and physical conditions, without human disturbance and absolutely protected. However, in reality, GLNP experiences human disturbance. This can be seen from the fact that the core and wilderness zones contain a land cover of plantations, cropland, settlements and paddy fields. This means these zones are no longer in pristine condition and without any human interference. Plantations, cropland, settlements and paddy fields in the core and wilderness zones add up to 1,729 ha (0.19% of the core and wilderness zone). Forest in the rehabilitation zone covers 96,804 ha (67.33% of the rehabilitation zone) Meanwhile, the rehabilitation zone is meant for damaged areas in need of ecosystem recovery. Thus, it is feared that an ecosystem recovery program will not be effective and optimal (Tables 8-9).

The spatial pattern distribution is obtained by an overlay of the Provincial Spatial Plans of Aceh and North Sumatera with the land cover in 2014. It still shows a discrepancy that can be seen from the existence of plantations, settlements, cropland and paddy fields in the conservation area.

In addition to a discrepancy between the spatial pattern and land cover in 2014, Figure 4 also shows a difference between the spatial pattern in the Provincial Spatial Plan and the GLNP map based on Decree of the Minister of Forestry No. 276/1997, especially in the province of Aceh.

Table 8. Land Cover According to Spatial Pattern Distribution in the Provincial Spatial Plan (RTRWP)

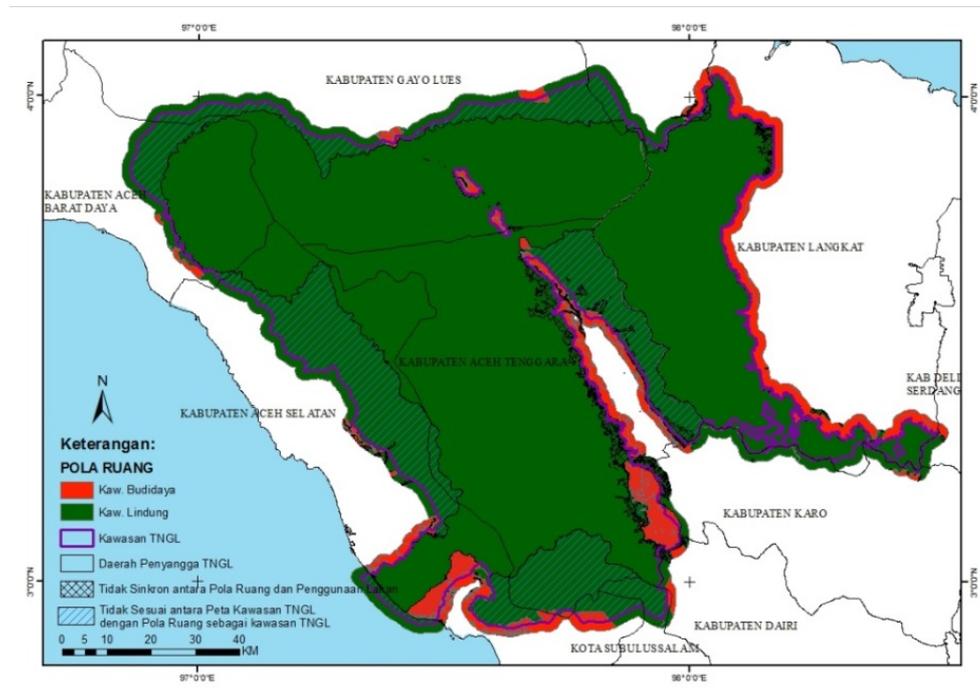| No	Land Cover 2014	Spatial Pattern		Total
		Cultivation area	Conservation area	
1	Water body	197	1,418	1,615
2	Forest	26,613	1,067,823	1,094,436
3	Plantation	16,141	3,249	19,390
4	Settlement	754	85	839
5	Cropland	22,810	20,148	42,958
6	Grass/Shrubs	28,958	46,482	75,440
7	Paddy fields	7,948	1,081	9,029
8	Open Area	1,952	7,151	9,103
	Total	**105,373**	**1,147,437**	**1,252,810**

Figure 4. Conformity of Land Cover with the Spatial Pattern in the Regional Spatial Plan

Guidelines and recommendations are developed based on the above to control land cover change and to support GLNP management. They are as follows:

a.   Conservation Village Model

The Population Pressure Index showed villages that have the potential to expand plantations, cropland and paddy fields into GLNP. Therefore, scenarios and policies need to be developed that can divert this expansion through other activities that can improve the local economy without threatening the existence and management of GLNP. The Conservation Village Model (MDK) is a possible policy. It is one of the programs of the Ministry of Forestry that has been ongoing since 2006. It is developed into a model to empower communities in and around conservation forests, taking into account social, economic, cultural, and other aspects, and will be used as an example for empowerment elsewhere. Conservation Village Model can create and strengthen community capacity, reduce dependence on the conservation area and have a positive impact on the protection, preservation, and utilization of the conservation area.

Regulation of the Minister of Forestry No. 67/2011 states that conservation villages are determined by the head of technical and implementation units. The aim is to increase income and reduce poverty by developing conservation villages and empowering communities by developing of bio-based businesses or activities suited to local conditions. The conservation village model is implemented by offering the community alternative activities by providing working capital for businesses in the form of plant and animal breeding, cultivation, nature tourism services, and other economic activities.

The analysis of the population pressure index shows 228 villages with a population pressure index > 1. This analysis can be used as a reference in establishing Conservation Village Model locations. *Center for Gunung Leuser National Park,* as the GLNP management, until now has

established 13 Conservation Village Model. Six of these have a population pressure index above 1 while seven have a population pressure index below 1.

b.   Revised Zoning GLNP

GLNP has experienced two types of changes, i.e. changes in land cover and changes in its shape and size. Consequently, it is necessary to evaluate GLNP management to achieve sustainable management. Changes in the shape and size of GLNP are based on Decree of the Minister of Environment and Forestry No. 6589/2014 and No. 4039/2014. Meanwhile, the current GLNP zoning management still refers to the designation of GLNP through Decree of the Minister of Forestry No. 276/1997 with a total size of 1,094,692 hectares.

Image analysis of GLNP land cover in 2014 can be used as information on the actual environmental conditions to be used in the regional zoning arrangement. Guidelines and recommendations to determine proper zoning can be developed by linking zoning criteria contained in the regulation with the current actual environmental conditions and with the change of GLNP's shape and size. Connecting this with the land cover analysis only provides input for the zoning revision of three zones, i.e. the core zone, wilderness zone, and rehabilitation zone.

Table 9. Zoning criteria based on Regulation of the Minister of Environment and Forestry number 76 Year 2015

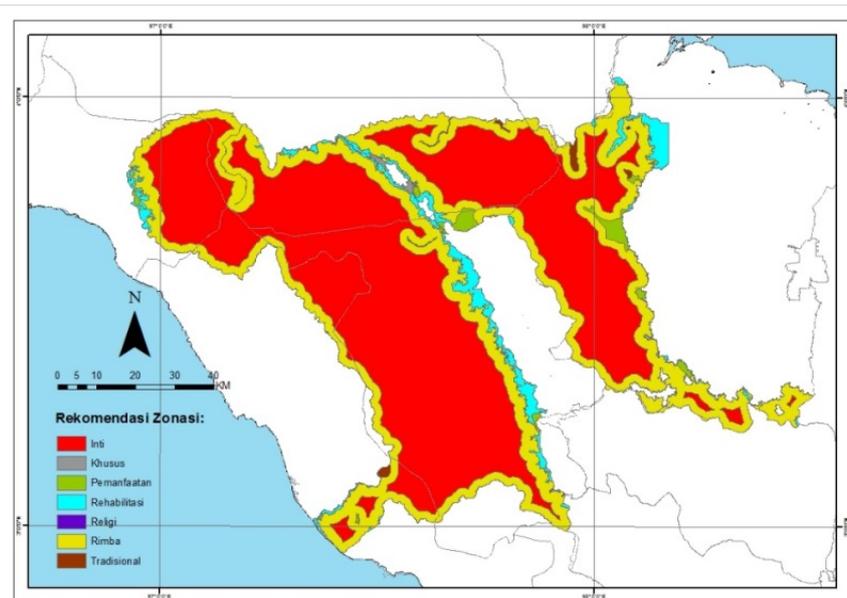| Core Zone	Wilderness Zone	Rehabilitation Zone
• Has an ecosystem with natural conditions and native and natural geological formations	• bordering the core zone and/or utilization zone/ function border • has a native and natural ecosystem	• damaged areas that are in need of ecosystem recovery

Figure 5. Guidelines for Revised GLNP Zoning

The criteria for the core zone and wilderness zone state that these zones have native and natural ecosystems; thus, forest is the right land cover for the core and wilderness zone. It can be assumed that the land cover of plantations, cropland, paddy fields, settlements, and shrubs are fitting for the rehabilitation zone. This is because these types of land cover require ecosystem recovery to return it to its natural ecosystem as forest. The criteria for other zones require additional data, which is not included in the analysis of land cover changes. Consequently, for the other zones, the previous zoning maps are used which are conformed to the map that determines GLNP boundaries (Figure 5).

c.   Implementation of Ecosystem Recovery for GLNP

The latest regulations and guidelines for recovery of conservation areas are found in Regulation of the Minister of Forestry No. 48/2014. In addition, Regulation of the Director General of Natural Resources and Ecosystem Conservation No. 12/2015 and No. 13/2015 were drafted as the implementation of the Regulation of the Minister of Forestry. Ecosystem recovery is aimed at fully restoring ecosystem integrity to its original level/condition or to future conditions that are consistent with the management objectives. Ecosystem recovery as referred to in this regulation is done in three ways, i.e. natural mechanisms, rehabilitation or restoration.

A natural mechanism is an act to recover ecosystems that experience a decline in function through measurements to protect natural processes, to achieve a balance of natural resources, and for the ecosystem to return to its original condition. Rehabilitation of ecosystems restores ecosystem damage in the form of reduced land cover functions, damage to water bodies or seascape by planting, or rehabilitating water bodies or the seascape to achieve a balance of natural resources and to return the ecosystem to its original condition. Ecosystem restoration is an act of recovery of damaged ecosystems in the form of reduction of land cover, damage to water bodies or seascape and the disruption of the status of wildlife, aquatic or marine life by planting, and by rehabilitating water bodies or marine landscapes, and guiding habitats and populations to achieve a balance of natural resources and the ecosystem to return to its original condition. Rehabilitation and restoration are only differentiated in terms of the wildlife being the focus of attention and the target to be managed. Therefore, to determine the rehabilitation or restoration activities for a location requires a study on the distribution and types of wildlife species.
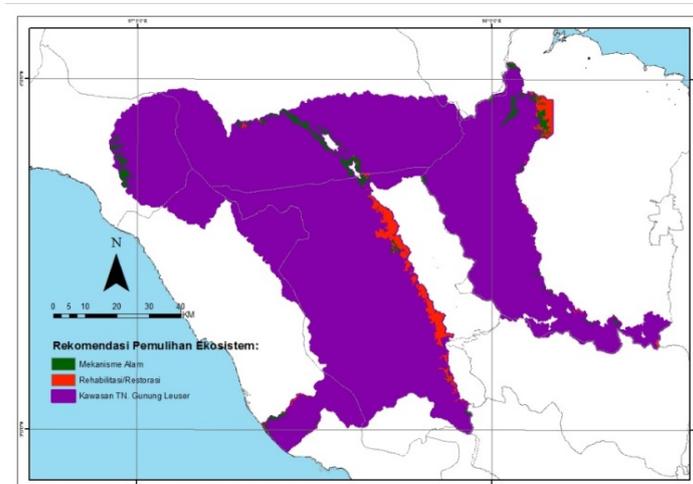

Figure 6. Recommendation Guidelines for Ecosystem Restoration.

Guidelines to support area management through ecosystem recovery are based on linking the regulations with land cover/land use conditions and changes in land use and land cover in GLNP (Table 10). Damaged forest ecosystems that experienced function changes in the form of plantations, cropland, paddy fields, settlements, Open Area, and shrubs require ecosystem rehabilitation or restoration. The land cover of shrubs has experienced a decline in the ecosystem and, therefore, requires ecosystem recovery by natural mechanisms. Currently, ecosystem recovery such as forest and land rehabilitation only focuses on rehabilitation/restoration. The choice of ecosystem recovery method will also affect the amount of human resources and costs required by the management unit (Figure 6).

Table 10. Guidelines for Ecosystem Rehabilitation in GLNP

No	Land cover	Directive for Ecosystem Recovery	Size	Total
1	Plantations	Rehabilitation / Restoration	1.,991	
2	Settlements	Rehabilitation / Restoration	13	
3	Cropland	Rehabilitation / Restoration	12, 659	
4	Paddy fields	Rehabilitation / Restoration	465	
5	Open Area	Rehabilitation / Restoration	2,841	17,969
6	Grass/Shrubs	Natural mechanism	15,384	15,384
	Total Ecosystem Recovery		**33,353**	**33,353**

Regulation of the Director General of Natural Resources and Ecosystem Conservation No. 18/2016 states that the Gunung Leuser National Park is one of the conservation areas that require ecosystem recovery. This ecosystem recovery should be implemented in an area of 9,130 ha in 2015 – 2019 with the budget provided by the Directorate of Conservation Areas and the Secretary General of Natural Resources and Ecosystem Conservation of the Ministry of Environment and Forestry.

Conclusion

In 1996, 2005 and 2014 GLNP and its buffer zone are dominated by the land cover of forest, grass/shrubs, and cropland. Changes in land cover indicate that forest is the land cover that always decreases the most. The most extensive addition in the 1996-2005 period is cropland and plantations for the 2005-2014 period.

228 out of 336 villages have a PPI> 1. The overlay of PPI and land cover/land use in 2014 showed that for 213 out of 240 villages land cover is dominated by plantations, cropland and paddy fields.

Guidelines and recommendations for the management of GLNP consist of zoning revision and ecosystem recovery based on the land cover in 2014 and developing Conservation Village Model for villages with potentially high population pressure.

Further research should consider physical factors in more detail to study changes in land cover related to physical factors such as slope, soil type, altitude and its influence on GLNP.

More intensive cooperation between the stakeholders is needed, especially in the case of local governments that have very high potential to experience changes in land cover and have a high

potential for population pressure on GLNP such as the regencies of Southeast Aceh, Langkat, Gayo Lues and South Aceh.

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