Identification of Potential Protection Area Using GIS and Remote Sensing: A Case Study in The Upper Stream of Ciliwung Watershed of West Java, Indonesia

GIS とリモートセンシングを利用した潜在的保護地域の特定 ーインドネシア、西ジャワ、チリウン川上流域におけるケーススタディー

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要旨

Bogor-Puncak-Cianjur (BOPUNJUR) 地方では、特に Ciliwung 川上流域において 1983 年から 1993 年の 10 年間に無秩序で急速な変化が起こっている。そこで本研究は、（１）潜在的保護地域の配置を特定し、（２）潜在的保護地域内の土地利用と BOPUNJUR 地域土地利用計画(RTRW)を評価することを目的とした。潜在的保護地域を特定する基準としてランドスケープの特徴を使用した。解析の結果、対象地域の 15.76 % のみが非保護区域とされ、大部分が高、中、低程度の潜在的な保護区域に分類された。

キーワード：GIS,　土地利用計画、Landsat、ランドスケープ、保護地域

Abstract Uncontrollable rapid changes in the Bogor-Puncak-Cianjur (BOPUNJUR) region occurred within one decade (1983-1993), particularly in the upper stream region of Ciliwung watershed. The areas which were once protected as a catchment have been converted into settlement areas or intensive agricultural lands. Therefore, identification of protection areas needs to be applied. The objectives of this study were (1) to identify the distribution of potential protection areas (2) to evaluate the existing land use in potential protection areas and also the Regional Land Use Planning of BOPUNJUR (RTRW). The study site was located in Ciawi, Megamendung and Cisarua sub-districts, Bogor District, West Java. Several landscape features (elevation, slope, soil, riparian zone, primary catchment area and potential landslide area) were used as criteria to identify the potential protection areas. The results showed that only 15.76 % of the study area was classed in the non-potential protection category while the 84.24 % was classed in the high, medium or low potential protection categories.

Key words: GIS, land use planning, landscape features, protection area.

I. Introduction

In human culture, population and economic growth are dominant factors in land use and land cover changes (LUCC) throughout the world (Weng, 2001). Urbanization also contributes to LUCC causing deforestation and agriculture farmland degradation. This area, which once functioned as a catchment area has been changed into a settlement area with impermeable characteristics.

Ciliwung River in west Java, Indonesia empties into Jakarta Bay and extends for 117 km and the watershed covers an area of about 347 km^2. Twenty years ago natural damage started occurring throughout the whole watershed. Based on the Government Regulation (PP No. 47/1997) concerning regional land use planning, Bogor-Puncak-Cianjur (BOPUNJUR) region is categorized as a specific area that needs special management and land use planning. In addition, the Presidential Decree (KEPPRES No. 114/1999) regarding BOPUNJUR defines the area as having two main functions: protection areas and cultivation areas.

In the upper stream region of Ciliwung watershed, in particular the conservation areas of Ciawi and Cisarua sub-districts, land ownership of 2,200 ha changed over a 10 years period from 1985 - 1995 (Harijono, 2002). As a result, land use change occurred more quickly, changing from green open space into built areas. Arifin (2002) reported that converting green open space into built areas happened in the BOPUNJUR region within a decade (1983-1993), previously constituting 5,310 hectares of dry land, 3,754 hectares of plantation estates, and 1,748 hectares of paddy fields and 740 hectares of forest. Consequently, these uncontrolled rapid changes in the land use contributed to big floods in Jakarta in early February 2002.

The upper stream region of Ciliwung watershed is a major part of the entire Ciliwung watershed. Therefore, in order to avoid floods in Jakarta, a comprehensive approach is needed especially to conserve the upper stream are of Ciliwung watershed using water and land conservation approaches. Identification of potential protection areas needs to be carried out using GIS and Remote Sensing particularly focusing on the distribution of potential protection areas.

The objectives of this study were (1) to identify the distribution of potential protection and non-protection areas, (2) to evaluate the existing land use in potential protection areas and also the Regional Land Use Planning of BOPUNJUR (RTRW) produced by the Regional Planning Division of Bogor District (BAPPEDA-Bogor) for 2000 —2010 as well. The results of this study are expected to give useful information in land use planning and also for integrated watershed management.

II. Material and Methods

The study area covers 3 sub-districts (Ciawi, Megamendung and Cisarua) in the upper stream area of Ciliwung watershed, Bogor district, West Java (Fig.1). This area is located in BOPUNJUR region (latitude of S6° 37' 10" - S6° 46' 15" and longitude of E106° 49' 48" -E107° 0' 25") and covers 18,681.75 hectares. The average annual temperature is about 16.9° C with 65.5% relative humidity and precipitation of 3,925 mm/year. The population of the study area in 2000 was estimated to be about 224,406 with a density of 1,919 inhabitants/km^2 (BPS, 2000). In this area, the big tea plantation of PTPN VIII, Gunung Mas already exists. In addition, there is also a lot of agricultural land consisting of paddy fields and dry land farming.

A remote sensing and GIS approach was applied to the uppert part of ciliwung watershed, to create a fundamental GIS dataset which was used for the analysis. The whole process was conducted using GIS software, MicroImages TNT Mips Version 6.8 and ERDAS Imagine 8.5.

Topographic Maps

Five sheets of topographic maps scale 1:25 000, sheet number 1209-141, 1209-142, 1209-144, 1209-231 were digitized, and contour vector data were created using GIS. A digital elevation model (DEM) was generated from the contour data by a triangulated irregular network creation. Slope and aspect layers were generated from DEM.

Satellite remotely sensed data

Landsat ETM+ (taken on 2001/12/22) was used in this study. In pre-processing, the satellite image was geo-referenced to a UTM projection using more than 40 GCPs (ground control points) selected from the topographic maps. The maximum error of the geometric correction was less than 0.5 pixels. After geometric correction, the image was resampled to 30m x 30m pixel size by nearest neighborhood method. Satellite data, were then available to correct the topographic effects using a modified Minnaert function (Ekstrand, 1996). The modified Minnaert function used is as follows:

$$L_n = L\left(\cos e \cos^k z / \left(cos^k i \cos^k e\right)\right)$$

Ln = the radiance of horizontal surfaces

L = the radiance of inclines

e = surface normal zenith angle or terrain slope

z = solar zenith angle

i = vertical vector of the slope

k = Minnaert coefficient

The modified Minnaert correction maintains the original number characteristics statistically better than the Minnaert correction (Kato. 2003). A land use/cover map was created using the maximum likelihood classification method. Land use/cover classifications were categorized into 7 classes: 1) Forest, 2) Tea plantation, 3) Shrub, 4) Dry field, 5) Paddy field, 6) Built up, 7) Water. The whole process of using satellite remotely sensed data can be seen in Fig. 2.

Ground-truth data

A field investigation was conducted in September 2002 to identify land use/land cover of the area. Landmark data were recorded at 90 points (latitude/ longitude) using a GPS receiver (Garmin GPS76S).

III. Potential Protection Criteria

Landscape feature is one of the potential protection criteria. For this study several landscape features were used i.e.: 1) Elevation > 2000 m asl, 2) Slope > 40 %, 3) Soil: Litosol with slope > 15% and Regosol with slope > 15 %, 4) Riparian zone, 100 m from river side, 5) The primary catchment area, 6) Potential landslide areas. These criteria are based on the technical regulations of protection areas from the RTRW of BOPUNJUR. All these features were prepared as raster data with a pixel size 30*30 m.

The need for re-classification data with GIS is due to the importance of integrating them into an evaluation process data measured not only in different unit but also in different scales of measurement (Pereira *et al*. 1993). The first step taken in the analysis process was to re-classify all the criteria into binary code (0 or 1). Code 1 indicated the cell consisted of potential protection criteria and 0 otherwise. For the next step all the landscape features were overlaid by 'addition' options from GIS. Finally, all the cells were divided into 3 categories: (1) if there were only 1 - 2 criteria, the cells were categorized as low (2) 3 - 4 criteria were categorized as medium and (3) 5 - 6 criteria were categorized as high.

IV. Results and Discussion

Spatial Databases

All spatial databases were produced by GIS and remote sensing, which was used to identify potential protection areas, and can be seen in Fig. 3 and Fig. 4. The overall accuracy of land use classification (ETM+ 2001/12/22) was 75.34% (Table 1). The RTRW produced by the Regional Planning Division of Bogor District (BAPPEDA-Bogor) for 2000-2010 were used as decision rules in order to construct appropriate management for each protection category.

Potential Protection Area

The landscape features were overlaid as criteria for determining potential protection areas. The results showed that only 15.7% (2,910.3ha) of the study region was categorized as non-potential protection areas while 84.24 % (15,734.8ha) was categorized as potential protection areas. Furthermore, the potential protection areas were distributed into high, medium and low categories of 1.6% (246.4ha), 18% (2,834.7ha), and 80.4% (12,653.7ha), respectively (Fig.5). The distribution of potential protection areas should be useful information for land use planning of this region. In addition, appropriate management for each potential protection category can be devised for an integrated management system for the watershed.

Table 2 shows that only 5.2% (246.4ha) of forest was categorized as a high potential protection area and the remaining were 34.2% (1,615.3ha) and 60.6% (2,857.6ha) as medium and low categories, respectively. However, taking account of the forest’s function, even the existing forest in the low potential protection category should be conserved. Meanwhile, the medium potential protection category, located in existing cultivation areas such as tea plantations, paddy fields, dry land and settlements, requires more consideration about appropriate management such as land rehabilitation by incentive systems and re-evaluation of land use policies. Policy and regulation for the low potential protection area should consider social-economic and demographic conditions in the area.

Comparison of existing land use and RTRW

Comparison of existing land use and RTRW in potential protection areas is useful to evaluate existing land use and land use planning (Fig. 6). As a result, forests and protected forests covered the largest area in the medium potential protection areas. However, particularly as seen in the medium potential protection area, the area of the existing forest and the planned forest is significantly different i.e. 1,615.3 ha and 2,665.9 ha respectively (Fig. 7). This evidence shows that the area of existing forest area in the medium potential protection areas should be increased to be as large as the planned forest area e.g. by reforestation. The difference between the existing forest and the planned forest is 16.4% (926.4ha). This difference means that in order to achieve the planned area for forest (5,645.6ha), reforestation of about 16.4% (926.4ha) of the potential protection area is needed.

Conclusion

The identification of distribution of potential protection areas using 6 criteria from landscape features, comprising high, medium and low categories, is very valuable for land use planning as well for an integrated watershed management. A difference of about 16.4% (926.4ha) was detected between the existing forest and the planned forest in the potential protection areas. Analysis using GIS and remote sensing approaches was very helpful in producing spatial database for an advanced planning process efficiently and effectively. Using human and biological criteria as additional criteria to identify potential protection area is recommended for future studies.

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Table 1.

Land use	Forest	Tea plant.	Shrub	Paddy field	Dry land	Settle.	Water
Forest	**54**	1	8	1	2	0	0
Tea plantation	0	**23**	14	1	1	0	0
Shrub	4	5	**37**	3	8	0	0
Paddy field	1	1	5	**45**	18	5	1
Dry land	0	10	8	22	**242**	16	1
Settlement	0	0	0	1	7	**39**	1
Water	0	0	0	0	0	0	**0**
Overall accuracy	**75.34%**						
Kappa accuracy	0.65						

Table 2.

Existing Land	Potential protection categories (%(ha))			Total
	Low	Medium	High	
Forest	60.6 (2857.6ha)	34.2 (1615.3ha)	5.2 (246.3ha)	100 (4719.2ha)
Tea plantation	78.2 (909.3ha)	21.8 (253.0ha)	0	100(1162.2.2ha)
Shrub	76.8 (1777.5ha)	23.2 (537.0ha)	0	100 (2314.4ha)
Paddy field	95.6 (1750.1ha)	4.4 (80.8ha)	0	100 (1830.8ha)
Dry land	93.0 (4386.2ha)	7.0(328.3ha)	0	100 (4714.5ha)
Settlement	97.9 (753.0ha)	2.1(16.2ha)	0	100 (769.1ha)
Water	99.8 (22.4ha)	0.2 (0.1ha)	0	100 (22.5ha)

Fig.1

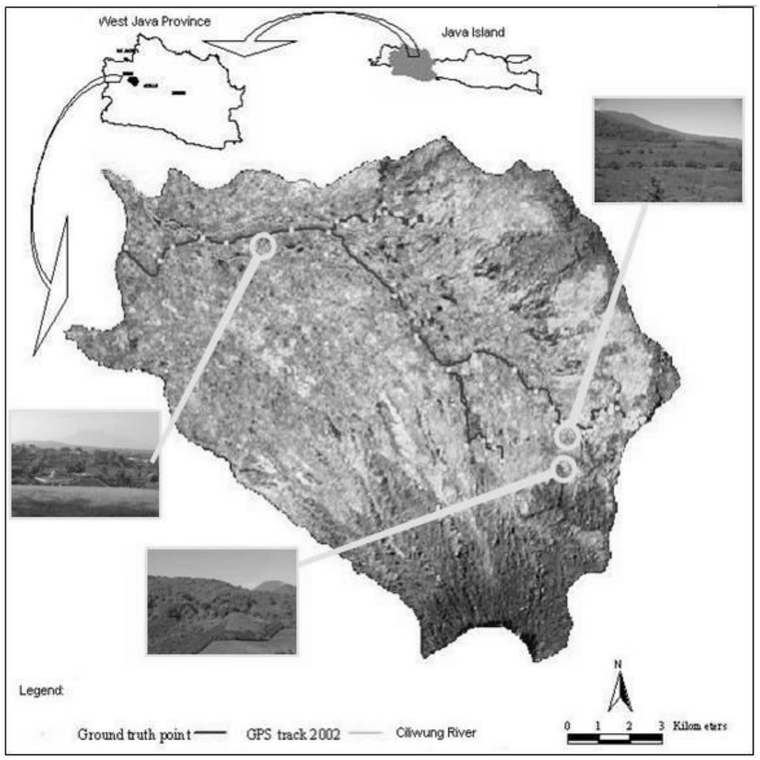
West Java Province
Java Island
Legend:
Ground truth point
GPS track 2002
Ciliwung River
N
0 1 2 3 Kilometers

Fig.2

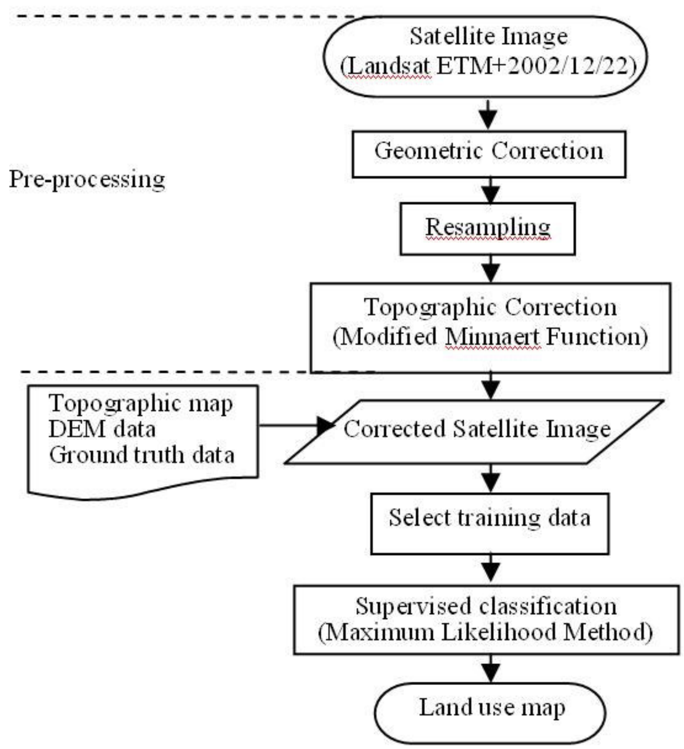
Satellite Image
(Landsat ETM+2002/12/22)
Geometric Correction
Pre-processing
Resampling
Topographic Correction
(Modified Minnaert Function)
Topographic map
DEM data
Ground truth data
Corrected Satellite Image
Select training data
Supervised classification
(Maximum Likelihood Method)
Land use map

Fig.3A

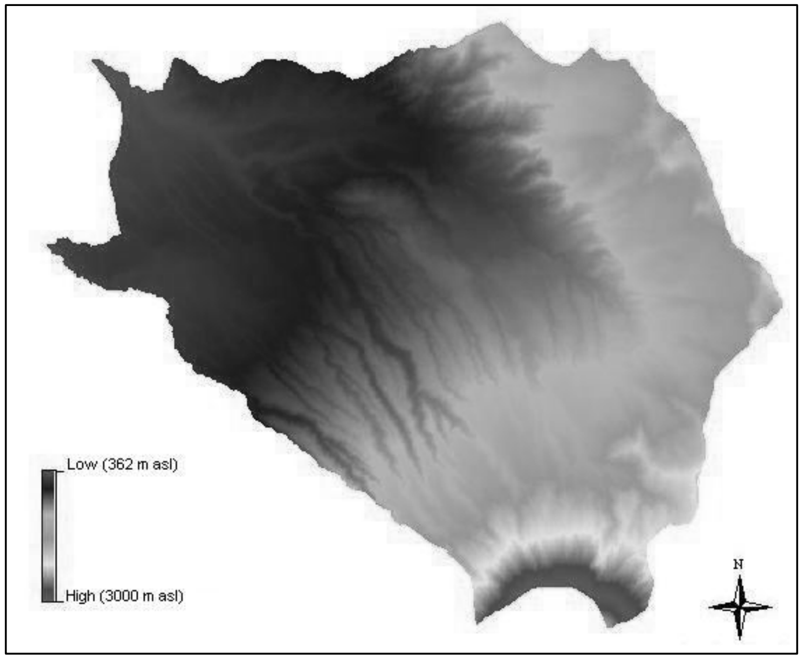
Low (362 m asl)
High (3000 m asl)
N

Fig.3B

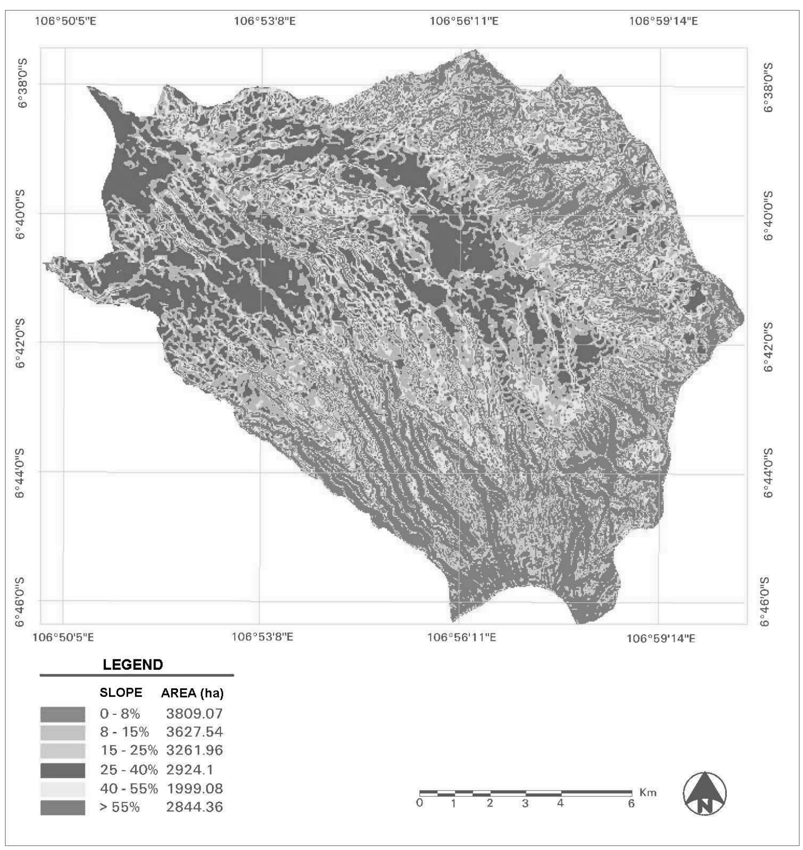
106°50'5"E
106°53'8"E
106°56'11"E
106°59'14"E
6°38'0"S
6°40'0"S
6°42'0"S
6°44'0"S
6°46'0"S
LEGEND
SLOPE AREA (ha)
0 - 8% 3809.07
8 - 15% 3627.54
15 - 25% 3261.96
25 - 40% 2924.1
40 - 55% 1999.08
> 55% 2844.36
0 1 2 3 4 6
Km
N

Fig. 3C

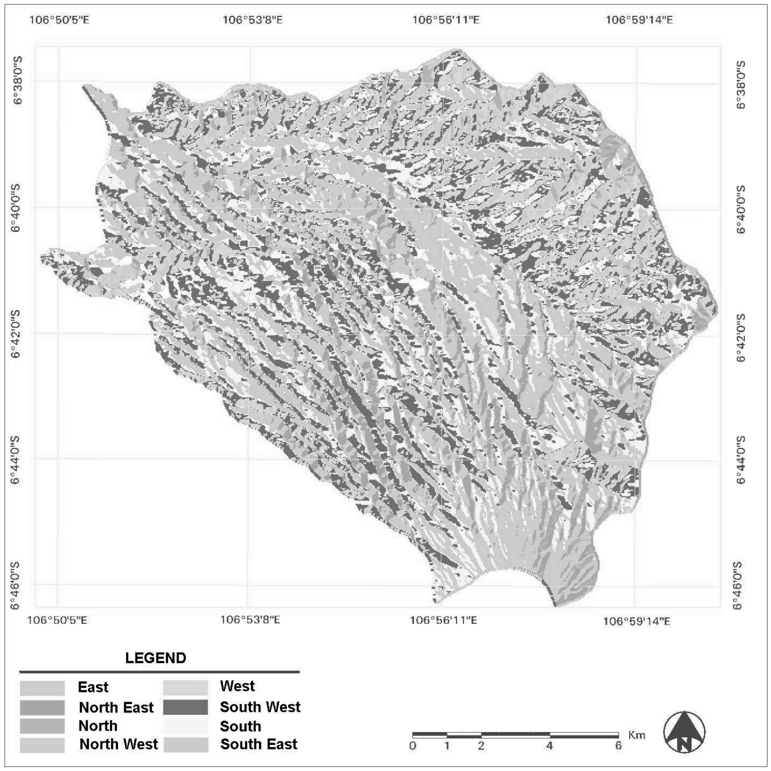
106°50'5"E
106°53'8"E
106°56'11"E
106°59'14"E
6°38'0"S
6°40'0"S
6°42'0"S
6°44'0"S
6°46'0"S
LEGEND
East
North East
North
North West
West
South West
South
South East
Km
0 1 2 4 6

Fig.4A

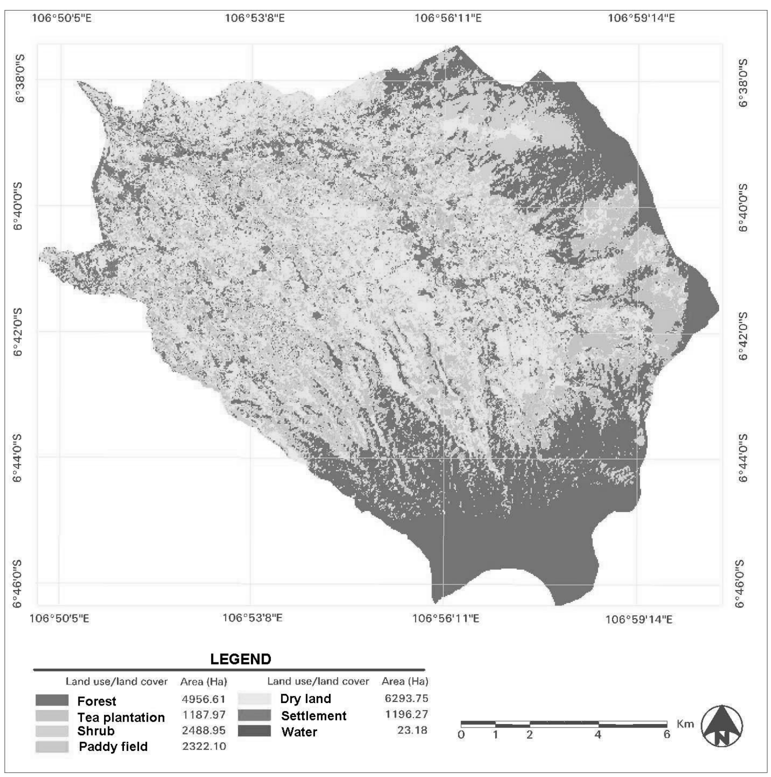
106°50'5"E
106°53'8"E
106°56'11"E
106°59'14"E
6°38'0"S
6°40'0"S
6°42'0"S
6°44'0"S
6°46'0"S
LEGEND
Land use/land cover Area (Ha)
Forest 4956.61
Tea plantation 1187.97
Shrub 2488.95
Paddy field 2322.10
Dry land 6293.75
Settlement 1196.27
Water 23.18
Km
0 1 2 4 6

Fig.4B

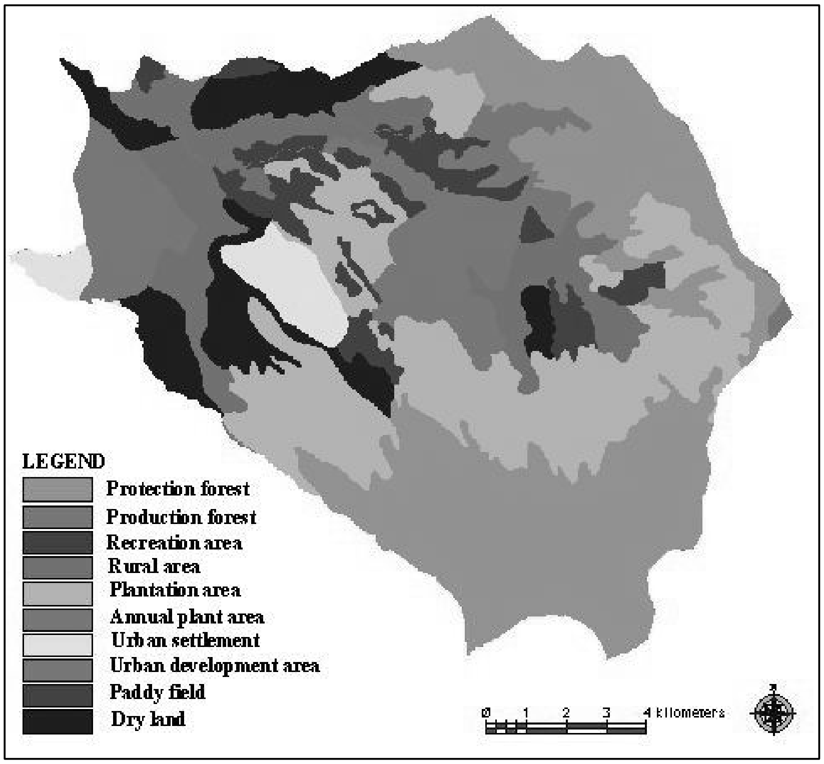
LEGEND
Protection forest
Production forest
Recreation area
Rural area
Plantation area
Annual plant area
Urban settlement
Urban development area
Paddy field
Dry land
0 1 2 3 4 kilometers

Fig.5-1

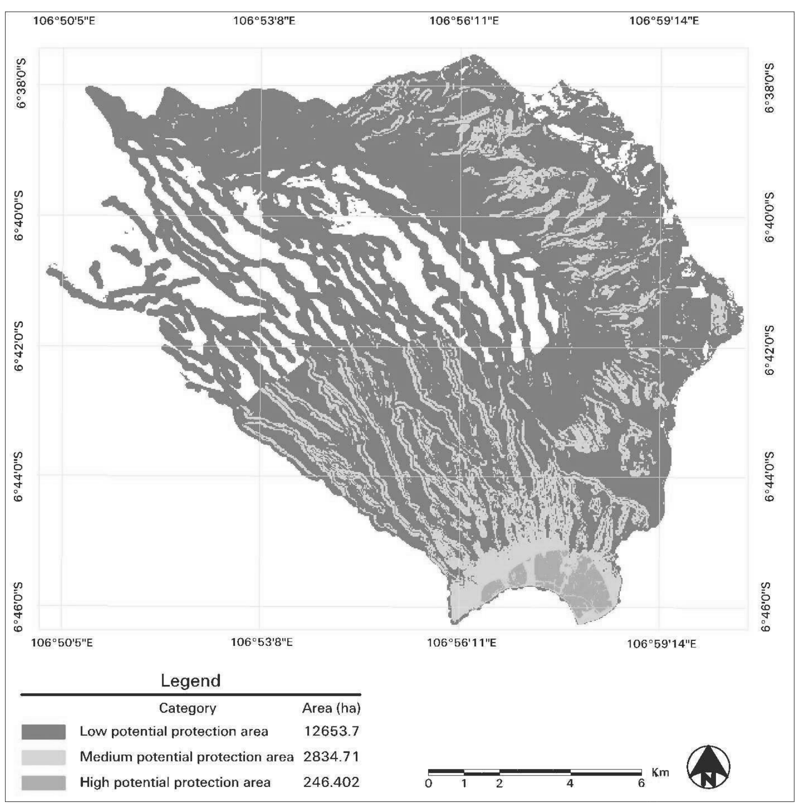
106°50'5"E
106°53'8"E
106°56'11"E
106°59'14"E
6°38'0"S
6°40'0"S
6°42'0"S
6°44'0"S
6°46'0"S
Legend
Category
Area (ha)
Low potential protection area 12653.7
Medium potential protection area 2834.71
High potential protection area 246.402
0 1 2 4 6 Km

Fig.5-2

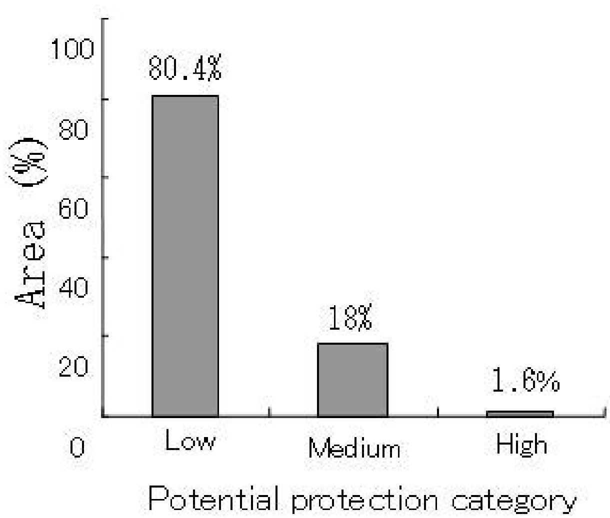

Fig.6

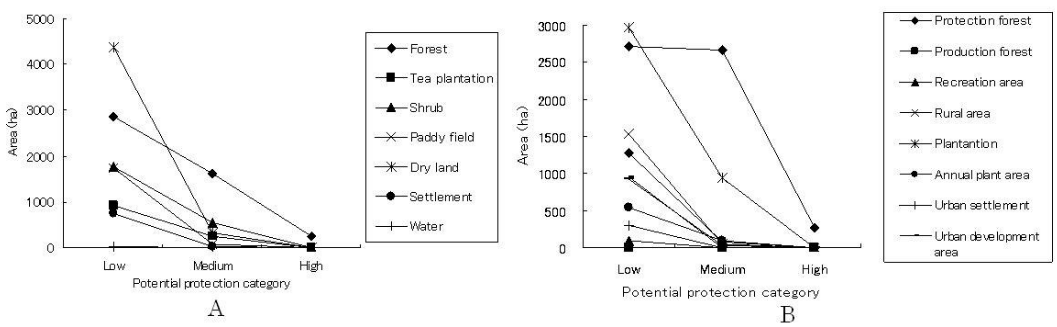

Fig.7