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Study on Community's Land Allocation in Long Pahangai District

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Abstract

Land use allocation for community has been a crucial process for supporting the spatial allocation either at the regency or provincial level. This study was emphasized on the analysis of land allocation at the district level. The study applied a linear programming approach to optimize the land use in Long Pahangai District then linked with the spatial information. The optimization considered several factors, i.e., land productivity, the degree of erosion and the preference of the community living in the study area. To support the optimization, the availability of land use was determined by considering the land capability using the query tools in the Geographic Information System. The level of land capability applied five constraints, namely, slope, drainage, soil texture, effective depth and erosion. The study found that the optimal allocation of land use in the study area are primary forest of 6,635.11 ha (25.19%), secondary forest of 19,025.7 ha (71.9%), mixed plantation area of 289.61 ha (1.1%), settlement area of 8.3 ha (0.03%) and rice field of 487.35 ha (1.844%). This optimal allocation might increase the community income per capita by approximately 80% from 9,602,000, to 17,275,171.-/capita/ha/year.

Keywords: *GIS, land use, land capability, linear programming, land allocation*

1. Introduction

Good land use planning requires a participative process which involves the community, either as a party that is affected by the spatial planning, or as a main actor in development. The communities affected either directly or indirectly by the planning are mainly traditional communities who are residing around the area of ineterst. The main actors themselve are the actor who plays an important role in spatial management, including planner and decision maker.

In Kalimantan, one of the traditional communities that plays an important role in conserving the forest is the Dayak tribe people, where they are able to conserve forest resources through their social life and traditions. The Dayak people usually live in the forest with their local wisdom in utilizing the forest, especially in spatial planning [1]. Traditional communities, especially those in East Kalimantan, have their own unique way in managing the forest wisely. The indigenous communities form different groups because they are the users of the forest resources [2]. They possess wisdom in forest management [3-5]

In sustainable forest management, the use spatial analysis as consideration in making policy decisions is a must. One of the spatial analysis approaches to achieve the spatial utilization is by using the geographic information system (GIS) technology. This GIS approach has capability to integrate the spatial and tabular data all at once. The successes of using the geographic information system (GIS) for spatial planning in forestry has been proven by a number researchers or practitioners. For example, determined optimal spatial utilization to maximize income and minimize conflict [6]; while assessed the forest and land optimation in the Citamiang River Basin using GIS by considering the erosion rate [7]. In addition land optimization may enhance the land productivity (also called, biocapacity) based on productive land and water availability [8].

Now, the GIS method has been a backbond during the process of spatial planning. The presence of geographic information system (GIS) benefits in facilitating the spatial planning optimization. Today, the concept of "digital forestry" grows rapidly by relying on 3G wireless communications, GIS, GPS and other software. Therefore, the combination of those technologies is able to produce accurate information regarding the data required in forest resources [9]. Moreover, as many people use the internet network facility, information on forest

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resources should be fully provided, one example is by establishing classification text of forest resources [10]. The GIS has been also combined with the double-criteria decision making in database management, spatial-based analysis, outward presentation of analysis results, and other GIS functions [11]. The GIS's ability to be used repeatedly with a consistent results, consistent accuracy and precision, efficient had made it as an effective tool in spatial modeling. The accuracy of a certain model, various scenarios could be developed in both the macro and micro level [12].

In this study, spatial optimization in Long Pahangai District, Mahakam Ulu Regency was studied by integrating the land utilization patterns conducted by the Dayak traditional community and the bio-physical and economy factors. The objective of the study was to optimize the spatial land utilization by considering the land carrying capacity derived from the use of the physical factors; social factor (i.e. community preference) and economic factors (i.e., community's income) using spatial technology of the geographic information system (GIS).

2. Research Method

2.1. Land Capability Analysis

The land capabilty method had been used for assessing the suitability of the land for agricultural uses, protection areas (the land that should be protected), and for other uses. In this study, land capability was classified using the criteria developed by Arsyad 2010, where the land capability classes consisted of 8 (eight) classes.

The Land capability was classified into 8 (eight) classes, coded with Roman numerals I to VIII. The increase the class the more constrains were provided. The first two classes (class I and class II) are categorized as a land that is suitable for agricultural use; while the last 2 (two) classes i.e., class VII and class VIII are suitable for protected for conservation. Class III to class VI could be considered for other uses. However, class III and class IV land are allowable to be used for agriculture. Since not all of the information for the indicators were found in the map attributes, then thie study only used five constraining factors, i.e., (1) texture, (2) surface slope, (3) drainage, (4) effective depth, and (5) erosion.

By overlaying all five constraining factors, namely the slope, erosion class rate, soil depth, soil drainage, and soil texture, then the identification of the land capability was derived. The information about the distribution and are of each capability class can be seen in detail in Table 1.

Table 1. The Area and Percentage of Land Capability

No	Land Capability Class	Area	%
1	IV	9002.2	34.0
2	VI	5727.5	21.7
3	VII	8249.3	31.2
4	VIII	3466.9	13.1
	Total	26446.1	100

The data analysis found that there is no land capability belong to classes of I-III in the Long Pahangai District. The widest land capability class area was class IV covering of approximately 9,002.27 hectares or approximately 34.04%, whereas the capability class with the smallest area was class VIII at 3,466.91 hectares or approximately 13.11% of the total area.

2.2. Analysis of Land Productivity

The productivity value analyzed for each land use was defined as the amount of income subtracted by fixed cost and operational costs [13].

$$P = Rr - Cc$$

Where:

P = Productivity value (IDR/Ha/Year)
Rr = Amount of income (IDR/Ha/Year)
Cc = Fixed cost and operational costs (IDR/Ha/Year)

It should be noted that the value of the formula need to be converted nto IDR per ha per year (IDR/Ha/Year) so that the land productivity result for each land use could be calculated.

The results of the calculation conducted on a number of land use activities in the study site demonstrated that the largest land productivity value was for plantations. The lowest productivity value was for primary forests. The complete land productivity values are presented in Table 2.

Table 2. Land Productivity for a Number of Land uses in Long Pahangai District

No	Land use	Actual Land Productivity (IDR/Ha/Year)
1	Primary forest	662,000
2	Plantation	3,220,000
3	Secondary forest	2,640,000
4	Settlement	1,340,000
5	Dryland farming	1,740,000

Based on Table 2, the high productivity of land used as plantations in the study site did not necessarily mean that the study site will be directed towards using the land for plantations fully. The main consideration will still be based on the land capability in the study site. The land productivity value generated was still considered as low; this was might be due to the very limited land management. For example, to get fertilizer, the people must spend much higher cost because lack of transportation, making the people resort to the available resources. In addition, the people's knowledge of how to increase land productivity is still limited because the agricultural extension officers assigned to this area have yet to be effective. Therefore, this factor had a influence on the people's income which was still categorized as low. The decline in land productivity may be affected by the absence of government support in terms of increasing knowledge of farmers for good land management [14]

2.3. The Analysis of the People's Preference

In this study, the people's preferences were obtained from their response whether they agreed or disagree with the changes in land use. In this context, the changes in land use were grouped into four type of changes,i.e., 1) change from paddy fields to forest, 2) change from mixed plantations to forest, 3) change from forest to paddy fields, and 4) change from forest to mixed plantations. Perception is a certain opinion, stance, and behavior which is personal and subjective, but has an important role and a strong position in every individual [15]. The people's preference tends to be related to the regulations in effect in their area and also the customs which stem from their ancestors rules. From in-depth interviews with tribal elders, there were 5 (five) rules that were applied in this area. The utilization rules are explained in detail in Table 3.

Table 3. Rules in Land Utilization In The Indigenous Area

Area Status	Utilization Rule
Tana'aq Adat	It is prohibited for taking natural resources, both timber and non-timber, except for cultural tourism. Utilization of non-timber resources is very limited
Tana'aq Peraq	It is allowed in very limited amounts for taking natural resources both timber and non-timber (particularly for building houses, *etc*.) and for hunting grounds.
Tana'aq Lemaliq	Hallowed/sacred/haunted land
Tana'aq Lumaq	1. For agriculture (plantations), 2. For plantations
Umaq	Land set side for settlement

In this study, there were 50 respondents who were interviewed, some community members, the village elders from Kampung Long Pahangai, the officials from the District Headquarters, the Kampung Elder Office. The results of the interview are presented in Table 4.

Table 4. The people's desires in land use change

No	Changes in Land Use	The People's Desires	
		Agree	Disagree
1	Plantation - Dryland farming	32	18
2	Secondary forest – Plantation	45	5
3	Secondary forest - Dryland farming	43	7
4	Dryland farming – Plantation	28	12

Table 6 shows that as many as 64 % of respondents agree a change occurs in the use of plantation to dryland farming. Usually respondents seeking such changes due to the use of agricultural lands are no longer productive. The interesting thing happens to the majority of respondents wanted a change of land use of secondary forests into the mixed plantation as much as 90 % and an advanced secondary forest dry land farming as much as 86%. People assume that if the forest can be made in the mixed plantation or dry land farming can increase revenue.

2.4. Land Use Optimization with a Linear Program

Optimization of land use/land cover is done in the effort to maximize the people's income. In this study, it was focused more on the modification of plant management/ land use factor (factor C), because this factor is the factor which could be fully manipulated with erosion, land productivity, and the people's preference as the constraining factors. A mathematical analysis of this scenario model from the optimization analysis which aimed to maximize income (Z) could be expressed with the following equation and inequality:

$$Maximum\ Z = (\sum_{i=1}^{n} CiXi2)/A$$

Table 5. Constraining Functions

No	Constraining Function	Notes
1	$\sum_{i=1}^{n} Xi2 = \sum_{i=1}^{n} Xi1$	The total area of land before optimization was equal to the total area of land after optimization.
2	X4(t2) ≥ X 4(t1)	The land area for settlement resulting from the optimization (t2) ≥ original settlement (t1 = 5.08 Ha).
3	X1(t2) = X 1(t1)	The land area for primary forests resulting from the optimization (t2) was = 6,635.11 Ha at the land capability classes VII and VIII
4	X5(t2) ≥ X 5(t1)	The land area for dryland farming resulting from the optimization (t2) ≥ the original land area for dryland farming (t1 = 393.84 Ha) at land capability class IV
5	X2(t2) ≥ X 2(t1) + P. X3(t1)	The people's preference: the people wish to change secondary forest X3(t1) to plantation X2(t2). The people's preference survey emonstrated that the area of secondary forest that could be converted was 84% of the original area of the secondary forest (P = 0.84)
6	X2(t2) ≥ X 2(t1)	The land area for plantation resulting from the optimization (t2) ≥ the land area for mixed plantations before the optimization (t1 = 224.53 Ha) at land capability class IV
7	X3(t2) ≤ 0.84.X3(t1)	The land area for secondary forest resulting from the the optimization (t2) ≤ the original area of secondary forest (t1 = 19,187.50 Ha) at land capability class VI
8	$\sum_{i=1}^{n} Xi2\,Yi \geq \sum_{i=1}^{n} Xi1Yi$	The land productivity resulting from the optimization (Y2) should be higher than the productivity before optimization (Y1). Yprimary forest ≥ IDR 662,000,- Ysecondary forest ≥ IDR 2,640,000.- Yplantation≥ IDR 3,220,000.- Ysettlement ≥ IDR 1,340,000.- Ydryland farming ≥ IDR 1,740,000.-
9	Xi2 ≥ 0	Non-negativity obstacles: land area must be Positive

Where,

Z = Income in (IDR)

Xij = land area (area for each *i*th land use and *j*th time)

i = 1,2......5 (1 = primary forest, 2 = plantation, 3 = secondary forest, 4 = settlement and 5 = dryland farming).
n = 5 (number of land uses/land cover types in the study site)
j = 1,2, (1 = initial and 2 = optimal).
A = total land area
Yi = land productivity for the *i*th land use
P = the proportion of people's preference
Ci = *i*th land erosion rate for the *i*th land use (actual data)

3. Results and Discussion

3.1. The Availability of Land Use and land cover

In the study site, there are five land use and land cover available, namely primary forests of about 6635.11 Ha, secondary forests 19,187.50 Ha, plantations 224.53 Ha, settlements 5.08 Ha and dryland farming 393.84 Ha. It is noticed that the secondary forest was the dominant land cover in Long Pahangai District, covering of approximately 72.55%. The land covered by land primary forest was the second largest of approximately 25.09%.

3.2. Erosion Rate Prediction

The actual land use in Long Pahangai District caused an erosion rate ranging from 27.77 to 4,377.6 tons per ha per year. The actual land use group that contributed the most erosion (A) 4,377.6 tons/ha/year was settlements which were directly along the Mahakam River. The actual land use which contributed the least erosion (A) was primary forests at 27.77 tons/ha/year. This was due to the tree density dominance factor on that land use. Water does not directly reach the forest floor. The erosion prediction is presented in detail in Table 6.

Table 6. Erosion Prediction in Land uses in Long Pahangai District

No	Land use	Erosion Prediction (A) (Tons/ha/year)	*Tolerable Soil Loss* (TSL)	Area
1	Primary forest	27.8	32.1	6635.1
2	Secondary forest	65.0	41.3	19187.5
3	Plantation	485	37.1	224.5
4	Settlement	4377.6	16.1	5.1
5	Dryland farming	1694.9	39.6	393.8
	Total	6680.3	166.11	26446.1

The tolerable erosion rate at the study site was between 16.05 and 39.06 tons/ha/year. This is also dubbed the T value which describes the highest erosion rate that could be tolerated every year but could still retain a certain depth for plant growth which enables the achievement of a sustainable high productivity [16]. The T value is influenced by effective depth, soil depth, and soil content factors. In general, the erosion was higher than or exceeded the TSL (*Tolerable Soil Loss*). Only primary forests demonstrated an erosion rate lower than the TSL. Erosion proper handling such as setting the temporal pattern of rotational cropping patterns can restore soil conditions that have an impact on the spatial conditions [17].

3.3. Optimization of Land Use with a Linear Program and Spacial Allocation

The optimization results of all the scenarios using the linear model program could be compared to each other on the basis of the income and erosion rate. The function of constraint criterias can be the factors to determine some scenarios. The results of the analysis using the linear program model were 3 combination scenarios of the optimal land use area presented in Table 7.

In scenarios 1 and 2, the increase in the land use area was not yet significant, so the increase in people's income was also not yet significant in addition to the erosion which still exceeded the TSL. In the optimal condition in scenario 3, the area used for secondary forests decreased 0.61% from the previous area. The consequence of the decrease was the increase in plantation area by 0.24% and dryland farms by 0.35% from the actual condition. The optimization results also demonstrated that the people's income increased.

Table 7. Optimal Land Use/Coverage Scenarios

	Luas	Land Use				
		PF	SF	P	S	DLF
Scenario 1	Land Area	6635.1	19225.0	147.2	5.1	433.6
	A	130.5	180.5	230.8	530.2	830.2
	Income	662000	3640755	2874600	1118625	1630445
Scenario 2	Land Area	6635.1	19169.0	188.7	5.1	448.2
	A	128.2	188.2	228.2	528.2	828.2
	Income	662000	3883769	2944850	1260433	1821440
Scenario 3	Land Area	6635.1	19025.7	289.6	8.3	487.4
	A	28.8	38.8	37.5	17.1	40.8
	Income	662000	5189759	3289650	1356177	2355220

PF=Primary forest, SF=Secondary forest, P=Plantation, S=Settlement, DLF=Dryland farming

The optimal land use scenario which was selected was scenario 3 (three) because it had the most impact on the community's income, a 35% increase, and the erosion was also within the TSL. Land use for plantations and dryland farming contributed to the increased income. Figure 1 depicts the condition of land use before and after the optimization. Optimization of land use is influenced by the goal to be achieved with some constraints that occur in the area. Goals are usually to be achieved is a social benefit, ecology, economy of use of the land [18].

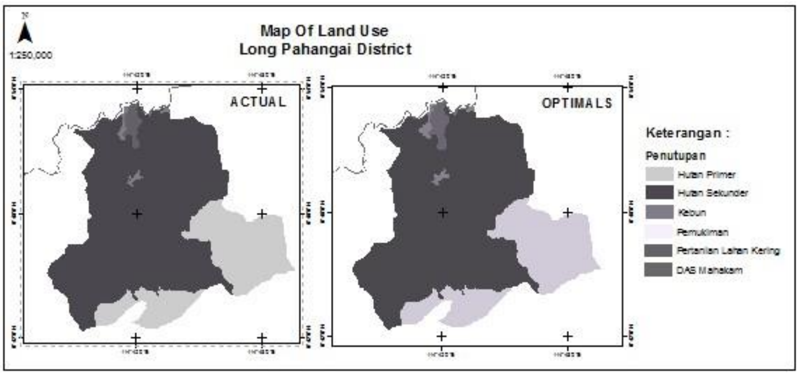

Figure 1. The Actual and Optimal Land Use/Coverage Configuration

Table 8. Indigenous Land Spatial Utilization Allocation

No	Land use/coverage	Allocation	Area
1	Primary forest	Prohibited area	284.20
		Non Timber, Ecotourism	6350.91
2	Secondary forest	Non Timber, Ecotourism	9042.34
		Agroforestry Pattern	
		Forest Plantation of Community	8184.28
		Intensive farming/Plantations	1799.10
		Agroforestry Pattern	
	Plantation	Forest Plantation of Community	143.00
3		Settlement	0.03
		Intensive farming/Plantations	146.58
4	Settlement	Settlement	8.27
5	Dryland farming	Settlement	55.30
		Intensive farming/Plantations	432.05
	Total		26446.05

Based on the spatial analysis with query on the forest area for the optimal land capability and land use in scenario 3 there were 10,705.01 hectares or 40.47 % that could be used as cultivation in the form of intensive agriculture, plantations, village forests, community forests and community timber plantations, and there were 15,677.44 hectares or 59.28% of the indigenous land whose function could be maintained as a conservation area; however, the non-timber forest resources could also be utilized in a limited way with conservation in mind. The details are presented in Table 8.

Space allocated to cultivation areas could increase income by 80%, from IDR 9,602,869.- to IDR 17,275,171 per capita per ha per year. Based on the recommendation for community space utilization pattern, it could be seen that this area would be dominated by the conservation area. Therefore, the forest protectiion function could be maximized. In addition, the domination by the conservation area within the indigenous land could decrease the rate of deforestation [19-22].

4. Conclusion

From the foregoing discussion, several conclusion can be derived as follows:

1) Based on the land use optimization results using the linear program, there were 3 scenario created. The selected scenario was scenario 3 with a composition as follows: the area for primary forests was not changed from its original 6,635.11 ha, secondary forest 19,025.72 ha, plantation 289.61 ha, and dryland farmland 487.35 ha, settlement 8.27 ha with an increase in community 's income by approximately 35% from IDR 9,602,000. To IDR12,852,805.-

2) Based on spatial utilization allocation that had been designed, there were 10,705.01 hectares or 40.47% that could be used as cultivation land in the form of intensive agriculture, plantations, village forests, community forests and community forest timber plantations. On the other hand, there was 15,677.44 hectares or 59.28% of the indigenous land whose function could be maintained as conservation areas with an increase in the people's income by approximately 80%.

3) The actual land use and land cover had caused erosion rate ranging from 27.77 to 4.377,6 tons/ha/year. In general, the erosion (A) was higher than or exceeded the TSL (Tolerable Soil Loss). Only primary forests demonstrated an erosion rate lower than the TSL. This was proven by the primary forest's good density.

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