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Land use management and carrying capacity of Bangsri Micro Watershed, East Java, Indonesia: A baseline study

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Abstract

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The increase of unsustainable human activities in watershed areas gave a huge pressure, causing land degradation and reduced the river water quality. This study aimed to describe the land use management and calculate the carrying capacity as a part of natural resource management of Bangsri Micro Watershed, the upper Brantas watershed in East Java, Indonesia. Data was gathered from five villages through interviews, questionnaires, and focus group discussions with multiple stakeholders. In addition, data from the local government statistics bureau (i.e., Statistics Indonesia) was also used. From the total 2 765 ha land area, eight different land use were identified with agroforestry (970 ha) being the largest and bare land (43 ha) being the smallest. There were 17 crop patterns with 10 different commodities recorded. Based on the present land use, the total land monetary value (biocapacity) was 298 billion Indonesian Rupiah (IDR) or equal to 27 278 tonnes of rice production. From the total population of 27 645; the total annual income (i.e., ecological footprint based on the minimum wage and real household income) needed is 577-854 billion IDR (72 101-106 771 tonnes of rice), thus considered as a deficit carrying capacity value. An urgent watershed management planning is needed to reduce the environmental pressure while ensuring the fulfilment needs of the people in Bangsri Micro Watershed.

Keywords: carrying capacity; Bangsri Micro Watershed; upper Brantas watershed; East Java; sustainability

Introduction

Watershed is one of the crucial resources for humankind that needs to be sustainably managed. The pressure given by humans, especially in the areas with high population density has led to watershed degradation; resulting in land erosion, decreased water quality, drought, and land degradation (Repetto, 1986). For instance, changes in land use and land cover in watershed areas, especially riparian areas can reduce the river water quality, e.g., by degrading surface runoff and increasing waste disposal input from agro-industry and households (Mello, Randhir, Valente, & Vettorazzi, 2017; Meneses, Reis, Vale, & Saraiva, 2015; Valentin et al., 2008). Moreover, farmers with activity centred around the watershed areas depend greatly on their crop production as their main source of income. The watershed degradation has led to a decrease in crop yield, leaving the farmers and surrounding people who depend greatly on it to become the most affected. The decrease in their main income, clean water scarcity, and the high-risk of landslide/erosion have led them to become more vulnerable facing climate change and pandemic.

Protecting riparian areas and land conservation practices are critical to improve the watershed ecosystem and the people's well-being. Reliable system simulation is required

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to link socio-economic development with the water environment and comprehensively represent the dynamic features of the watershed (Liu, Benoit, Liu, Liu, & Guo, 2015). Intervention is needed to find the most effective and sustainable way of managing the watershed. Indonesian government through the ministry of environment has carried the initiatives to use a bottom-up approach to countering this problem through several programs involving people or the society inhabiting the watershed areas as their main strategy. However, before such program started, a baseline study is needed to describe the current land use management practices (i.e., land utilization, crop pattern, commodities planted) and land carrying capacity in watershed areas that directly related to the society. Through the baseline study results, the most effective and efficient strategy can be applied.

Carrying capacity can be used to measure the ecological sustainability because it shows the relationship between the demands of economic activities of the inhabitants with the supply given by the environment. One of the known approaches to measuring carrying capacity is by using the concept of biocapacity (BC) and ecological footprint (EF). BC and EF are a simple measurement tool to measure ecological sustainability (Mathis Wackernagel & Yount, 1998). These measurements can be used to view the state of a country's development by comparing the consumption and production activities to describe the resilience condition and ecological potentials for sustainable development (Liu et al., 2015).

Biocapacity shows the overall productivity area and indicates the maximum level of available resources, which are part of the footprint (Monfreda, Wackernagel, & Deumling, 2004; M. Wackernagel, Onisto, Bello, Linares, & Guerrero, 1999; Mathis Wackernagel & Rees, 1998). The calculation of EF is a rather simple method and gives an overview of the necessary conditions to achieve sustainability, which is useful to calculate the nation's ecological assets (Monfreda et al., 2004) and evaluate the land adequacy for human resources (Salvo et al., 2015). The relationship between EF and BC can be described as follows: (1) EF > BC shows an ecological deficit (ED), which means that the country is an ecological debtor; (2) EF < BC shows an ecological surplus (ES), which means that the country is ecological creditors (Rugani, Roviani, Hild, Schmitt, & Benetto, 2014).

Bangsri Micro Watershed (BW) is a sub-sub-part of the Brantas watershed, the second-largest watershed (1.2 million ha) in Java island. Brantas River serves as the main source of drinking water and hydroelectric power in East Java, yet it was categorized as a critically degraded river. High rate sedimentation, basin erosion, and decrease of water flow were identified as the main cause. The watershed rehabilitation is focused mainly on the upper watershed areas where most of the problems originated. BW is located in the upper part of Brantas watershed, with the mainland use being agroforestry, rain-fed fields, natural secondary forest, settlements, and production forest. There were several environmental problems occurring in BW, i.e., land-slide erosion, reduced crop production, and drought; which were mainly led by land use change and illegal sand mining. Understanding the land use management and the land carrying capacity based on multiple stakeholder's perspectives in BW area will help to design effective and efficient strategies to rehabilitate the watershed areas.

This study is a part of a bigger collaborative research project initiated by the Indonesian Ministry of Environment, United Nations Development Programme, and Brawijaya University, which aimed to restore the degraded watershed and develop the surrounding community in East Java, Indonesia (see: https://cccd.id/en/eastjava/ for more details). This study aimed to: (1) describe the land use management of the Bangsri Micro Watershed through the land use utilization, crop pattern, and commodities planted; and (2) calculate the land carrying capacity in Bangsri Micro Watershed as a part of the baseline study on the Brantas Watershed rehabilitation plan. The results of this study will help the stakeholders to design a proper collaborative management plan based on the needs of the people of the Bangsri Micro Watershed area. This baseline study can also serve as a template on other future projects to calculate the carrying capacity of watershed areas.

Material and Methods

Study area

The study was done at a part of Brantas watershed called Bangsri Micro Watershed (BW) located in Malang regency, East Java, Indonesia (8.2422° S, 112.7152° E; see Fig. 1). Brantas watershed is the second biggest watershed in Java island (1.2 million ha) and consisted of three main parts, i.e., upstream, middle, and downstream. Bangsri sub-sub watershed is a part of sub-watershed Lesti, which located near to Bromo Tengger Semeru National Park in the upstream Brantas watershed. The ministry of environment in Indonesia considered Brantas watershed as one of the critical watersheds, due to the decrease in permanent vegetation cover which affected its water holding capacity (Sulistyaningsih, 2017). Administratively, BW consisted of eight villages (i.e., Bambang, Bringin, Dadapan, Patokpicis, Sanankerto, Sananrejo, Sumberputih, and Wonoayu) with a total area of 2 985 ha, however, this study only covers five main villages (i.e., Bambang, Bringin, Dadapan, Patokpicis, and Sanankerto) which represents 92.6% (2 765 ha) land area of BW.

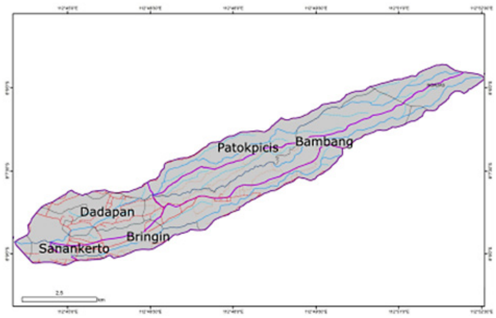

Fig. 1. The map of Bangsri Micro Watershed and the location of five studied village (Sudarto, 2018)

Data collection

This study used two types of data, i.e., primary and secondary data. Primary data was obtained from the Focus Group Discussion (FGD), field observations, and interviews. Secondary data was gathered from Statistics Indonesia (Balai Pusat Statistik; BPS) of Malang Regency. FGD was done by collecting information from related government institutions, heads of districts, and heads of villages in MWB. Field observation was done by observing water distribution, surrounding riparian vegetation, and all activities affecting the riparian areas, e.g., sand mining. Furthermore, the interview method with some key informants was done to explore the existence of currently available resources. Land use cover data used in this study was based on a previous study belong to the same project by Sudarto (2018). The land use type was determined based on spatial analysis using ArcGIS 9.3 on the Landsat image year 2017. Other data used from the same project was the crop pattern data and cover crop (Prayogo, pers. communication); and commodity on each land use (Sukesi, pers. communication). All graphs were done using package ggplot2 (Wickham, 2009) in R statistical software version 3.6.1 (R Core Team, 2019).

Data analysis

The primary and secondary data gathered were used to calculate the land carrying capacity. This study used the carrying capacity and ecological footprint formula in accordance to the Indonesian government's regulation (i.e., Ministry of Environment Decree number 17/2009) and by modifying the formula from previous studies (Bagliani & Martini, 2012; Borucke et al., 2013; Cheng & Yue, 2011; Nakajima & Ortega, 2016). The land use types considered, i.e., (1) agroforestry, areas planted with timber (i.e., *Parasianthes falcataria*) mixed with other crops (i.e., chili, coffee, cassava, corn); (2) bare land, a generally degraded, non-cultivated area with the presence of small grass patches; (3) dryland, a rain-fed cultivated area planted with crops, i.e., chili, tomato, corn; (4) natural secondary forest, non-planted secondary forest areas which were maintained as a conservation area; (5) production forest, areas planted mainly with timber (i.e., *Pinus sp*., *Canarium asperum,* and *Swietenia sp*.) and (sometimes) small patches of chili; (6) rice field, an area planted with at least one planting season of rice per year and other crops (i.e., chili, corn, cassava, cucumber, tomato); (7) settlements, a human residential area; and (7) shrub, a non-cultivated area with the presence of grass and shrubs.

The calculation of carrying capacity of the land was done in several steps, i.e., (1) calculation of biocapacity (BC) or the capacity of productive land in a given watershed area to generate monetary value for its inhabitant, (2) calculation of ecological footprint (EF) or the total amount of land needed to support its inhabitant, (3) comparison of BC against EF. To compare BC and EF, both values were converted into total land area to produce rice in a year period by dividing it with the rice equivalence factor (r). The rice equivalence factor is based on the total income derived from the rice yield in one-hectare rice field area. The r is calculated based on the price of rice from the farmers (Indonesian Rupiah-IDR 8 million/ton) multiplied by the yield per hectare (7000 ton/ha) and conversion coefficient of harvested rice from the total grain yield (0.55). The price, yield and harvest coefficient conversion of rice were based on the assumption that those values were the same throughout the year and across different studied villages.

To calculate biocapacity or the supply of natural resources, several data were used, i.e., (1) land use cover (Sudarto, 2018), (2) crop pattern and its land use area (Prayogo, pers. communication), (3) commodities planted on each crop pattern and its productivity (Sukesi, pers. communication), (4) the commodity's price, (5) crop yield on each crop pattern and land use. Those data were then used to calculate BC with the following formula, i.e:

$$BC = \frac{\sum_i^N \sum_j^M P_i Y_i A_{ij}}{r} \tag{3.1}$$

BC: biocapacity (ha) equal to land area needed equivalent to producing rice in a year

P_i : i^{th} commodity's price (IDR/ton)

Y_i: i^{th} crop yield (ton/ha)

i: 1, 2, .., 10 (crops, i.e., rice, corn, chili, tomato, coffee, woody plants, cattle food, cucumber, pine resin)

A_{ij}: *i*-th commodities' land area in j-th land (ha) in a year

j: 1 (agroforestry), 2 (bare land), 3 (dry land), 4 (production forest), 5 (rice field), 6 (shrub)

r: rice equivalence factor = 30 800 000

The basic concept of ecological footprint is the demand of the human population on natural resources. The calculation of EF was based on two scenarios, i.e., (1) the Malang regency's minimum wage (Upah Minimum Kabupaten; UMK) based on East Java Governor's decree number 75/2017 (EF_{UMK}; Eq. 3.2) and (2) the real income based on questionnaires and interviews (EF_{real}; Eq. 3.3). The income rate considered is shown in Table 1.

The use of minimum wage to calculate ecological footprint is based on the consideration that minimum wage has cover standard basic needs in order to live a decent and proper life, e.g., food, transportation, housing, health, education, etc. The real income was profit generated from several activities and calculated based on several data, i.e., farmers' land ownership, total land area owned, crop pattern and commodities planted, labour cost, yield quantity, commodity price, other source of income (e.g., cattle, honey, sand mining), and other cost (e.g., fertilizer, pesticide, tools):

$$EF = \frac{N12UMK}{r} \quad (3.2)$$

EF: total land area needed to support its inhabitant (ha) equivalent to producing rice in a year

N: population (person)

12: total month in a year

UMK: monthly minimum wage (IDR 2 574 807)

r: rice equivalence factor = 30 800 000

$$EF_{real} = \frac{NI}{r} \quad (3.3)$$

EF_{real}: total land area needed to support its inhabitant (ha) equivalent to producing rice in a year

N: population (person)

I: Annual income per capita (IDR/year)

r: rice equivalence factor = 30 800 000

Results

Land area proportion

From the total land area studied, 35.1% belong to agroforestry area, 24.0% dry land, 12.0% natural secondary forest, 10.9% settlements, 7.8% production forest, 4.9% rice field, 3.7% shrub, and 1.6% bare land (Table 2). Almost all areas in the villages were utilized (88%, 2 433 ha) and subjected to direct cultivation (71.8%; 1 986 ha). The village land areas were ranging from 217-1,086 ha with the biggest area owned by Bambang village and the smallest area owned by Sanankerto village. Except for Bambang and Sanankerto,

Table 1. Annual monetary value of different land use from five studied villages

Land use type	Monetary value (in millions IDR)					Total land use income
	Bambang	Bringin	Dadapan	Patokpicis	Sanankerto	
Agroforestry	18 710	15 562	8 249	22 953	2 297	67 772
Bare land	446	152	30	40	75	744
Dry land	56 686	41 964	45 525	28 459	11 992	184 627
Production forest	3 233	81	45	12 971	1	16 331
Rice field	125	773	0	692	27 185	28 170
Shrub	492	29	16	37	6	580
Village income	79 692	58 563	53 865	65 152	41 557	298 224

Table 2. The land area (ha) from different land use at the five studied villages

Landuse type	Land area (ha)					Total area
	Bambang	Bringin	Dadapan	Patokpicis	Sanankerto	
Agroforestry	281.0	199.9	164.6	294.9	30.1	970.4
Bare land	29.8	6.8	1.3	1.8	3.3	43.0
Dry land	270.7	129.6	69.6	175.1	18.6	663.6
Natural secondary forest	294.0	3.3	0.4	33.4	1.1	332.3
Production forest	42.7	0.9	0.8	170.2	0	214.7
Rice field	6.3	6.5	0	2.1	122.0	136.9
Settlement	79.2	100.5	66.3	15.8	40.5	302.3
Shrub	82.0	6.5	3.6	8.3	1.3	101.7
Village land area	1 085.6	454.1	306.6	701.6	216.9	2 764.9

the highest land use proportion was agroforestry in all studied villages (Figure 2). The biggest land use area in Bambang was natural secondary forest which accounts for 88.5% of the overall studied area from this category. Sanankerto has the biggest land use area of rice fields compared with others (Figure 2). In the micro watershed scale, the protected natural secondary forest area is almost equal to the settlements area (Figure 2).

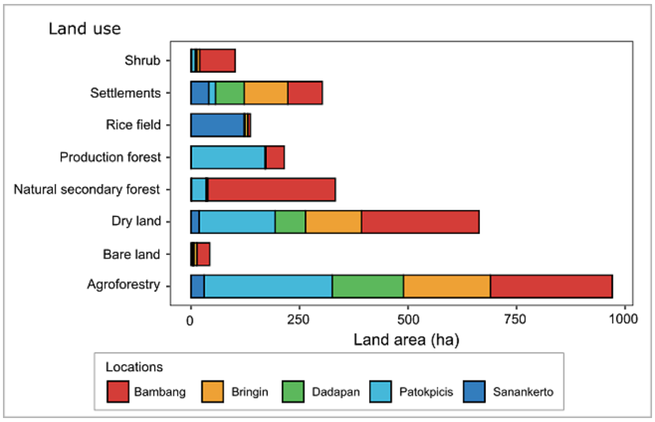

Fig. 2. The land area (ha) based on different land use at five studied villages

Monetary value from different land use

Analysis results based on the primary data gathered showed an overall annual monetary value derived from different land use from five villages of IDR 298.2 billion or around USD 19.9 million (exchange rate of 1 USD=15 000 IDR). The two highest monetary value was from dry land (61.9%) and agroforestry (22.7%). The mean total monetary value was IDR 59.6 billion (USD 3.9 million) with the highest monetary value was shown by Bambang and the lowest shown by Sanankerto (Table 1).

Based on the annual monetary value per hectare land area (Figure 3), every village shared an almost similar income from the agroforestry and production forest. Meanwhile, dry lands in Dadapan and Sanankerto were considered more productive than the others (Figure 3). Also, Patokpicis and Sanankerto has more productive rice fields compared with the others (Figure 3).

Crop patterns and their monetary value

From the six land uses that generate monetary value, there were seventeen crop patterns observed (Table 3) at the five studied villages. In general, the five villages shared similarities on the types of crop pattern and planted commodities, except the rice field in Patokpicis and Sanankerto which

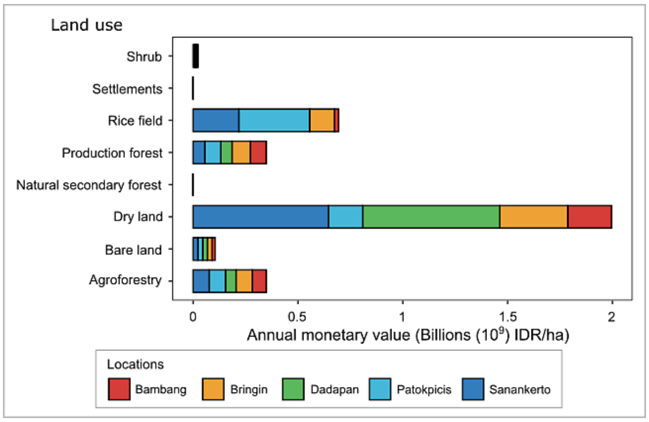

Fig. 3. Annual monetary value per hectare (IDR/ha) of different land use from five studied villages

were planted with tomato and cucumber. Planting a monoculture seasonal crops or mixed with timber trees is more preferred since it generates more value (Table 4).

Based on the primary data gathered through interviews, dry land and rice field can be planted with two or three different crop patterns in a year period. The farmers' decision on choosing the crop pattern and commodities depends on the farmers' knowledge on cultivating a certain commodity and the market demand. Some farmer household may own more than one type of land use and they tend to diversify their planted commodities so that the income can be obtained at a different period of the year. Mostly, the main income comes from seasonal crops (e.g., rice, chili, corn) and income from long-lived plants such as wood is considered as their savings which were only sold when they need additional income. Commodity which grow without maintenance such as grass in bare land and shrub also contributes to the farmers' income since there are several households who own cattle in the studied area.

Monetary value based on commodities

From the 10 main commodities produced, all five villages shared seven similar commodities, i.e., cassava, chili, coffee, corn, grass, and wood (Table 5). Meanwhile, the monetary value calculation from different commodities produced (Table 5) showed that the highest annual value was obtained from chili (72.2%; USD 14.4 million) and wood (14.3%; USD 2.8 million).

Figure 3 showed the productivity of these two commodities based on the calculation of monetary value per hectare. The productivity of chili seems to vary, depending on land use where the commodity is planted (Figure 4a). Chilies planted in open areas, i.e., dry land and rice

Table 3. Seventeen crop patterns and the commodities planted at five studied villages

Nr.	Land use type/Crop pattern		Commodities	Presence in each village				
				Bambang	Bringin	Dadapan	Patokpicis	Sanankerto
	Agroforestry							
1		Simple	Wood (*P. falcataria*)	v	v	v	v	v
			Grass (cattle food)	v	v	v	v	v
			Coffee	v	v	v	v	v
			Grass *Pennisetum sp.*		v	v	v	
2		Multi-strata	Wood (*P. falcataria*)	v	v	v	v	v
			Cassava	v	v	v	v	v
			Corn	v	v	v	v	v
			Coffee	v	v	v	v	v
			Chili	v	v	v	v	v
	Bare land							
3		Bare land	Grass	v	v	v	v	v
	Dry land							
4		Palawija	Corn	v	v	v	v	
5		Corn and vegetable	Corn	v	v	v	v	v
			Chili	v	v	v	v	v
6		Vegetable	Chili	v	v	v	v	v
			Tomato					v
	Production forest							
7		Young *Swietenia sp.*	Wood (*Swietenia sp.*)	v	v	v	v	
			Chili	v	v	v	v	
8		Old *Swietenia sp.*	Wood (*Swietenia sp.*)	v	v	v	v	v
			Grass (cattle food)	v				
			Grass (*Pennisetum sp.*)		v	v	v	
9		Canarium asperum	Wood (*C. asperum*)	v			v	
10		Pine monoculture	Pine resin	v	v	v	v	
11		Pine and vegetables	Pine resin	v	v	v	v	
			Chili	v	v	v	v	
	Rice field							
12		Rice	Rice	v	v			v
13		Rice and corn	Rice		v		v	
			Corn		v		v	
14		Rice and vegetable	Rice		v			v
			Chili		v			v
			Tomato					v
15		Rice, corn, and vegetable	Rice				v	v
			Corn				v	v
			Chili				v	v
16		Vegetables	Cucumber				v	
			Chili				v	
			Tomato				v	
	Shrub							
17		Shrub	Grass	v	v	v	v	v

Table 4. Monetary value of seventeen crop patterns from five studied villages

Nr	Land use type/Crop pattern		Monetary value (in millions IDR)				
			Bambang	Bringin	Dadapan	Patokpicis	Sanankerto
	Agroforestry						
1		Simple	9 203	6 549	5 390	9 658	941
2		Multi-strata	9 507	9 014	2 859	13 294	1 357
	Bare land						
3		Bare land	446	152	30	40	75
	Dry land						
4		Palawija	4 737	972	609	2 627	0
5		Corn and vegetables	18 103	8 587	7 348	11 602	6 886
6		Vegetables	33 837	32 405	37 568	14 229	5 107
	Production forest						
7		Young *Swietenia sp.*	889	19	17	3 546	0
8		Old *Swietenia sp.*	436	13	9	1 738	1
9		Canarium asperum	107	0	0	426	0
10		Pine monoculture	68	1	2	271	0
11		Pine and vegetables	1 734	47	17	6 980	0
	Rice field						
12		Rice	124	516	0	0	6 643
13		Rice and corn	0	66	0	41	0
14		Rice and vegetable	0	191	0	0	7 695
15		Rice, corn, and vegetable	0	0	0	357	12 847
16		Vegetables	0	0	0	293	0
	Shrub						
17		Shrub	492	29	16	37	6

Table 5. Annual income from different commodities of five studied villages

Commodity	Monetary value (in millions IDR)					Total commodity value
	Bambang	Bringin	Dadapan	Patokpicis	Sanankerto	
Cassava	1 517	1 080	355	1 592	163	4 707
Chili	56 722	45 474	45 844	39 236	28 327	215 603
Coffee	330	235	135	347	35	1 083
Corn	6 069	1 577	1 201	3 479	875	13 202
Cucumber	0	0	0	16	0	16
Grass	2 283	1 083	788	1 724	171	6 049
Pine resin	95	2	2	452	0	551
Rice	0	602	0	50	8 455	9 108
Tomato	0	0	0	3 314	2 251	5 566
Wood	12 542	8 509	5 538	14 940	1 280	42 809
Village monetary value	79 559	58 563	53 865	65 152	41 557	298 695

field showed higher average productivity (IDR 432.3 million/ha) compared to the ones planted under the shade, i.e., agroforestry and production forest (IDR 147.8 million/ha).

The productivity of wood calculated by monetary value obtained per hectare area showed a 30% higher average value in agroforestry (IDR 41.6 million/ha) compared with production forest (32.3 million/ha; Figure 4b). This could be explained by the fact that the wood commodity planted in agroforestry is a fast-growing species (i.e., *P. falcataria*) compared to the ones planted in the production forest (i.e., *Pinus sp.*, *C. asperum,* and *Swietenia sp.*).

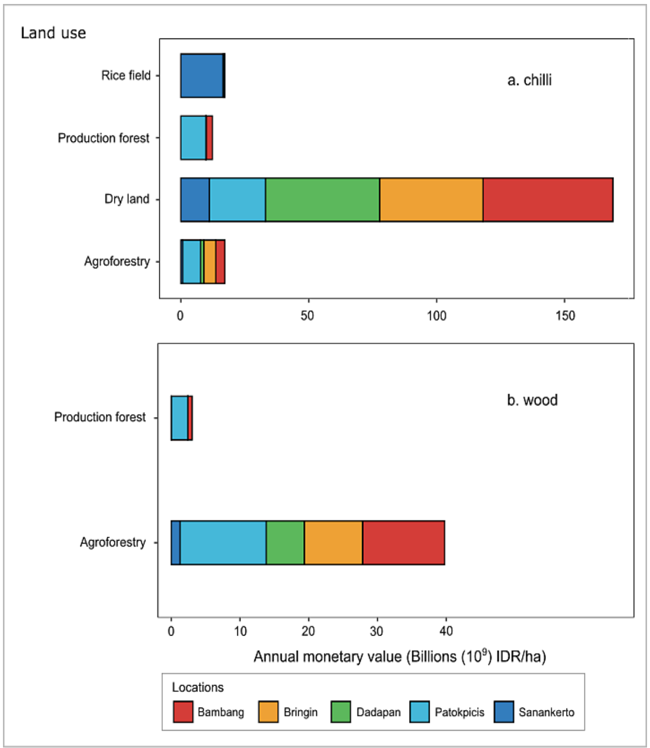

Figure 4. Annual monetary value per hectare (IDR/ha) from different commodities: a. chili, b. wood, planted in different land use of five studied villages

Carrying capacity

The calculation of income derived from different commodities and land use or biocapacity (BC), showed values ranging from 1 349 to 2 587 ha. Bambang has the highest biocapacity value, followed by Patokpicis, Bringin, Dadapan, and Sanankerto (Table 6). The biocapacity per capita value were ranging between 0.3-0.7 ha/capita. Bambang village has the most land area available per person compared with the others.

The ecological capacity based on the regional minimum wage (EF_{UMK}) was higher compared to ecological capacity based on the real income (EF_{real}) at all villages. The calculation of EF_{UMK} values ranging from 3 961-7 728 ha (1 ha/person). Meanwhile, the values of EF_{real} showed lower values, ranging from 3 075-5 645 ha (0.4-1 ha/person; Table 6). According to these results, each EF is higher than BC and carrying capacity is considered as deficit. Meaning, the income derived from the commodities produced from the villages' land area was not sufficient to support a decent living standard according to the Malang regency's regulation and according to the real farmer's income.

Discussion

Land area proportion

Even though there was a slightly higher proportion of tree-dominated areas (i.e., natural secondary forest, production forest, agroforestry; 55%) compared with areas with a low tree coverage (i.e., rice field, settlements, bare land, shrub, dry land; 45%) in the five studied villages, however, the land use spatial arrangements were not in accordance with the designated spatial planning. For instance, according to the regional spatial planning, there are 171.2 ha areas in the five villages which supposed to be a conservation area (land capability class VIII; Sudarto 2018). The regional spatial planning was determined mainly based on the type of soil and topography. In general, areas with a high slope are designated as non-cultivated areas and trees should be planted in this area as a part of a conservation effort to mitigate the landslide. Thus, the mismatch between spatial planning and the real situation can contribute to the high risk of landslide, especially in the non-vegetated areas with high slope.

Besides that, another major problem that may contribute to erosion, landslide, and an increase in sedimentation in the river is sand mining activity (Lusiagustin & Kusratmoko, 2017). The sand input from the volcanic activity of the nearby mount Semeru has made the BW areas rich with high-quality sand material. The sand from these areas is considered as the best sand for construction material. The continuous sand mining activity has caused a rapid land use conversion from the production forest and other areas nearby the river into degraded bare land. In some areas, sandpit was dug up to the 3-meter depth and left untreated afterwards. The sandy soil of BW area caused the rainwater to easily infiltrate the soil, however, most of the rainwater will flow in the surface in the case that the vegetation coverage (especially trees with a vast root area) does not exist. This caused a decrease in the groundwater and an increase in river sedimentation. Based on our interviews, farmers already complained about the drought during the dry monsoon months. Indeed, the Brantas river sedimentation has been reported to significantly increase the water level of the Sutami and Sengguruh reservoir which were considered as a serious problem in generating electricity at the reservoirs' hydroelectric power plant (Perum Jasa Tirta, 2003). Therefore, an effort to restore the vegetation cover in the ex-sand mining area is urgently needed. An integrated program between the government and the people of BW area to manage the land use according to the designated and proper regional planning is also needed.

Table 6. Biocapacity and Ecological Footprint of five studied villages

Component	Bambang	Bringin	Dadapan	Patokpicis	Sanankerto
Biocapacity (BC)					
Annual monetary value from different land use (millions IDR/year)	79 692	58 563	5 397	65 152	40 953
Population	3 948	6 159	5 842	7 704	3 992
Annual monetary value from different land use per capita (millions IDR/year)	20	9	9	8	10
Biocapacity (ha)	2 587	1 901	1 749	2 115	1 349
Biocapacity per capita (ha)	0.7	0.3	0.3	0.3	0.3
Ecological Footprint (a. based on the regional minimum wage (UMK Malang Regency))					
Monthly minimum wage (millions IDR)	2.6	2.6	2.6	2.6	2.6
Annual minimum wage (millions IDR)	31	31	31	31	31
EF_{UMK} (ha)	3 961	6 179	5 861	7 728	4 005
Total land needed per capita (ha)	1.0	1.0	1.0	1.0	1.0
Ecological Footprint (b. based on the real household income (questionnaire & interview))					
Monthly income per capita (millions IDR)	2.0	1.5	2.5	1.1	2.1
Annual income per capita (millions IDR)	24	17	30	13	25
EF_{real} (ha)	3 075	3 505	5 645	3 250	3 253
Total land needed per capita (ha)	0.8	0.6	1.0	0.4	0.8
BC – EF_{UMK}	-1 373	-4 277	-4 112	-5 613	-2 655
BC – EF_{real}	-488	-1 603	-3 896	-1 135	-1 904

Monetary value from different land use, crop pattern, and commodities

In general, the monetary value differences from different land use were due to the differences in the crop pattern and the main commodities planted in each land use and the productivity level of each commodity in every land use. For instance, the productivity of chili planted in the areas with tree coverage (i.e., agroforestry and production forest) was ranging between 25-35% than the ones planted in open areas (i.e., rice field and dry land). The same case also observed with corn and cassava where the productivity declined to 30-35% when planted under the tree shade. Indeed, these commodities are light-demanding species or species that grow best in open areas with high sun exposure.

Even though chili (i.e., red chili and cayenne pepper) has given a high proportion of agriculture value in BW area, the productivity is considered low (12.6 ton/ha) compared with the Malang Regency (27.9 ton/ha; (BPS-Statistics of Malang Regency, 2018) in the same year. This might due to the fact that the land is not suitable for planting chili. Interestingly, the main value from production forest and agroforestry are both from chili (production forest: 78.0%; agroforestry: 60.3%) compared to wood (production forest: 18.5%; agroforestry: 24.8%). Theoretically, the production forest was designated as a buffer zone between protected forest areas (i.e., natural secondary forest) and cultivation areas (i.e., agroforestry, rice field, dry land). Most of the production forest areas in Java were under the authority of the Indonesian state forestry company (Perhutani) and were meant to be planted only with timber trees. In practice, the forest production area in BW was managed together by Perhutani and the local community. Due to the economic pressure, some local communities breached the contract with Perhutani and planted these areas with non-timber commodities. The conversion of production forest into semi-dry land can increase the risk of landslide and river sedimentation due to the increase in the surface runoff (Astuti, Sahoo, Milewski, & Mishra, 2019; Valentin et al., 2008). This situation calls for strict law enforcement to stop the non-timber cultivation activities and replanting the areas with suitable trees.

Deficit carrying capacity: low income from farming and possible solutions

Based on the comparison between biocapacity (BC) and the ecological footprint (EF) from the Malang Regency's minimum wage and the real farmers' income, the land capacity in BW area is considered a deficit. It seems that agricultural activity could not provide sufficient income for farmers. Indeed, according to the data provided by Statistics of East Java Province (2019), the average household monthly income from agriculture in 2018 in Malang Regency is IDR 1,397,794, which is almost half of the regency's minimum wage (IDR 2,574,807). This situation has caused a trend in the East Java province for the past years; there were lesser farmer, lesser arable land, thus less income from this sector (Oktavia, Hanani, & Suhartini, 2016).

The low income obtained from agricultural farming activity observed in this study has created more pressure on the environment through the practice of land use conversion. Based on the field observation and primary information from different stakeholders in the BW area, there are several environmental problems related to the low income obtained from farming, i.e., low soil fertility, decrease in arable land due to the pre-existing sand mining activity, and lower crop productivity in tree-dominated areas.

The low soil fertility as one of the main reasons for low farming income was probably due to the nature of the soil type in the BW area. Through his study, Sudarto (2018) mentioned inceptisols and entisols as the main soil type of BW area. Inceptisols and entisols are considered as immature soil without complex soil horizon formed yet, tend to be acidic, and has low soil organic material content and thus low soil fertility (Brady & Weil, 2014; Palmer, 2004). However, several studies have reported a successful attempt to increase the soil fertility of this type of soil by adding biochar (Widowati, Sutoyo, Karamina, & Fikrinda, 2020; Zhang et al., 2016). Biochar or a lightweight charcoal-like substance made by burning biomass waste helps to increases the soil pH and act as a potential source of macro and micronutrients needed by plants (Chan, B, Meszaros, Downie, & Joseph, 2008; van Zwieten et al., 2010). Besides that, the application of manure or mixed manure (i.e., manure and chemical fertilizer) instead of only chemical fertilizer has been proved to increase the crop productivity, such as rice in inceptisols soil (Syamsiyah, Sumarno, Suryono, Sari, & Anwar, 2018). Another study in an inceptisols rainfed agriculture area showed that crop rotation and planting nitrogen-fixing legumes can help to significantly increase crop yield such as corn (Sileshi, Akinnifesi, Ajayi, & Place, 2008; Singh, Alagarswamy, Hoogenboom, et al., 1999; Singh, Alagarswamy, Pathak, et al., 1999).

The sand mining activity in the BW area happened in the river and surrounding areas (e.g., home garden, agroforestry). This activity started circa the 1990s and was thought of as an income solution for low land productivity. As a result, the tree vegetation was loss, landslide and erosion risk increased, and arable land in the BW area decreased. Furthermore, a study in Cirebon, West Java mentioned that the sand mining activity has caused soil damage and affected the soil fauna with the total estimated loss of IDR 39 billion from 2 ha soil mining area (Wasis, Saharjo, Kusumadewi, Utami, & Putra, 2018). A study in Lumajang, East Java revealed that most sand mining practices have caused a financial loss for the government due to the tax-leakage practices (Prestianawati, Mulyaningsih, Manzilati, & Ashar, 2020). Therefore, strict law enforcement by the government is urgently needed to avoid further loss in the environment and finances. A possible solution to restore this area is through reclamation by adding organic mulch as a source of soil organic material; adding soil microbes such as arbuscular mycorrhizal fungi; and planting adaptive plant suitable for this soil type, e.g., dragon fruit (*Hylocereus costariensis*) (Nurbaity, Yuniarti, & Sungkono, 2017). After the soil structure gradually improved, trees can be planted to decrease the landslide and erosion risk.

In the studied area, the lower crop productivity planted in the tree-dominated areas (i.e., production forest and agroforestry) has tempted the farmers to harvest the trees and convert the land into rainfed drylands or open areas planted with seasonal crops such as chili, corn, tomatoes, and rice. Indeed, every crop has specific environmental requirements in order to achieve optimum yield, which in this case is the minimum light requirement. However, several studies have shown that crops can grow well and productive in the agroforestry system, as long as some basic requirements met (Brown, Miller, Ordonez, & Baylis, 2018). For instance, cacao can achieve the productivity of 50% and higher when planted together with 100 shade trees per hectare in a spatially organized manner (Waldron, Justicia, & Smith, 2015). The significant increase in cacao yield was also observed in the agroforestry system that supports the presence of insectivorous bats and birds which control the insect pests' population (Maas, Clough, & Tscharntke, 2013).

There are numerous proven advantages from agroforestry which did not directly calculate as income, instead, it offers services that can be calculated as a financial loss when such services did not exist anymore. Several crucial ecosystem services identified from agroforestry systems, i.e., help to mitigate the effects of climate change, increase the water and air quality, improve the soil structure and nutrient cycling, increase carbon sequestration, increase the water infiltration from surface runoff, control of pest and diseases, and helps to conserve related biodiversity (Brown et al., 2018; Garrity et al., 2010; Lasco, Delfino, & Espaldon, 2014). Such knowledge was not readily accessible for the local farmers in BW. At this point, an intervention from the government is needed to evaluate the ecosystem services provided by the agroforestry system. An incentive program which gives a direct benefit for the local farmers can be an attractive solution to stimulate farmers on maintaining the pre-existing agroforestry and/or plant trees in between their crops. Several direct actions which can be initiated by the local government, i.e., (1) initiating and giving trainings on agroforestry, biodiversity, and sustainable farming to the farmers' group, (2) selecting and providing timber trees suitable with the soil and climate type in BW area, (3) provide free seedlings of coffee and timber trees for the farmers who attend the training, (4) designing and executing tree planting program to rehabilitate degraded areas together with the local inhabitant in BW area.

Conclusion

The land use utilization in BW area was not in accordance with the designated spatial planning. Farmers in five studied villages used various crop pattern and prefer to cultivate seasonal commodities since it generates more income in a shorter planting period. The farmers' land management decision on choosing the crop pattern and commodities were based on their knowledge and the market price and demand. The calculation of biocapacity and ecological footprint of BW showed a deficit carrying capacity value. The income from agricultural activity did not provide sufficient needs for the people in the BW area. This situation has forced farmers to search for another source of income, which creates more pressure on the environment. Areas covered with trees have been converted into dryland for cultivation or bare land from sand mining activity, resulting in a higher risk of landslide, river sedimentation, and low water availability. There are several possible intervention action plan to solve this problem, i.e., a more strict law enforcement to stop land use conversion; rehabilitate the post-sand mining bare land into arable land; planting suitable trees in degraded areas with high-risk of landslide; providing training and incentives for farmers; and increase the low soil fertility with organic mulch, adding biochar, and include legumes as one of the crops.

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