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Research Article

Food Carrying Capacity as an Indicator of Sustainability of Smallholder Oil Palm Plantations in Riau Province

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Abstract

The food carrying capacity of smallholder oil palm plantations as an indicator of the performance of ecosystem services can be seen from the carrying capacity of actual and potential food. The carrying capacity of potential food is calculated based on indirect food potential while the carrying capacity of actual food is calculated based on the availability of food produced from the production of Fresh Fruit Bunches (FFB) of oil palm which is converted into a staple food. This study aims to calculate the food carrying capacity of smallholder oil palm plantations in Riau Province. The research methods employed were spatial analysis and farm analysis. The results indicate that smallholder oil palm plantations are able to produce food of 199,979 kg/ha/year originating from the potential food carrying capacity of 198,865 kg/ha/year and the actual 1,114 kg/ha/year. The food requirement of 73,916 kg/ha/year comes from the potential food need of 73,298 kg/ha/year and the actual food need of 618 kg/ha/year. To conclude, oil palm plantations have a surplus food carrying capacity of 126,063 kg/ha/yr originating from potential food of 125,567 kg/ha/yr and actual food of 496 kg/ha/yr.

Keywords: spatial, carrying capacity, food, sustainability, palm oil

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Introduction

Global population growth is still very difficult to control for even though every country has made preventive efforts, it has not yet obtained optimal results (Bah et al., 2014). Therefore, it will have an impact on social, economic, and legal conditions (Bailey, 2004; Fang, 2013). The limited availability of space and natural resources will slowly experience pressure and decrease in the loss of biodiversity, soil degradation, and air, water, and soil pollution (Braat & De Groot, 2012). This pressure will result in an ecological deficit because the availability of resources is decreasing, while the need is increasing (Bull, Suttle, Gordon, Singh, & Milner-Gulland, 2013).

Riau Province is one of the areas experiencing ecological pressures in the form of extensive land cover changes due to the frequent forest and land fires and land conversion to oil palm plantations over the last few decades (Bull, Suttle, Gordon, et al., 2013). The conversion of land oil palm plantations is the most dominant, the high demand for land for oil palm plantations has changed the function of forest ecosystems into plantation ecosystems (Bull, Suttle, Singh, & Milner-Gulland, 2013). To restrain the rate of transfer of functions, it is necessary to control through a moratorium to maintain the balance of ecosystem services (Chaudhary, McGregor, Houston, & Chettri, 2018) to meet food availability (Cumming et al., 2014).

Oil palm plantations have been a moratorium on through the Indicative Map for Moratorium of New Permit (*Peta Indikatif Pendundaan Izin Baru* abbreviated as PIPPIB) through the Decree No. 666/MENLHK-PKTL/IPSDH/PLA.1/2/2021 dated February 15, 2021. The purpose of the PIPPIB issuance is to postpone and improve plantation governance sustainability. On the other hand, oil palm plantations provide great benefits for the welfare of the community (Curtsdotter et al., 2019) especially during the Covid-19 pandemic which has lasted for two years (Dislich et al., 2017). However, ecologically, oil palm plantations are considered to be the cause of the decline in the carrying capacity and capacity of the environment based on ecosystem services (Chaudhary et al., 2018).

Existing conditions of oil palm plantation ecosystem services are dominated by moderate, low, and very low conditions (Diaz-Chavez, Mutimba, Watson, Rodriguez-Sanchez, & Nguer, 2010), especially in water supply services, climate regulation, and floodwater flow management. Under these conditions, it is necessary to calculate the carrying capacity of food as an indicator of the sustainability of smallholder oil palm plantations in Riau Province (Zhao, Zhu, Wu, & Lu, 2022). Food sustainability is the basic ability of the environment/earth to support living things (Faizal & Ateeb, 2018a) as the basis for making economic and environmental decisions (Hamdan, Burnham, & Ruhana, 2000).

Law Number 41 of 2009 concerning the protection of sustainable food agricultural land mandates that food security contains four essences that serve as barometers of food security, namely food availability, food stability, food accessibility, and food quality. One of the world's food producers comes from oil palm plantations which produce various derivative products for human needs and increase economic growth (Hammam & Mohamed, 2020). Palm oil is also an energy source that provides added economic value and prevents excessive use of resources, especially in the exploitation of mining products (Hapsoh, Dini, & Rahman, 2020).

This study aims to analyze the sustainability of smallholder oil palm plantations in Riau Province using the analysis of food carrying capacity as an indicator (Lotze-Campen et al., 2008). Food carrying capacity analysis was used as an important component in decision-making (Hermon, Iskarni, Oktorie, & Wilis, 2017) to prepare scenarios for food needs in sustainable development (Homer et al., 2015). The carrying capacity of food was obtained from the calculation of the carrying capacity of ecosystem services and the carrying capacity of food comes from oil palm farming activities (Huddleston & Tonts, 2007), converted into food (Izakovičová, Mederly, & Petrovič, 2017).

Literature review

Plantation plants are seasonal plants or annual plants whose types and management objectives are determined for plantation businesses, while plantation businesses are businesses that produce plantation goods and/or services. Planters are people who carry out plantation farming within the limits that have been set, namely a maximum of 25 ha per person which is managed independently where the income comes from the agricultural sector (Adib & Daliman, 2021) (Kano & Rahmat, 2019).

The main concept of carrying capacity is the comparison between availability and demand, the availability of which is increasingly limited while the need for it is increasing (Xuecao Li, Gong, & Liang, 2015). Environmental carrying capacity can be interpreted as the ability of an environment/earth to support living things that feel on it both in terms of economy, environment, culture, and demography, int his case the carrying capacity has a maximum limit in supporting the needs of living things (Yosephine, Gunawan, & Kurniawan, 2021). The carrying capacity of food in an area is to describe the ability of the region to produce food to meet the food needs of the population to achieve food self-sufficiency (Faizal & Ateeb, 2018a).

Food needs are calculated based on basic needs which require approximately 2100 calories/day/capita converted into kg/ha/year (Marwanto, Sabiham, Sudadi, & Agus, 2013) and the food needs of living things (Mea, 2005). Potential food supply is calculated based on the availability of land cover and vegetation index (Faizal & Ateeb, 2018a) from natural sources. Meanwhile, actual food supplies are calculated from Fresh Fruit Bunches (FFB) which are converted into food ingredients (Lotze-Campen et al., 2008) and derivative products (Adib & Daliman, 2021) as energy sources (Moniaga, 2011) to support food security.

Spatial information provides an overview of the earth's surface quickly, broadly, accurately, and easily represents conditions above the earth's surface naturally and by the human intervention (Mulyani & Agus, 2017). Land cover is built geomorphology that affects human life and the environment (Mustofa & Bakce, 2019) for human welfare and environmental sustainability, especially on land that has been built (Mustofa & Dewi, 2016).

Method

This study is quantitative research in nature using primary data and secondary data on a ratio data scale. Primary data were obtained through surveys and measurements, interviews, and observations. Secondary data were obtained from a second or third party outside the researchers (Mustofa, 2021). Existing condition data analysis was carried out by spatial analysis (Mustofa & Suwondo) and farm analysis (Xuefen Li, 2021). Spatial analysis was carried out to determine the existing condition of the ecosystem service status in the form of food carrying capacity as an ecosystem function directly and indirectly for human welfare (Pacheco, Gnych, Dermawan, Komarudin, & Okarda, 2017) which was built based on ecoregion maps, and land cover and natural vegetation (Danylo et al., 2021).

The advantages of spatial analysis as a tool for making spatial decisions include location positions, conditions, trends, patterns, and modeling (Kasim, Stöhr, & Herzig, 2021) in integrating location descriptions with characteristics and phenomena, predicting patterns, and modeling (Pires, Martins, Alvim-Ferraz, & Simões, 2011). The tool used in the spatial analysis was ArcMap GIS software 10.5 version from Environmental Systems Research Institute (ESRI) in the calculation of ecosystem services. The higher the availability of food in the plantation as an indicator that the better the ecosystem services for the sustainability of the existence of the plantation.

The next analysis was farm analysis used to calculate the income of smallholder oil palm farmers in Riau Province. Farming income was calculated for a certain period from the sale of FFB, in this study the period used was a year (Katsura et al., 2008). Farming income was obtained from the difference between the sales of FFB during a certain period minus the fixed and variable costs. Fixed costs components include plantation development costs from land preparation to the maintenance of unproductive crops for 3 years and equipment usage costs. Meanwhile, the variable costs include the cost of maintenance, fertilization, and the cost of harvesting the results to the sale of FFB. The higher land productivity and income indicate that the better the management of the garden and the level of farmers' welfare (Husodo, Wulandari, Abdoellah, Cahyandito, & Shanida, 2021). Farm analysis was denoted by the simple equation $\Pi = TR-TC$ and $TR = P.Q$

Findings and Discussion

Spatial Analysis

As the area that has the largest oil palm plantation in Indonesia, Riau Province has a total area of 107,932.71 Km^2, consisting of 8,915,016 hectares of land (80.11%) and 1,878,155 Ha of seas/waters

(19.89%). Its existence stretches from the slope of Bukit Barisan to the Malacca Strait, located between 01⁰ 05' 00" South Latitude 02⁰ 25' 00" North Latitude and between 100⁰ 00" 00 East Longitude to 105⁰ 05' 00" East Longitude. Riau's climate has dynamic conditions and changes easily over a certain period which is 10 years or more (Pittock, Cork, & Maynard, 2012). Climate change shows that rainfall with low intensity from June to August, low to the moderate-intensity from January to May, moderate to the high intensity from September to December (Syahza & Hosobuchi, 2021) which can be seen from various aspects as follows:

a. Ecoregion Distribution

one form of land geomorphology in Riau Province consists of three main parts, namely 0-10 meters above sea level, undulating plains, and hilly plains formed by the Bukit Barisan cluster (Gatto, Ogata, & Lytle, 2021). The widest distribution of the ecoregion is peat plains, followed by alluvial plains and folded structural hills that dominate the land area.

Table 1
Distribution of Landscapes in Riau Province

Ecoregion	Width	
	Ha	%
Alluvial Plains	2,055,516	22.84
Fluvio-marine Plains	99,549	1.11
Peatlands	3,644,648	40.50
Urban Plain	6,859	0.08
Coastal Plains with Muddy Beach	322,679	3.59
Coastline	765	0.01
Valley between Hills Structural Folds (synclines)	583,222	6.48
Valley between Hills Structural Fault (anticlines)	17,064	0.19
Folded Structural Mountains	165	0.00
Structural Fault Mountains	127	0.00
Waters	54,722	0.61
Folded Structural Hills	1,578,947	17.54
Structural Fault Hills	635,601	7.06
Coral Island	32	0.00
Total	**8,999,895**	**100.00**

Source: Result of Overlay Map of Riau Province Ecoregion and Administrative Region

Table 2
Land Cover Conditions in Riau Province

Land Cover	Width	
	Ha	%
Water body	104,047	1.16
Airport/Port	725	0.01
Scrub	48,115	0.53
Swamp Scrub	532,502	5.92
Primary Dryland Forest	162,359	1.80
Secondary Dryland Forest	261,435	2.90
Primary Mangrove Forest	4,099	0.05
Secondary Mangrove Forest	161,163	1.79
Primary Swamp Forest	47,154	0.52
Secondary Swamp Forest	902,823	10.03
Plantation Forest	919,722	10.22
Settlement	157,759	1.75
Plantation	3,947,370	43.86
Mining	38,890	0.43
Dryland Farming	152,757	1.70
Mixed Dryland Farming	1.126,146	12.51
Swamp	27,137	0.30
Rice field	141,623	1.57
Fishpond	2,378	0.03
Open Ground	257,733	2.86
Transmigration	3,956	0.04
Total	8.999,895	100.00

The table above shows that in general, every mainland ecoregion can grow oil palm, but not all oil palm farming is carried out, both smallholder plantations and large private and national plantations. The geological structure of Riau Province consists of folds along the Bukit Barisan, which are active faults with the potential for geological natural disasters. Riau Province has a flat topography which is very good for farming activities, especially oil palm (Idayu & Supriyanto, 2014; Salzman, Bennett, Carroll, Goldstein, & Jenkins, 2018).

b. Land Cover

The existing condition of land cover in Riau Province is based on the 2020 land cover map with a scale of 1:250,000 consisting of 21 land cover criteria. The highest land cover is dominated by plantations, agriculture, and forestry. These three criteria indicate that land-based spatial use activities are dominated by plantation, agriculture, and forestry activities followed by other activities (Sembiring, 2017).

Plantation land cover is a plantation farming activity carried out by the community as smallholder plantations that produce oil palm Fresh Fruit Bunches (FFB) and large private and national oil palm plantation farming activities that produce FFB and its derivative industries (Sharma, Baral, Pacheco, & Laumonier, 2017). Plantation activities in the upstream to downstream sectors provide benefits through employment opportunities and a multiplier effect for the surrounding community because they have an impact on the business field (Dislich et al., 2017). High plantation land cover is always considered to reduce the land cover quality index (Simshauser, 2020) and reduce the performance of ecosystem services, on the other hand, oil palm plantation land cover is able to reduce CO_2 (Solecka, Sylla, & Świąder, 2017).

Cover Land cover conditions are also used as an indicator of climate change and to understand the relationship between human activities in contributing to global change (Sumarga & Hein, 2014). Changes in land cover occur when the high demand for land exceeds the availability of land, thus, the balance of land cover exceeds the land capability limit (Gomes et al., 2021). The balance of land cover and use is an indicator of environmental conditions. Environmental conditions can be seen from the capacity of ecosystem services (Xuecao Li et al., 2015) through the carrying capacity of food and water carrying capacity as a tool to evaluate maintaining ecosystem balance (Lotze-Campen et al., 2008). There are two criteria for the actual land cover of smallholder oil palm plantations, namely those who have applied Good Agriculture Practice (GAP) and those who have not implemented GAP. Differences occur in the capacity of biodiversity and land productivity.

c. Food Carrying Capacity

The carrying capacity of food includes the provision of food and other than food. The provision of food consists of direct and indirect food (Suwondo, Darmadi, & Yunus, 2017). Direct food is the provision of food that can be consumed directly, while indirect food is food that is consumed through processing Food supply is influenced by many types of land cover and biodiversity index (Lotze-Campen et al., 2008). The higher the biodiversity index, the higher the land's ability to provide food carrying capacity. The detailed food carrying capacity is presented in Table 3 and Figure 1.

Table 3

Condition of Food Carrying Capacity of Oil Palm Plantations in Riau Province

Ecoregion	Food Carrying Capacity (kg/ha/yr)		
	Supply	**Demand**	**Difference**
Alluvial Plains	60,520,634	22,415,050	38,105,584
Peatlands	53,796,119	31,381,070	22,415,050
Valley between Hills	96,384,714	23,535,802	72,848,911
Fold Mountains	1,120,752	672,450	1,120,752
Fold Hills	2,241,505	1,117,302	2,241,505
Total	**214,063,724**	**79,121,673**	**136,731,803**

The food carrying capacity of oil palm plantations in each ecoregion in Riau Province is entirely in a condition that has not been exceeded or is in surplus. The surplus condition occurs because the availability of food is higher than the need. The agricultural sector of the oil palm plantation subsector has a role as a supplier of food, industrial raw materials, and a source of income for the community, and a contributor to Gross Domestic Product in each regency (Diaz-Chavez et al., 2010). The added value of food products derived from oil palm plantations is proportional to the social and environmental costs (Świąder et al., 2018). Although often considered to reduce the carrying capacity of food, oil palm plantations still have a high level of food production that still exceeds demand.

The capacity to provide food carrying capacity and food needs is highest in the inter-hill valley ecoregion, the process of plant weathering increases land fertility (Syahza & Irianti, 2021). Meanwhile, the lowest food supply and demand is in the fold mountain ecoregion. Conversion of land from forest to gardens does not reduce the ability to provide food but increases the ability to carry food (Syahza & Asmit, 2019) through the extraction of indirect foodstuffs into food. Increasing food availability and production capacity is done through increasing productivity and expanding the area (Hamdan et al., 2000).

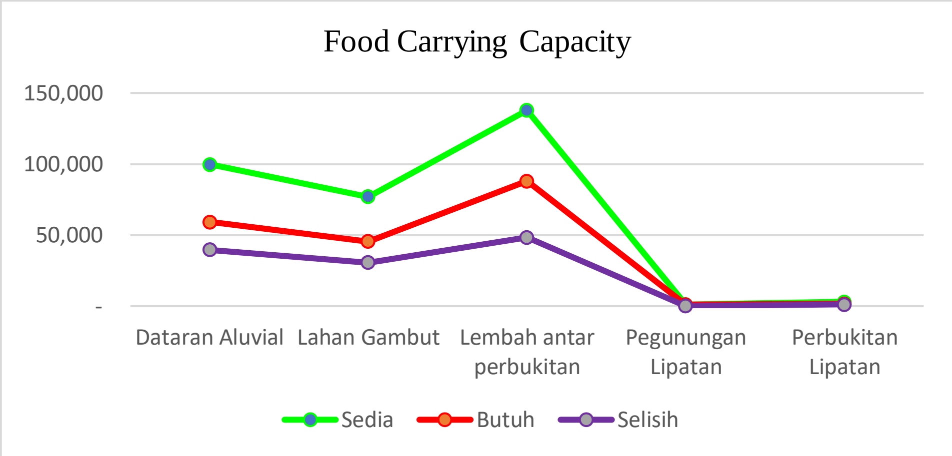

Figure 1: Condition of Food Carrying Capacity of Oil Palm Plantations in Riau Province

Farm Analysis

The existing condition of oil palm plantations spread across Riau Province is 4,170,358 ha and 3,374,996 ha or 81% are smallholder oil palm plantations. Oil palm plantations are conversion of forest land or other crops (Simshauser, 2020) due to limited land availability. The limitations of optimal land availability (Syahza, Bakce, Irianti, Asmit, & Nasrul, 2021; Syahza, Irianti, & Nasrul, 2020).

Farmers do farming on three land typologies, namely mineral land of 60.77% peat land 36.54% and transition land of 60.77%, peatland 36.54%, and transition land of 2.69% (Syahza, 2016) the initial land condition is shrubs and land that has failed to be cultivated occurs natural succession to become forest where various types of plants and animals breed (Syahza & Hosobuchi, 2021). Sources of seeds used by farmers are certified superior seeds of 7% and the rest are not superior (Syahza, Suwondo, Nasrul, & Mustofa, 2020). Therefore, the return on capital is slow. The pattern of oil palm cultivation by smallholders has implemented GAP and most have not. Thus, the production of fresh fruit bunches (FFB) (Syahza, 2019) has not yet achieved optimal results. Farmers who have not implemented GAP crop conditions are very vulnerable to pests, diseases, and climate influences that affect productivity.

Land productivity is determined by three factors, namely land, capital, and technology (Dadi, 2021). The lowest productivity of smallholder oil palm plantations in the study area is 499 kg/ha/month above the lowest productivity in Indonesia of 417 kg/ha/month or equivalent to 5 tons/ha/year. Large plantations in fertilizing apply the 6T rules (right type, right dose, right time, right method, right place, and right tool). The application of the 6T rule is needed to achieve the effectiveness and efficiency of fertilization. The realization of the type of fertilizer and the timing of fertilization as well as the placement of fertilizer have been following the PPKS recommendations (Vaissière, Quétier, Calvet, Levrel, & Wunder, 2020). The high production of oil palm is influenced by fertilization and innovation and technology (Wijaya & Susilo, 2013). Smallholder oil palm farmers in fertilizing are not based on recommendations but the availability of resources and are carried out sporadically (Hamdan et al., 2000).

The results of farm analysis show that the income of oil palm farmers is better than before becoming oil palm farmers, although the lowest income of smallholder oil palm farmers in the study area is IDR 154,894/ha/month with FFB production of 499 kg/ha/month. The highest income of smallholder oil palm plantation farmers in the study area is IDR 1,742,953/ha/month with FFB production of 2,014 kg/ha/month. This high productivity is still lower than the productivity of large plantations, which is 2,133 kg/ha/month (BC, 2019; Syahza, 2016) as presented in Table 4.

Table 4
Farm Analysis

Income	Minimal	Maximum	Average
FFB Production (kg)	499	2,014	1,355
Price (IDR/kg)	983	2,235	1,573
FFB Sales	490,438	4,502,129	2,131,036
Cost Component (IDR)			
Harvest Cost	165,000	535,333	313,984
Freight Cost	10	503,500	102,549
Herbicide Cleaning Cost	-	553,333	45,136
Maintenance Fee with Slash	-	166,667	56,806
Dish Maintenance Fee	-	270,833	8,477
Leaf Disposal Fee	18,750	168,750	64,613
Plant Depreciation Cost	143,450	165,760	205,746
Garden Maintenance Fee	8,333	50,000	32,019
Fertilization Cost	-	345,000	180,953
Total Cost (HPP)	**335,543**	**2,759,177**	**1,010,284**
HPP FFB (IDR.)	*673*	*1,370*	*746*
Net Income (IDR/month)	**154,894**	**1,742,953**	**1,120,752**

Source: Analysis Results, 2021

Average income is calculated from the sum of all farmers' income in the study area divided by the number of farmers or respondents. The average income is IDR 1,120,752/ha/month with an average production of 1,355 kg/ha/month. In general, the average income of smallholder oil palm plantation farmers in the study area is still far below the productivity of the Nucleus-Plasma scheme and large plantations but is still the highest in Indonesia at 417 kg/ha/month or equivalent to 5 tons/ha/year (BC, 2019).

Conclusion

The results of the spatial analysis show that the carrying capacity of food and water carrying capacity of smallholder oil palm plantations in Riau Province is in a condition that has not been exceeded or is in surplus (good). Meanwhile, the results of farm analysis indicate that land productivity and income are the highest in Indonesia. therefore, smallholder oil palm plantations in Riau Province are the best in Indonesia and have fulfilled the carrying capacity of the environment based on ecosystem services as one of the indicators of sustainability.

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