Carrying capacity trend and projection analysis for Sumatra Selatan agricultural land in 2030

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Abstract. This research is conducted to determine and analyze carrying capacity of agricultural land of Sumatra Selatan in 2015 as well as to project it in 2030. The analysis is also carried out to describe the Optimum Population Number and Land Requirement per Hectare of each regency and municipality in 2030. The research method applied using quantitatively descriptive method in which the data is collected from secondary source such as Agricultural Ministry and Central Statistics Agency publication and supported by literature study. The result shows that Sumatra Selatan has high carrying capacity (τ > 1) in 2015 and 2030. It means that the province is capable of food self-sufficiency since the province is underpopulated. The projection indicates that there is decline of carrying capacity in 2030 occurring across the province. For example, Ogan Komering Ulu (OKU) Regency which previously has high carrying capacity, is predicted to have experience low carrying capacity.

1. Introduction
Recently, the population growth causes changes in the need to utilize natural resources. Significant population increase has increased pressure of land resources utilization by over exploitation of existing natural resources or land conversion [1]. This phenomenon can result a negative impact towards the sustainability of the ecosystem, including environmental degradation and decrease of productivity. This negative impact can be tackled by considering environmental policies and using more efficient technology in processing natural resources regarding to the population need.

One way to use natural resources wisely is to pay attention to the carrying capacity of the region. Therefore, the carrying capacity of the environment is very important to be known, studied, and implemented as a reference for allocating the natural resources and spatial planning of the environment. Mostly, land in Sumatra Selatan Province is used as agricultural land because the province is renowned for its fertile soils. The province has long been depending on agricultural sector for its economic growth and development [2]. Thus, it is important to know and study the carrying capacity of the environment for agricultural land in Sumatra Selatan Province.

The carrying capacity of agricultural land areas is the ability of agricultural land to be able to produce rice that is used to meet population food needs so that life can remain prosperous or to achieve food self-sufficiency [3]. The environmental carrying capacity of the agricultural land in Sumatra Selatan can be projected to find out and become the basis for development planning and establishing agricultural
policies in the region. Therefore, this paper is made to determine and analyze the environmental carrying capacity of agricultural land in 2015 and project it in 2030.

2. Materials and Method
The research uses descriptive method through geographical approach. The method enables qualitative and quantitative analysis to explain the problem regarding to the objective of the study. The data analysis explains the population projection, carrying capacity, optimum population, and land need to describe the existing carrying capacity, to quantify the optimum population, and to determine the land need required for the projected population.

2.1. Location
The studied area of the research is the Province of Sumatra Selatan. Sumatra Selatan comprises of 13 regencies and 4 municipalities as shown on Figure 1 Sumatra Selatan located in southern part of Sumatra Island. Its area consists of various morphology such as mountain ranges, basins, and coastal plain. Some area offers favorable features and has the required potential for agricultural activity and improvement of food productivity. Sumatra Selatan was chosen for the research area because it has the National Food Barns Program. This program is inseparable from the characteristics of the province of Sumatra Selatan which has various land resource potential [4]. Sumatra Selatan also has significant population growth.

2.2. Data
The secondary data used in the research is in form of statistics. The statistics were taken from the Indonesia’s Agricultural Ministry and Sumatra Selatan in Figures 2012-2017 published by the Indonesia’s Central Bureau of Statistics (BPS). The data comprises of population data, crop yields data, and crop yields area data.
2.3. Research Design
The conducted research is designed as shown in the flowchart on Figure 2. The first step is determining population projection of each regency and municipality in 2030. The second step is determining carrying capacity which is subsequently continued by determining the optimum population number and agricultural land requirement.

2.3.1 Population Projection. Population projection plays important role on planning about future development policies since the provided data can be useful for short term event such as Population Census or Inter-Census Population Survey [5]. Population projection itself means the total population predicted at a certain time in the future by calculating the recent population with expected population growth. Population projection in this research measured by exponential growth model as in the research about applied exponential growth model for population projection through a birth and death diffusion growth rate processes [6]. The model using following mathematical function
\[
\frac{dP(t)}{d(t)} = rP(t) 
\]

(1)

\[
P(t) = P(o)e^{rt} 
\]

(2)

in which \(P(t)\) represents the projected population, where \(P(o)\) is the initial population or recent population. \(e\) is natural number, \(r\) is the population growth rate, and \(t\) is time.

2.3.2 Carrying Capacity. Carrying capacity, related to agricultural land, is the ability of materials or resources in a unit of land to support and meet human needs, especially food [7]. Carrying capacity is an important aspect for spatial planning but the high demand due to population growth has conflicted with the carrying capacity of a certain area at some point. The analysis of carrying capacity will be useful to know whether there is needed land for sustain food productivity. Carrying capacity in the research is specified to agricultural carrying capacity. It is measured by following equation

\[
\tau = \frac{X}{K} 
\]

(3)

in which \(\tau\) represents the carrying capacity itself. \(\tau\) value has range between 0 and 1. When the \(\tau\) value less than 1, it means that a certain area is underpopulated. Otherwise, an area would be said overpopulated when the \(\tau\) value more than 1 [8]. \(X\) is for crop yields area per capita and \(K\) symbolizes agricultural land area for food self-sufficiency. \(X\) and \(K\) value are determined by these following formulas.

\[
X = \frac{\text{Crop yields area (ha)}}{\text{Total population}} 
\]

(4)

\[
K = \frac{\text{Minimum physical need}}{\text{Crop yields area per year (ha/year)}} 
\]

(5)

Minimum physical need is a value to express the minimum food need should be fulfilled for a person in a certain area. A region is said to be self-sufficient on food if it can fulfill the minimum physical need of each person as much as 1600 calories/capita/day (average value), which equals to 265 kilograms rice/capita/year [9].

2.3.3 Optimum Population. A certain area is said to have an optimum population if the \(\tau\) value is 1. It means that the resources, especially foods can support the existing population in a balanced way. It is supposed to determine how many populations can be supported optimally in a certain region with a certain agricultural land.

2.3.4 Land Requirement. Land requirement represents the minimum agricultural land in hectare needed to produce sufficient crop yields for the existing and projected population. The final analysis is whether the recent carrying capacity of each regency and municipality in Sumatra Selatan reflects the availability of agricultural land in the province. Subsequently, it aims to justify which regencies or municipalities will overcome food shortages if the projected population cannot be supported by the existing agricultural productivity. Agricultural land need can be determined through the following equation

\[
\text{Agricultural Land Requirement (hectare)} = \frac{R \times Pt \times Pr (\text{kg/ha})}{0.632} 
\]

(6)
in which Pt stands for population projection while Pr represents average rice production in a certain agricultural land. R is the rice need per capita which is predetermined as much as 154.1 kg per capita, following the average rice need in Indonesia [9].

3. Result and Discussion

3.1. Carrying Capacity in 2015

Table 1 shows that the carrying capacity of Sumatra Selatan in 2015 reaches 3.42 which belongs to high carrying capacity. It refers to the assumption in which τ < 1 means the region is not able to carry out food self-sufficiency or related to overpopulation, τ > 1 means the region is able food self-sufficiency or the area is less populated compared to its natural resources, and τ = 1 means that the region has optimal environmental carrying capacity [3]. The carrying capacity class of each regency and municipality is expressed on Table 2. There are 12 both regencies and municipalities have high carrying capacity namely Ogan Komering Ulu (OKU), Ogan Komering Ilir (OKI), Muara Enim, Lahat, Musi Rawas, Musi Banyuasin, Banyuasin, Ogan Komering Ulu Selatan (OKUS), Ogan Komering Ulu Timur (OKUT), Ogan Ilir, Empat Lawang, and Pagaralam City. The remaining 5 regencies / municipalities are included in the low-class carrying capacity, namely Penukal Abab Lematang Ilir (PALI), Musi Rawas Utara, Palembang Municipality, Prabumulih Municipality, and Lubuk Linggau Municipality. The lowest carrying capacity was in Prabumulih Municipality with a value of 0.06 followed by Palembang Municipality of 0.11 and Musi Rawas Utara Regency which was equal to 0.62, while the highest carrying capacity value is Banyuasin Regency which reached 9.89 and Ogan Komering Ulu Timur Regency at 8.64 and followed by Ogan Komering Ilir Regency at 5.14. Banyuasin Regency has the highest carrying capacity which valued for 9.89. It is due to the presence of wetland including lowland swamp, lowland peatlands, and tidal lowlands which covers approximately 80 per cent area of the regency. Banyuasin Regency has contributed to 26 per cent of rice production in Sumatra Selatan Province and has great prospects for becoming a center for agricultural and plantation production [10].

Prabumulih Municipality has the lowest carrying capacity value because the area has been developed into a growing urban area. In contrast, even though Prabumulih Municipality is passed by several rivers such as Lematang River, Rambang River and Kelekar River, the river conditions are quite alarming, especially during the dry season. Surface water level and water discharge have decreased dramatically making it less potential to be utilized for agricultural activities [11].

In 2015, most regencies and municipalities have high carrying capacity as depicted on Figure 4. It can be explained that the agricultural land to produce foods and support the most population exists and adequate. By the time the province develops, there will be increase of population and population need. It will cause additional stress on existing agricultural land which competes with the land need for settlements, buildings, and industries. Thus, it needs to project population hence it will useful to predict whether the carrying capacity grows or declines. Moreover, the population projection is also helpful to estimate the need of agricultural land to support the future population.

3.2. Carrying Capacity in 2030

Projections are made to estimate the value of carrying capacity in 2030. Projections are only carried out for the population while for the parameters of crop yield area, minimum physical need value, and average rice production are assumed to continue to use the base year of 2015.

The crop yield area is assumed to remain constant. Nevertheless, trend of paddy fields in Sumatra Selatan Province in 1995-2003 has decreased by an average proportion of around 3.65 per cent based on data from Indonesia Central Bureau of Statistics. On the other hand, data from the Food Crops and Horticulture Office (DPTH) and the Regional Office of the National Land Agency (Kanwil BPN) show the opposite results where paddy fields in Sumatra Selatan Province are increasing with an average
growth rate of 1.53 per cent per year and 3.45 per cent per year. Data aggregation from the three agencies concluded that paddy fields in Sumatra Selatan Province tended to increase every year [12].

The projected carrying capacity of Sumatra Selatan is 2.77 as shown on Table 1, which belongs to high carrying capacity. The projected value has meaning that Sumatra Selatan Province is still capable of food self-sufficiency by 2030. The trend of carrying capacity in 2030 has similar pattern with the 2015 one as expressed on Figure 3. However, there was a change in OKU Regency, which is formerly has high carrying capacity of 1.02 becomes low carrying capacity with value of 0.82 since the population increased by 23.74 per cent from 2015. The population in OKU Regency has increased following the improvement and development progress undertaken by the government both in education, family planning, and information access. The triggered factors of decline in land carrying capacity are influenced by population growth rate, incoming migration, and urban area condition are considered as the dominant factors which are possible to increase the population rate [13]. The regency is then divided into 3 regencies, namely Ogan Komering Ulu (OKU), Ogan Komering Ulu Timur (OKUT), and Ogan Komering Ulu Selatan (OKUS), where up to 25.02 per cent of population in the three regencies residing in OKU. Increasing population, decreasing land area along with the percentage of farmers and the area of land needed to live properly has caused decrease in environmental carrying capacity for agricultural land [14]. Conversely, the regency has yet to have a technical irrigation network for food crops and annual crops hence less potential for development exists [15].

Table 1. Carrying Capacity of Sumatra Selatan by Regency and Municipality

| Regency/Municipality | Population (2015) | CC (2015) | Land Need (2015) | Population (2030) | CC (2030) | Land Need (2030) | Optimum Population (2030) |
|----------------------|------------------|----------|-----------------|------------------|----------|-----------------|---------------------------|
| OKU                  | 349787           | 1.02     | 8211            | 432821           | 0.82     | 10160           | 355909                    |
| OKI                  | 787513           | 5.14     | 17044           | 982583           | 4.12     | 21266           | 4049328                   |
| Musa Enim            | 600398           | 1.85     | 11737           | 763116           | 1.45     | 14918           | 1108325                   |
| Lahat                | 393235           | 2.64     | 7914            | 465465           | 2.23     | 9368            | 1036224                   |
| Musi Rawas           | 384333           | 4.68     | 6989            | 474675           | 3.79     | 8631            | 1797127                   |
| Musi Banyuasin       | 611506           | 2.65     | 12583           | 776311           | 2.09     | 15974           | 1621506                   |
| Banyuasin            | 811501           | 9.89     | 16262           | 1009655          | 7.95     | 20233           | 8025465                   |
| OKUS                 | 344074           | 3.82     | 6828            | 425008           | 3.09     | 8434            | 1315064                   |
| OKUT                 | 649394           | 8.64     | 10487           | 772705           | 7.26     | 12478           | 5609339                   |
| Ogan Ilir            | 409171           | 2.79     | 10512           | 500188           | 2.28     | 12850           | 1141605                   |
| Empat Lawang         | 238118           | 3.37     | 5413            | 293064           | 2.74     | 6662            | 802951                    |
| PALI                 | 179529           | 0.94     | 5982            | 225727           | 0.74     | 7521            | 167982                    |
| Musi Rawas Utara     | 182828           | 0.62     | 5363            | 225866           | 0.50     | 6626            | 113496                    |
| Palembang Municipality| 1580517         | 0.11     | 34536           | 1959344          | 0.09     | 42814           | 168157                    |
| Prabumulih Municipality| 177078         | 0.06     | 6184            | 222478           | 0.05     | 7769            | 10533                     |
| Pagar Alam Municipality| 133862        | 2.09     | 2633            | 158154           | 1.77     | 3111            | 279325                    |
| Lubuk Linggau        | 219471           | 0.75     | 4649            | 275756           | 0.59     | 5841            | 163571                    |
| Sumatra Selatan      | 8052315          | 3.42     | 161131          | 9962913          | 2.77     | 199363          | 2756399                   |

Table 2. Classification of the Carrying Capacity
Overall, there are 11 regencies included in the high carrying capacity class and there are 6 regencies and municipalities included in the low carrying capacity class as depicted on Figure 5. The average carrying capacity in 2030 experienced a downward trend of 0.56 from 2015. Declining Land Support Capacity can be resolved in various ways including: 1) Land conversion, or change the type of land use towards a business that is more profitable but adapted to its area; 2) Land intensification, i.e. using new technologies in farming; and 3) land conservation or efforts to prevent [16].

![Figure 3](image-url)  
**Figure 3.** Comparison Trend of the Carrying Capacity in 2015 and 2030
3.3. The Optimal Population

The Optimal Population that can be accommodated in 2030 is 27,563,991 people and the projected population is 9,962,913 people on a provincial scale. Meanwhile, the optimal population varies on regency scale as depicted on Figure 6. The various optimal population of each regency and municipality is strongly related to the existing population and environmental carrying capacity in each regency and municipality. From the Table 1 below can be seen that the regions whose population projections exceed the optimum population are included in the low carrying capacity class. For these areas, the addition of crop yield area and efforts to increase the rice production are needed to support the population.
3.4. Land Need
Figure 7 shows the projected agricultural land need compared with the 2015 one. From the land need calculations, the needs of agricultural land in Sumatra Selatan by 2030 can be fulfilled from the existing production land area. The land need conditions in each regency and municipality are quite varied. Insufficient agricultural land occurs in urban areas or areas that possess a lot of built-up lands. High population growth, economic growth, and speculation, real estate, infrastructure development is push up urban sprawl. Urban sprawl directly and indirectly causes decrease in agricultural area as they are diverted to other use [17].

Figure 6. Comparison of Total Population Projection and Total Optimal Population in 2030

Figure 7. Comparison of Land Need in 2015 and 2030
4. Conclusion

Sumatra Selatan Province has high fertility soil that make this province highly potential for agriculture activity. This province has the National Food Barns Program. Besides, this province has high population growth every year that affect the carrying capacity. In 2015 Sumatra Selatan carrying capacity reaches 3.42 which classified to high carrying capacity. The lowest carrying capacity was in Prabumulih Municipality with a value of 0.06 and the highest carrying capacity was Banyuasin Regency which reached 9.89. Prabumulih Municipality has the lowest carrying capacity value because the area has been developed into a growing urban area while Banyuasin has highest carrying capacity due to the presence of wetland including lowland swamp, lowland peatlands, and tidal lowlands which covers approximately 80 per cent area of the regency. In 2030 projected carrying capacity of Sumatera Selatan is 2.77 which experienced a downward trend of 0.56 from 2015 and still classified into high carrying capacity at province scale. More specifically there are 11 regencies which included into high class carrying capacity and 6 regencies and municipalities into low class carrying capacity. Then for the optimal population that can be accommodated in 2030 is 27,563,991 and the projected population is 9,962,913 on a provincial scale which indicated that this province still can accommodate the projected population. The needs of agricultural land also still can be fulfilled from the existing production land area.

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