Analysis of the Carrying City of Agricultural Land for Rice Crop in the Watershed of Beh, Nusa Tenggara Barat, Indonesia

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DOI: 10.22178/pos.105-16

LCC Subject Category: S1-(972)

Received 22.05.2024
Accepted 27.06.2024
Published online 30.06.2024

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Abstract. This research aims to analyze the carrying capacity of agricultural land for food self-sufficiency in the Beh Watershed, Sumbawa, West Nusa Tenggara, Indonesia. The research method used is a survey method and secondary data collection. The survey was carried out by interviewing respondents and key informants and direct observation of field conditions. The combined theory of Odum, Christeiler, Ebenezer Howard, and Issard is the method used to calculate the carrying capacity of agricultural land. Land's carrying capacity is, in principle, determined by the land's ability to produce food to meet food needs. To calculate the minimum physical needs, we use the per capita rice equivalent consumption level of 265 kg per person per year. The results showed that the minimum land area for rice self-sufficiency in the Beh watershed is 0.0754 ha per capita/year in Lunyuk District. In other districts, the minimum requirement for rice food self-sufficiency is 0.085 are/capita/year. The minimum requirement for rice self-sufficiency varies depending on each district's land productivity and harvest area. The average rice productivity in Beh watershed's seven districts is 3.28 tons/ha. The level of carrying capacity of agricultural land in the Beh watershed shows that there are three classes of carrying capacity in 7 districts, i.e., capable of food self-sufficiency (Lunyuk, Moyohulu, Ropang, Lenangguar), capable of food self-sufficiency but not yet able to provide a proper life (Orong Telu and Lantung districts), and not yet able to be self-sufficient in food (Batulanteh).

Keywords: Beh Watershed; Land Carrying Capacity; Minimum Land Requirement; Food Self-Sufficiency.

INTRODUCTION

Rapid population growth will cause various problems, significantly increasing food, clothing, and shelter needs; this has implications for the increasingly widespread conversion of forests into non-forest activities, including agriculture. Agricultural activities that do not consider the carrying capacity of the land and soil conservation practices have contributed to an increase in the area of critical land in Indonesia; in 2020, the essential area of land in Indonesia will reach 14 million hectares, according to [1].

Food security in West Nusa Tenggara (NTB) Province is excellent. It must continue to be maintained, considering environmental degradation during the same period in NTB Province, especially in land resources. This condition is indicated by the relatively broad distribution of critical land in NTB Province. In 2022, the essential distribution of land (categorized as necessary and very crucial) in NTB Province will be recorded at 490,324 ha or 25% of the land area of NTB Province [2].

Environmental damage in the Beh watershed will significantly disrupt agricultural production and local and regional food stocks, especially in the Sumbawa and West Sumbawa Regencies. Author [3] stated that apart from having an impact on reducing land productivity, watershed degradation will also threaten optimal water availability for food crop farming.

The real threat to food security and the emergence of food insecurity in NTB Province in the future is the decline in agricultural land productivity and shrinking agrarian land area due to massive environmental damage and land conversion. NTB states that in 2020, deforestation in NTB Province will reach 60% of the total forest area of 1,071,722 ha, while land degradation in NTB Province from year to year continues to increase, namely 177,576 ha.

Threats to food security also occur in the Beh watershed on Sumbawa Island, precisely in the Sumbawa and West Sumbawa Regencies. The Beh watershed, the largest in West Nusa Tenggara with an area of 201,534 ha, falls into the classification that requires restoration due to its carrying capacity. Restoring the carrying capacity of watersheds ensures that land conditions, water quality, quantity and continuity, socio-economics, investment in water structures, and regional space utilization function as they should, according to [4].

Decreased productivity and the threat of crop failure due to lack of water supply will disrupt food security at local and regional levels. The need for agricultural products, especially food, will continue to increase due to the increase in population author [3]. Meanwhile, increasingly extensive and uncontrolled degradation of productive agricultural land can cause a decrease in food production (supply) author [5] so that it cannot keep up with food demand. Food production (supply) needs to be increased to balance food demand. Agricultural intensification and extensification are two strategies to increase agricultural production [6, 7]. This research aims to analyze the carrying capacity of agricultural land for rice food self-sufficiency in the Beh Watershed, Sumbawa, Indonesia. Farmers and farming planners can use information on the carrying capacity of this land to increase food production and meet food demand in that location.

METHODS

Our team researched the Beh watershed on Sumbawa Island in Nusa Tenggara Province. The Beh watershed covers ten districts: Batulanteh, Brang Ene, Brang Rea, Jereweh, Lantung, Lenangguar, and Lunyuk districts, Moyohulu, Orong Telu, and Ropang. Administratively, the Beh watershed is in Sumbawa Regency and West Sumbawa Regency. The Beh watershed area includes seven districts in the Beh watershed, namely Batulanteh, Brang Ene, Brang Rea, Jereweh, Lantung, Lenangguar and Lunyuk districts, Moyohulu, Orong Telu and Ropang (Figure 1).

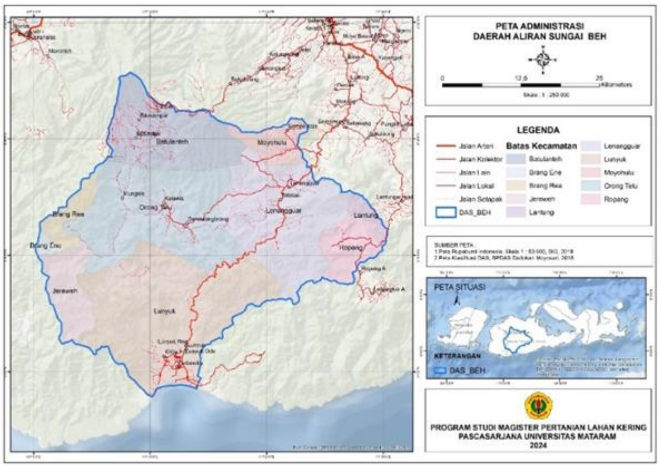


Figure 1 – Map of administrative Beh Watershed

The study was conducted only in districts in Sumbawa Regency, namely Batulanteh, Lantung, Lenangguar and Lunyuk, Moyohulu, Orong Telu, and Ropang districts, this is because the three districts, namely Brang Ene, Brang Rea, Jereweh, do not have agricultural land.

The study used several research methods, including survey methods by authors [8–12] and secondary data collection methods by authors [8, 11, 13]. The survey used two data collection methods: direct observation in the field and face-to-face interviews with respondents and critical informants using previously prepared questionnaires. We then supplement this data with information from available sources. Apart from that, coordinate points were also measured using GPS to make it easier to map the location of rice fields in the Beh watershed.

Analysis of the carrying capacity of agricultural land in the Beh Watershed is carried out in the following stages:

Calculation of Minimum Physical Requirements. The calculation of minimum physical needs (KFM) is based on the calorie needs per person per day, namely, 2600 per person per day or the equivalent of 265 kilograms of rice per person per year authors [14]. Understanding calories as a basis for calculations is based on the consideration that a person's healthy life requires a certain number of calories, which come from food ingredients in the form of protein, fat, and carbohydrates, plus minerals and vitamins. On this calorie basis, all food ingredients are included. Another consideration is that agricultural products are primarily carbohydrates, such as rice, the largest source of calories in food composition authors [15, 16]. The minimum essential physical needs value indicates that a person can generally live and work to meet their needs.

The area of food cropland required per capita for food self-sufficiency. The area of food cropland required per capita for food self-sufficiency, "K" (ha/person), is an essential component in calculating agricultural land's carrying capacity. The K value is calculated by dividing the minimum physical needs (KFM) value by the annual production of food crops, previously in tonnes, converted to calories, and then converted again to kg of rice for each commodity. This value will be compared with the production of food crops from each region converted earlier so that the unit becomes kilograms of rice/person/year. The smaller the K value, the better the agricultural land's carrying capacity level. The value of the area of food cropland required per capita for food self-sufficiency changes constantly over time and space because KFM and the land's ability to produce food crops influence it. The smaller the K value, the greater the carrying capacity of agricultural land. For this reason, in areas with a high K value, efforts are needed to reduce this number by increasing food crop productivity or expanding the area of food crops.

Available Food Crop Harvest Area per Capita. Another important component in calculating the carrying capacity of agricultural land is the harvested area of food crops available per capita (X). This X value is obtained from the harvested area of food crops divided by the number of residents. The value of the harvested area of this food crop is constantly changing, both between regions and over time. The value of X is the opposite of the value of K because the greater the value of food crop agricultural land required for food self-sufficiency, the more critical it is in determining the carrying capacity of agricultural land. You can calculate the area of food cropland required per capita by dividing the Minimum Physical Requirements (KFM) by the annual productivity of food crops. Food crop production data from BPS is converted back into kg of rice. The smaller the K value produced, the greater the land's carrying capacity. After getting the K value, the next step is to determine the harvest area of food crops available per capita "X." The available food crop harvest area per capita "X" is an essential component in determining the carrying capacity of agricultural land. We obtain this X value by calculating the food crop harvest area (ha) and dividing it by the number of residents (people) in the farming area. After obtaining the "K" and "X" values, the next step is to determine the level of carrying capacity of agricultural land and calculate the carrying capacity of agricultural land using a combined concept of theory authors [15, 17]. The formula used is:

$$\alpha = \frac{X}{k} \quad (1)$$

where α = Agricultural land capacity; X = land available for crop cultivation; k = land required for food self-sufficiency.

$$\mathrm{X} = \frac{\text{Harvest area}}{\text{Population}} \quad (2)$$

$$\mathrm{k} = \frac{\text{Minimum physical consumption}}{\text{Average production of rice per ha}} \quad (3)$$

$$\alpha = \frac{\text{Harvest x Production per ha per year}}{\text{Population x KFM}}. \quad (4)$$

RESULTS AND DISCUSSION

*Description of research location***.** We conducted this research in the Beh Watershed, Sumbawa Regency, West Nusa Tenggara Province. A more detailed description of this watershed is presented as follows. Based on the results of identifying the characteristics of the Beh watershed [2], the area of the Beh watershed is 151,270 ha. Geographically, the Beh watershed area is located at 117°7'20.64"– 117°11'54.6" East Longitude to 8°35'21.48"–8°38'3.12" South Latitude. Administratively, the Beh watershed is in Sumbawa Regency and West Sumbawa Regency.

Population. Based on [18], the population in the Beh watershed is 85,151 people and is spread across seven districts, as shown in Table 1. This population needs food to maintain their lives, especially a minimum amount of food. The average population density is 32 people/km^2. The area and population density of the Beh watershed according to district in 2023 are presented in Table 1.

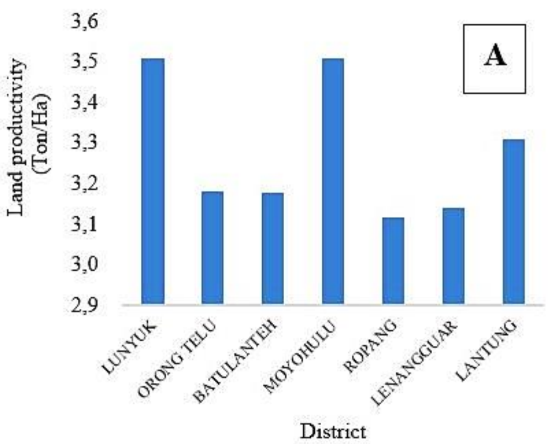
Table 1 – Size and population density in Beh Watershed by District, 2023 [18]

No	District	Size (km^2)	Population (person)	Density (person/km^2)
1	Lunyuk	513.74	22 939	45
2	Orong Telu	465.97	5 645	12
3	Batulanteh	391.40	12 093	31
4	Moyohulu	311.96	25 648	82
5	Ropang	444.48	6 374	14
6	Lenangguar	504.32	8 265	16
7	Lantung	167.45	4 187	25
Total		2799.32	85 151	32

Land use. Agricultural land is an area cultivated for the cultivation of food and horticultural crops. Agricultural land can generally be divided into dry land and rice fields [19]. Paddy fields are agricultural land plotted and bounded by embankment (galanga) channels to hold/channel water, which is usually planted with lowland rice regardless of where it was obtained or the status of the land. Agricultural land in the Beh watershed area is divided into fields/moors with secondary crops covering an area of 9,507 ha (58.66%), rice fields with rice interspersed with other crops covering an area of 5,020 ha (30.97 ha), rice fields with continuous rice covering an area of 4 ha (0.02%). The remainder is mixed plantations covering an area of 1,481 ha (9.14 %) and other plantations covering an area of 195 ha (1.20%). Overall, agricultural land in the Beh watershed area is 16,207 ha or 10.71% of the total area of the Beh watershed area.

Productivity and food production. Land productivity is the amount of output in 1 ha of land. Based on [18] figures, rice land productivity is 5.2 t/ha. The harvest area available for rice food crops in the Beh watershed is 15,347, spread across seven districts. The district with the largest harvested area is Moyohulu District, with a harvested area of more than 5 thousand ha, followed by Lunyuk District, with a harvested area of more than 4 thousand ha.

Furthermore, there are three districts with a harvest area of more than one thousand ha: Lenangguar District, Ropang District, and Orong Telu District. The districts with the narrowest harvest areas are Batulanteh and Lantung Districts. Both have harvested areas under one thousand ha.



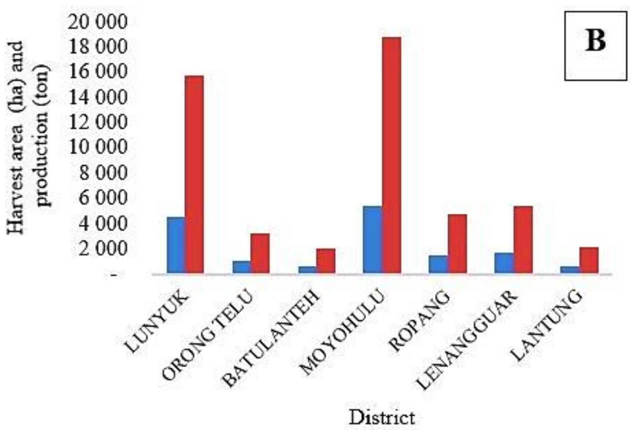


Figure 2 (A) – Productivity of rice, (B) Harvest area and production of rice by district in Beh Watershed

Food production, especially rice in milled dry unhulled grain (GKG), is obtained from [18]. Food production in the form of milled dry grain (GKG) in the Beh Watershed is shown in column 4, Table 2. The total reached 82,804 tons. Then, this amount of GKG was converted into rice with a conversion factor of 62.74% by the authors [20]. The results are shown in column 6, Table 2, showing the food availability in each district in the Beh watershed. When this amount of food equals the minimum amount needed in that district location, it is said that the district has achieved food self-sufficiency. In this research, food is defined as rice. The consideration is that the people in this location must consume rice as their food, and they stated that they had not eaten if they had not eaten rice. Based on production and harvested area, productivity can be calculated by dividing the production amount by the harvested area authors [21]. The highest rice production was produced in the Moyohulu district at 18,786 t/year (36.2%) t/year, followed by the Lunyuk district at 15.730%. Lantung District produced the most minor rice production at 2,079 t/year (4%).

Table 2 – Land Production by District [18]

No	District	Harvest area (ha)	Paddy production (t)	Rice production hulled (t/ha)	Rice production (t/year)	%
1	Lunyuk	4.481	25.071	3,51	15.730	30,3
2	Orong Telu	1.006	5.099	3,18	3.199	6,2
3	Batulanteh	640	3.242	3,18	2.034	3,9
4	Moyohulu	5.356	29.943	3,51	18.786	36,2
5	Ropang	1.516	7.528	3,12	4.723	9,1
6	Lenangguar	1.720	8.608	3,14	5.401	10,4
7	Lantung	628	3.313	3,31	2.079	4,0
			82.804		51.951	

The regression analysis results between harvested area and rice production (GKG) in the Beh watershed show a strong relationship, as indicated by the R2 value of 0.9988. The relationship formula is expressed as y=5.5198x, which shows that every 1,000 ha increase in the harvested area will increase rice production (GKG/year) by 5.5198 tons. The regression relationship is presented in Figure 3.

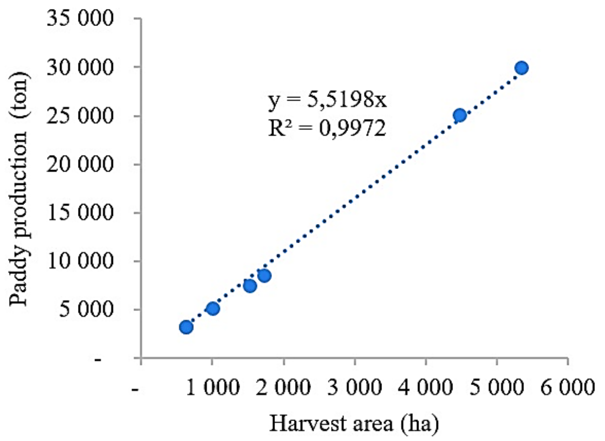


Figure 3 – Relationship between harvested area and rice production in the Beh Watershed

Population food needs. The Beh watershed's food availability and needs calculations show that the highest food availability is in Moyohulu District at 18,786,238 kg/year, with food needs of 6,771,072 kg/year; this means that Moyohulu District has the highest carrying capacity of 2,764 times yearly. To calculate the food needs of each Beh watershed district, researchers use 265 kilograms of rice per person per year [17]. The calculation is done by multiplying the population by the minimum food requirements [17]; this shows that the greater the population, the greater the food needs. The results of calculating food availability and needs are shown in Table 3.

Achieving Food Self-Sufficiency and Land Carrying Capacity. Farmers' ability to achieve food self-sufficiency depends on the available land area. The larger the area of land for food, the greater the level of food self-sufficiency in the region; in other words, the region has a large carrying capacity to achieve food self-sufficiency authors [22]. Farmers can achieve food self-sufficiency by expanding agricultural land for food, a process known as extensification [6, 7]. Farmers can conduct this business by converting non-agricultural land, such as forests, into food farming land. However, expanding agricultural land for food is increasingly difficult nowadays, so other strategies are needed to provide more food without increasing the area of agricultural land. This second strategy, known as intensification, is defined as adding agricultural inputs to the same land area by authors [6, 23–25].

Table 3 – The land capacity to support food self-sufficiency in Beh Watershed

No	District	Food availability (kg/year)	Population (person)	Food nedd (kg/year)	Land capacity (times)
1	Lunyuk	15 729 545	22 939	6 055 896	2 588
2	Orong Telu	3 199 113	5 645	1 490 280	2 139
3	Batulanteh	2 034 031	12 093	3 192 552	635
4	Moyohulu	18 786 238	25 648	6 771 072	2 764
5	Ropang	4 723 067	6 374	1 682 736	2 796
6	Lenangguar	5 400 659	8 265	2 181 960	2 466
7	Lantung	2 078 576	4 187	1 105 368	1 873
DAS Beh		51 951 230	85 151	22 479 864	2 438

The intensification strategy includes improving the quality of inputs obtained through agricultural innovation by authors [6, 23–25]. Apart from food self-sufficiency efforts, food can be met through food purchases or food access activities by authors [26–28]. Regions that lack food from their production, such as Batulanteh District, can fulfil their food by purchasing it. Of course, to buy this, you need income. This income can be obtained from other businesses, apart from food crop businesses, using the resources owned by the region.

Has the Beh River Basin achieved food self-sufficiency? The answer to this question is shown in Table 3. The seven districts in the Beh watershed have achieved food self-sufficiency (I guessed this). Food self-sufficiency achieved has exceeded 100%. Next, analysts calculate the land's carrying capacity for food self-sufficiency by comparing the minimum need for food with the availability of food at that location. It is shown in the last column of Table 3 that the Beh watershed has achieved food self-sufficiency around 1–3 times. From this, researchers conclude that the Beh watershed has the capacity for food self-sufficiency or can be self-sufficient in food. The only exception is one district, namely Batulanteh district, which is not yet capable of being self-sufficient in food. The categories for districts in the Beh watershed are M (capable of food self-sufficiency) and MT (capable of food self-sufficiency but not yet able to provide a decent life). The districts in the category of food self-sufficiency are the Lunyuk, Moyohulu, Ropang, and Lenanguar districts. The districts in the category of being self-sufficient in food but not having a decent life are Orong Telu District and Lantung District.

The analysis of land carrying capacity for food self-sufficiency in the Beh watershed shows that the highest achievement of self-sufficiency is in the Lantung District at 53.27%; this is due to food availability in a harvest area of 1,720 ha, affecting food availability. Apart from that, the population is the smallest, which results in the achievement of food self-sufficiency being the highest compared to other district areas. Agricultural land management in the Beh watershed is generally done 1–2 times a year. In areas with irrigation facilities, harvesting can be done twice a year, whereas in areas that do not have irrigation facilities, agricultural land is only planted twice. The land carrying capacity analysis results show that the average food carrying capacity in the Beh watershed is 2.438, meaning the land can be planted twice a year. The total harvest area in the Beh watershed is 15,347 ha. Spatially, the distribution of the level of carrying capacity of agricultural land in the Beh watershed can be seen in Figure 4.

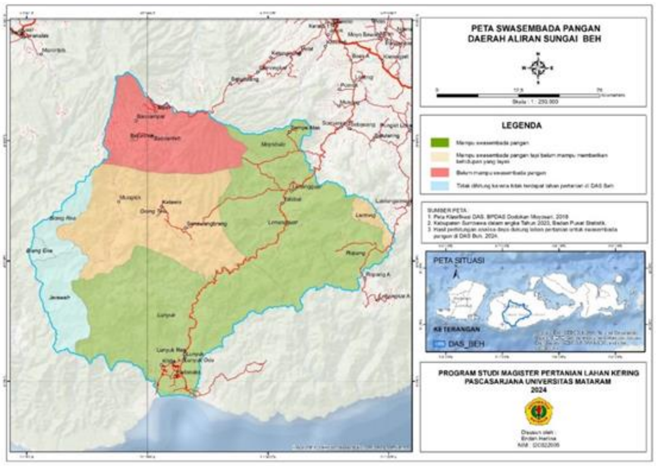


Figure 4 – Map of self-sufficiency level in Beh Watershed

Figure 4 shows that the green areas can be self-sufficient in food, while the yellow areas can be self-sufficient in food but cannot yet provide a decent life. Red areas are areas that cannot yet be self-reliant in food.

Minimum land requirement. The minimum land requirement is the minimum area of agricultural land that can meet farmers' food (rice) needs per capita in one year. The approach is a minimum physical consumption amount of 0.265 per capita/year. Based on the analysis of minimum agricultural land requirements, wide variations exist between districts in the Beh watershed; this is influenced by the amount of food produced and the harvest area. The calculations showed that the minimum land area for achieving rice food self-sufficiency in the Beh Watershed in Lunyuk District is 0.075 ha/capita/year. At the same time, in other districts, such as Ropang District, it is 0.085 ha/capita/year. To achieve food self-sufficiency, farmers must have a minimum of 0.085 ha/cap/year of land to meet their rice needs in the Beh watershed. However, land productivity also needs to be increased because the current average land productivity in 7 districts in the Beh watershed is 3.28 tonnes/ha. The analysis results are shown in Table 4.

Table 4 – Minimum land area for food self-sufficiency

No	District	Rice production-hulled	Minimum physical consumption (t/year)	Minimum land size (ha/caput/year)	Minimum land size ("are"/caput/year)
1	Lunyuk	15.730	0,265	0,075	7,54
2	Orong Telu	3.199	0,265	0,083	8,33
3	Batulanteh	2.034	0,265	0,083	8,33
4	Moyohulu	18.786	0,265	0,076	7,55
5	Ropang	4.723	0,265	0,085	8,50
6	Lenangguar	5.401	0,265	0,084	8,44
7	Lantung	2.079	0,265	0,080	8,00

Notes: The harvest area is the harvest area x 2 planting times

The level of land carrying capacity in the Beh watershed in 7 districts falls into three categories, namely capable of food self-sufficiency (Lunyuk, Moyohulu, Ropang, Lenangguar), capable of food self-sufficiency but not yet able to provide a decent life (Orong Telu and Lantung) and not yet capable of food self-sufficiency (Batu Lanteh). This assessment of the carrying capacity level is obtained from the land available for crop cultivation compared to the area required for food self-sufficiency. The highest carrying capacity level is in the Ropang and Moyohulu districts at 2,796 and 2,764, respectively, while the lowest is in the Batulanteh district at 0.635.

Table 5 – Carrying Capacity Level of Agricultural Land in the Beh Watershed

No	District	Population	Paddy production	Rice production	X/K	Criteria for land capacity
1	Lunyuk	22.939	25.071	15.730	2 588	M
2	Orong Telu	5.645	5.099	3.199	2 139	MT
3	Batulanteh	12.093	3.242	2.034	635	BM
4	Moyohulu	25.648	29.943	18.786	2 764	M
5	Ropang	6.374	7.528	4.723	2 796	M
6	Lenangguar	8.265	8.608	5.401	2 466	M
7	Lantung	4.187	3.313	2.079	1 873	MT

Notes: Minimum Physical Consumption of 0.265 t/year [14]; X – an area of land available for crop cultivation (harvest area/population); k – Land area required for food self-sufficiency; M – Able to be self-sufficient in food; MT – Able to be self-reliant in food but not yet able to provide a decent life; BM– Not yet capable of food self-sufficiency.

CONCLUSIONS

This research indicates that the Beh watershed has achieved food self-sufficiency, especially rice, with varying levels of food self-sufficiency. There are districts with a level of ability to be self-sufficient in food, namely Lunyuk District, Moyohulu District, Ropang District, and Lenangguar District. The district with a level of being able to be self-reliant in food but not yet living a decent life is Orong Telu District, and the district with a level of not yet self-sufficient is Batulanteh District. This level of self-sufficiency is determined by the availability of land that supports food self-sufficiency in the district. The research results show that this carrying capacity is generally within 1–3 times. District locations that have not yet achieved food self-sufficiency must look for other strategies to meet their food needs, including expanding agricultural land, intensifying rural activities, or purchasing food from different areas.

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