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Evaluating Land Carrying Capacity in Mount Bromo's Special Purpose Forest Areas

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ABSTRACT

Most people depend on the forest for their livelihood. Therefore, it is essential to study to what extent the capability of the land in forest areas designated for special purposes on Mount Bromo can satisfy the food needs of the surrounding community. The purpose of this study was to understand and analyze the carrying capacity of the land in the specially designated forest areas of Mount Bromo. This research is exploratory and descriptive, conducted through a survey method that included interviews, focus group discussions, and questionnaires. Data were collected by obtaining secondary data from the Central Statistics Agency of Karanganyar Regency. The data were analyzed using quantitative descriptive methods. The land carrying capacity was calculated by determining the supply and demand for land to ascertain the land's carrying capacity. The results showed that the land supply from the availability of land in the specially designated forest areas of Mount Bromo was 4,599.22 hectares, and the land needs were 14.85 hectares; therefore, the carrying capacity of the land was in a surplus or sufficient condition. As part of long-term planning, the policy for developing the agricultural sector should be directed towards improving accessibility for marketing agricultural products beyond the region.

1. INTRODUCTION

Forests are a fundamental sector that encompasses socioeconomic, demographic, and technological dimensions [1]. Forest areas designated for special purposes are an effective means of protecting biodiversity and biomass, although there are some activities that may impact these areas [2, 3]. Furthermore, it is noted [4] that forest areas with a specific purpose often include a buffer zone, which serves to enhance the protection against land use activities and benefits local communities. Agroforestry is regarded as an alternative that can achieve economic, social, and environmental benefits, contributing to food security, environmental sustainability, and the improvement of living standards in rural communities [3, 5, 6].

The degradation of natural resources, particularly agricultural land and forests, has become a global concern with respect to food needs, population growth, and environmental sustainability [7, 8]. Anthropogenic activities lead to environmental degradation, which includes the deterioration of water quality, erosion, soil degradation, and the loss of biodiversity. In the long term, such degradation can result in ecological changes with global impacts on land carrying capacity, soil quality, and climate change. Land use is critically important for maintaining its function and sustainability [9]. Achieving ecological balance presents a serious challenge in the context of land use and human activities. The conversion of non-industrial land to industrial use, and changes in forest land use, are particularly detrimental to environmental aspects [10].

Land degradation is defined as a temporary or permanent decline in land productivity, characterized by reductions in the physical, chemical, and biological qualities of the soil [10]. Physical deterioration manifests as compaction, movement or displacement, water imbalance, drainage obstructions, and damage to soil structure. Excessive or improper fertilization applications can significantly diminish soil fertility, quality, and productivity [11]. Land degradation resulting from human activities often occurs when the use of the environment disregards ecological balance.

According to the American Park and Burgess, carrying capacity represents the maximum number of living organisms that can be supported under certain environmental conditions, which include space, nutrients, sunlight, and other ecological factors. Land carrying capacity is defined as the ability of an area to support a certain number of inhabitants and human activities without causing land degradation. It is objective and dependent on the production capacity of specific land, thus, it is correlated with the economic level of a region. The carrying capacity of land is indicative of sustainable development for the population and the economic activities of a region [12].

The carrying capacity of the soil depends on the percentage

of usable soil and the agricultural yield per unit area and time. The larger the proportion of land that can be utilized for agriculture, the greater the carrying capacity of the area's land. Analyzing carrying capacity and land quality is one method to evaluate the application of agroforestry systems in forest areas. Soil is a crucial component that plays a role in biogeochemical cycles, carbon storage, and supports plant productivity [13-15]. The land's carrying capacity refers to the number of people who can be sustained by the land's resources in a given environment under prosperous conditions, with the application of appropriate agricultural technology and management.

The function of the forest includes maintaining the ecological balance, which encompasses preserving the hydrological cycle, supplying oxygen to living organisms, and acting as a medium for the flow of solar energy. Forest degradation, caused by excessive exploitation, can lead to environmental changes with global impacts on the land's carrying capacity, soil quality, and climate change. Therefore, it is necessary to maintain forest sustainability to ensure the proper functioning of these forest roles. Focusing on carrying capacity is key to creating a comfortable and sustainable habitat.

Special Purpose Forest Areas are designated for forestry research and development, forestry education and training, and for religious and cultural purposes, as stipulated in the Ministerial Regulation of Environmental and Forestry Number P.15 of 2018. The Mount Bromo Special Purpose Forest Area is managed by Universitas Sebelas Maret, having been transferred from the Ministry of Environment and Forestry in 2018. Programs implemented and undergoing development in the Mount Bromo Forest Area with Special Purposes include teaching programs that serve as practicum sites for nature orientation across various study programs, Klanceng Honey Bee cultivation, animal inventories and monitoring, vegetation and soil analysis by Universitas Sebelas Maret. As a research site, it has received several research grants from Universitas Sebelas Maret. There is a need for research infrastructure such as a Green House, in addition to community service programs that are conducted through real college work programs, collaborative activities with Forest Farmer Groups, and initiatives such as the establishment of Forest Farmer Groups and the Formation of Fire Care Communities.

The Special Purpose Forest Area of Mount Bromo has implemented erosion and landslide control measures, including the use of erosion control appeals, the construction of waterways, and terracing. Among the water resources in the area, some forest regions are part of the Water Catchment Area for the Tirtomarto Reservoir, which the local community utilizes for agricultural irrigation. The vegetation in the Mount Bromo Special Purpose Forest Area is predominantly Pine, Sonokeling, and Mahogany species. In terms of fauna, the area is home to the endemic brontox eagle (*Nisaetus cirrhatus*), a bird species protected by Indonesian law and considered to be of low-risk status. These eagles have established nests in the area, with three active birds closely monitored to preserve their habitat.

Previously managed by Perum Perhutani, the Mount Bromo forest area has been under the administration of Sebelas Maret University since 2018. Plans are underway to develop the area into an educational and training facility, as well as an alternative ecotourism-based recreation area for urban residents. The livelihoods of many local people are dependent on the forest. Therefore, it is crucial to assess how well the land within the Mount Bromo Special Purpose Forest Area can sustain the food requirements of the nearby communities. Additionally, the existence of the Bromo Forest plays a vital role in the lives of the surrounding community, particularly in maintaining hydrological functions and biodiversity. The aim of this study is to understand and analyze the carrying capacity of the land in the Mount Bromo Special Purpose Forest Area.

2. METHODOLOGY

2.1 Description of the studied area

The research was carried out in March-November 2022. The research was carried out in forest areas with the special purposes Mount Bromo. The forest areas with special purposes area of Mount Bromo is geographically located between 7°34'21.93"–7°35'38.9" South Latitude and -110°59'40.39"–111°0'49.36". East Longitude and administratively is located in two sub-districts, namely Delangan and Gedong Villages, Karanganyar District, Karanganyar Regency, Central Java. While Administrative forestry is included in the area Forest Management Unit Office of North Lawu, Surakarta Forest Management Unit, and Central Java Company History. The forest area of forest areas with special purposes is 126,291 ha. The zoning map for forest areas with special purposes Mount Bromo is shown in Figure 1.

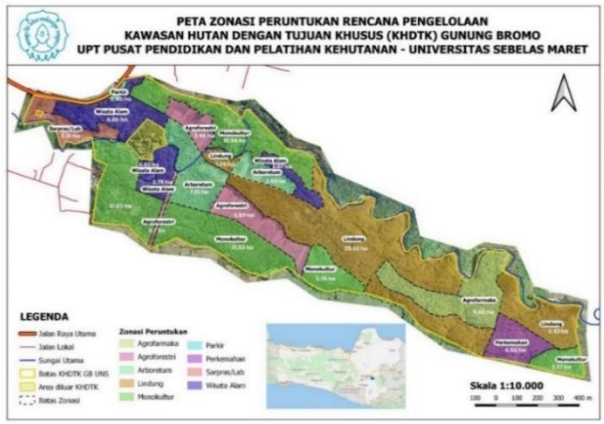

Figure 1. Zoning map for the management plan of forest areas with special purposes Mount Bromo

2.2 Calculation of land carrying capacity

The carrying capacity of land consists of calculating land supply and land demand. Calculation of land availability and needs using the following formula:

2.2.1 Land availablilty (supply)

$$SL = \sum \frac{(Pi \times Hi)}{Hb} \times \frac{1}{Ptvb} \quad (1)$$

where, *SL*=Availability of land (ha), *Pi*=Actual product of each type of commodity, *Hb*=Unit price of rice (Rp/kg) at producer level, *Hi*=Unit price for each type of commodity (Rp/unit) at producer level, *Ptvb*=Productivity rice (kg/ha) which is the total rice production (Pb) divided by the total harvested area of lowland rice and upland rice (Lb).

2.2.2 Land demand

$$DL = N \times KHL1 \quad (2)$$

where, *DL*=Total land requirement equivalent to rice (ha), *N*=Total population, *KHL* 1= Land area needed for decent living needs per resident with provisions (Regulation of the State Minister of the Environment Number 17 of 2009).

2.3 Data analysis

This research is exploratory descriptive research, conducted by survey method by conducting interviews, forum group discussion (FGD) and filling out questionnaires.

Research sampling was carried out by purposive sampling method. The criteria for the resource persons selected to fill out the questionnaire were local farmers around The Special Purpose Forest Area of Mount Bromo, namely Delingan Village, Gedong Village, and Sewurejo Village. The selected resource persons are farmers who own several lands or farmers who work on land in the area in The Special Purpose Forest Area of Mount Bromo. The questionnaire contains several questions regarding the identity of respondents, land ownership status, land use for plant species, planting patterns carried out and crop changes, then crop maintenance such as fertilizer use and dosage, how to overcome pests and weeds, and rice production, both rice fields and moor.

The participants of the group discussion forum were a combination of farmer groups from the area around The Special Purpose Forest Area of Mount Bromo, namely Delingan Village, Gedong Village, and Sewurejo Village. The group discussion forum discussed the opinions of obstacles to land processing felt by farmers and discussions on proper land processing so that forests become sustainable. Supporting data related to the calculation of land carrying capacity is carried out by collecting secondary data including population, land area, productivity and prices of agricultural products, plantations, forestry, animal husbandry and fisheries, and rice prices at the producer level. Secondary data was obtained from the Central Bureau of Statistics of Kanganyar District. The data were analyzed using quantitative descriptive methods.

3. RESULT AND DISCUSSION

3.1 Conditions of the research area

The soil type in forest areas with special purposes Mount Bromo is dominantly Alfisols soil. The forest areas with special purposes Mount Bromo is located at an altitude of 200–337.5 masl. The climatic conditions of forest areas with special purposes Mount Bromo based on the Schmidt and Ferguson climate classification include type C (A bit Wet), with a value of Q=33.33%–60%. The slope map of forest areas with special purposes Mount Bromo is shown in Figure 2.

3.2 Respondents criteria

Based on the results of interviews and questionnaire results in The Special Purpose Forest Area of Mount Bromo that farmers are divided into non-cultivators, sharecroppers and tapping farmers. Sharecroppers are farmers who work or work on other people's land. Non-cultivators are farmers who do not cultivate or work on other people's land but work on their own land. Respondent criteria are presented in Figure 3.

The criteria for respondents around forest areas with special purposes Mount Bromo consist of non-cultivators, sharecroppers and tapping farmers. Non-cultivator farmers are farmers who do not cultivate land within the forest areas with special purposes Mount Bromo, but cultivate their own land outside the forest areas with special purposes Mount Bromo. Cultivators are farmers who work on land in the forest areas with special purposes Mount Bromo. Based on the results of respondents' criteria, it is evident that the livelihood of the community around the forest area depends on forests with special purposes on Mount Bromo. The role of the community around the forest also plays an important role in forest management both in terms of land processing, plant management, and playing a role in a community that plays an important role in forest areas with special objectives of Mount Bromo.

Plant cultivation is carried out by farmers around forest areas with special purposes Mount Bromo consists of monoculture and intercropping patterns. Monoculture cropping patterns are plants that are cultivated on only one type of land so that they are easier to maintain but are susceptible to pests and diseases. While the intercropping patterns several types of plants that are cultivated in one land so that they are not susceptible to pests and diseases [16]. Based on the results of the questionnaire, some farmers planted with a monoculture cropping pattern and some planted with an intercropping pattern. Monoculture cropping patterns generally plant corn, peanuts, or cassava only. While the intercropping pattern is generally planted with corn, cassava, and peanuts.

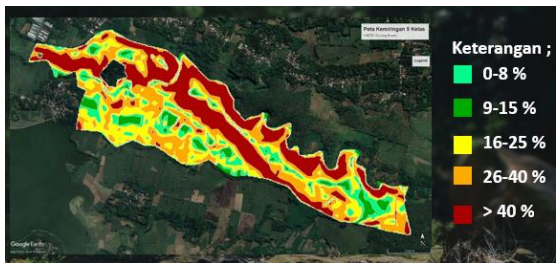

Figure 2. Slope map of forest areas with special purposes Mount Bromo

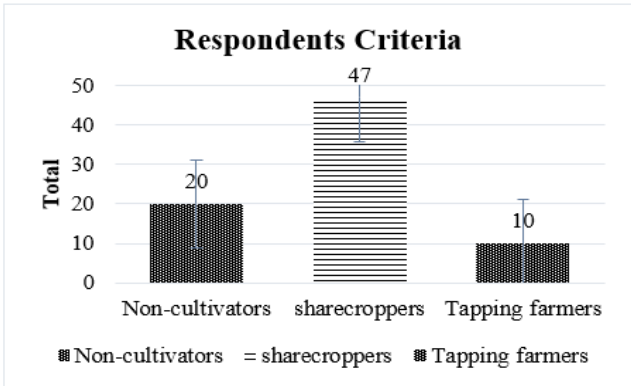

Figure 3. Respondent's criteria

3.3 Land availability

Land availability is determined based on data on the total local actual production of each commodity in an area, by

summing the products of all commodities in the region [10]. Commodities that are taken into account include agricultural, plantation, forestry, livestock, and fishery commodities in the forest areas with special purposes and Karanganyar District. To equalize non-rice products with rice, price conversion factors are used at the producer level of each commodity. The producer price data used is price data in the Karanganyar Regency area. The results of the analysis of land availability data in forest areas with special purposes Mount Bromo are presented in Table 1.

Table 1. Land Availability in forest areas with special purposes Mount Bromo

Number	Total Pi × Hi	Hb (Rp/kg)	Pvtb (kg/hectare)	SL (hectare)
1	122.391.763.500	4.600	5,784.84	4,599.22

Source: Secondary data analysis and [17]
Remarks: Pi=Actual product of each type of commodity, Hi=Unit price for each type of commodity at producer level, Hb=Unit price of rice at producer level, Ptvb=Productivity rice which is the total rice production divided by the total harvested area of lowland rice and upland rice, SL=Availability of land

Based on Table 1, the total value of biological production from agricultural, plantation, forestry, livestock, and fishery commodities in 2021 is IDR 122.391.763.500. This shows that the agricultural sector is an economic sector that has strategic value and provides high production value. The high diversity of agricultural sector commodities in The Special Purpose Forest Area of Mount Bromo will affect the amount of production value of the agricultural sector. This condition has a positive impact on the availability of land in The Special Purpose Forest Area of Mount Bromo, covering an area of 4,599.22 hectares, so it is very supportive in meeting the needs of biological products to realize regional food independence and security.

3.4 Land demand

Land needs are obtained from the multiplication of the number of residents by the area of land needed for decent living needs per population. The need for decent living per population is assumed to be one ton equivalent to rice/capita/year (Ministerial Regulation Environmental and Forestry Number 17 of 2009). The results of the analysis of land needs in forest areas with special purposes Mount Bromo are presented in Table 2.

Table 2. Land Demand in forest areas with special purposes Mount Bromo

Number	N	KHL	DL (hectare)
1	85.892	0.0002	14.85

Source: Secondary data analysis [18-20]
Remarks: N=Total population, KHL1=Land area needed for decent living needs per resident, DL=Total land requirement equivalent to rice

Based on Table 2, the area of land for decent living per inhabitant is 0.0002 with the total population around. The Special Purpose Forest Area of Mount Bromo based on population registration in 2021 which is 85,892 people. To meet the needs of biological products of residents around, The Special Purpose Forest Area of Mount Bromo, an area of 14.85 hectare is needed.

3.5 Land carrying capacity

The results of the environmental carrying capacity analysis with the land carrying capacity approach are based on a comparison between the availability and needs of land based on land productivity in supporting the fulfillment of the biological product needs of the population in the Karanganyar District and forest areas with special purposes Gunung Bromo. The results of the data analysis of land availability and land needs in forest areas with special purposes Mount Bromo are presented in Table 3.

Table 3. Land Availability and Land Demand at forest areas with special purposes Mount Bromo

Number	SL (hectare)	DL (hectare)	Remarks
1	4,599.22	14.85	Surplus

Source: Secondary data analysis
Remarks: SL=Availability of land, DL=Total land requirement equivalent to rice

Based on the results of data analysis, the land availability of forest areas with special purposes Mount Bromo is 4,599.22 hectare and the land requirement is 14.85 hectare. Based on these calculations, it can be seen that the need for land is smaller than the availability of land. This shows that the carrying capacity of the land is in a surplus condition. In accordance with what is stated in Ministerial Regulation Environmental and Forestry Number 17 of 2009 that the status of the carrying capacity of land is obtained from a comparison between land availability (SL) and land demand (DL). If SL > DL, the carrying capacity of the land is declared surplus, while if SL < DL, the carrying capacity of the land is declared deficit or exceeded. The surplus land carrying capacity in meeting the actual biological product needs in 2021 around the forest areas with special purposes area of Mount Bromo is a manifestation of resilient regional food security and is one of the main pillars in supporting economic resilience and sustainable regional resilience.

The productivity of agricultural land in the forest areas with special purposes area of Mount Bromo is influenced by various factors, especially the condition of fertile land and the system of managing agricultural land. The factors that affect agricultural production are biological factors (land processing, pesticide use) and socioeconomic factors namely production costs, commodity prices, labor, education level, income level, and so on [21].

The carrying capacity of land with surplus conditions can be influenced by several factors [21], namely the level of diversity of commodities in the agricultural sector, the dominant land use in the agricultural sector, the agricultural sector is a base sector that has comparative and competitive advantages, fertile soil types and climate micro suitable for agriculture, and has strong local wisdom in the farming system. The carrying capacity of land with surplus conditions with increasing population growth, and the growth of the building sector which has an impact on the conversion of agricultural land can result in threats. Things that can be done to overcome the decline in land carrying capacity according to the study by Moniaga [22] can be done using land version, changing the type of land use by land suitability, land intensification, namely in using new technology in farming, land conservation to prevent damage to land resources.

The Regional Government of Karanganyar Regency must

emphasize development policies in the agricultural sector which is a leading sector to support regional resilience in the food, economic, social, and environmental sectors. As a long-term planning, the policy of developing the agricultural sector as the leading sector of the Karanganyar Regency region needs to be directed by developing accessibility to marketing agricultural products outside the region. Cooperation contracts with food processing industries outside the region need to be facilitated by the Kanganyar District Government.

The processing of agricultural products in areas with special purposes area of Mount Bromo, Karanganyar Regency has not developed well, industry standards pay great attention to the quality of agricultural commodity products, so it needs to be considered and developed for the better. Supervision of the production process needs to be considered by intensifying production quality control in the areas of agricultural development centers. This needs to be determined by the biogeophysical characteristics of the region, diversification development, application of site-specific and appropriate agricultural technology, low or balanced use of external inputs in agricultural business development, development of agricultural infrastructure, and strengthening of farmer institutions and resources. The selection of commodities with high prices will increase the carrying capacity of the land, while still paying attention to the ability of the land, the suitability of the land to these crops, and how to manage the land sustainably.

4. CONCLUSION

The total value of biological production from agricultural, plantation, forestry, livestock, and fishery commodities in the Mount Bromo Special Purpose Forest Area in 2021 is IDR 122.391.763.500 with an area of 4,599.22 hectare. Land needs data (DL) in forest areas with special purposes Mount Bromo amounting to 14.85 hectare. Land demand is smaller than the availability of land. This shows that the carrying capacity of the land is in a surplus condition.

The policy of developing the agricultural sector as the leading sector of the Karanganyar Regency region needs to be directed by developing accessibility to marketing agricultural products outside the region. Cooperation contracts with food processing industries outside the region need to be facilitated by the Kanganyar District Government. Supervision of the production process needs to be considered by intensifying production quality control in the areas of agricultural development centers. The selection of commodities with high prices will increase the carrying capacity of the land, while still paying attention to the ability of the land, the suitability of the land to these crops, and how to manage the land sustainably.

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