Applying Geospatial Technology in Estimating Agricultural Wastes Carrying Capacity in Grobogan Regency, Indonesia

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Abstract. This study aimed to estimate using geospatial the feed carrying capacity of agricultural wastes, especially in Grobogan Regency, Central Java, Indonesia. The method that has been used in this study is the descriptive analysis which is sourced from secondary data from Grobogan Regency. Analysis of agricultural waste production includes rice straw, corn and soybeans converted into dry matter feed. Geospatial analysis using ArcGis 10.3 software to extract feed carrying capacity data in the form of maps. The result showed that dry matter agricultural wastes 405528.81 (tons/year), The capacity of beef cattle was 924606 (animal units) and the ability to add beef cattle was 791036 (animal units). The conclusion of the study that Grobogan Regency has to carrying capacity indexes were at safe levels.

Keywords: Carrying capacity, agricultural waste, beef cattle, geospatial

1. Introduction

Smart farming combines multiple technologies, devices, protocols, and computing paradigms to enable farmers to make the most of innovation. Innovations in agriculture are called the "digital agricultural revolution" and will transform all aspects of agriculture, resulting in more productive, efficient, sustainable, inclusive, transparent, and resilient systems. However, integrating technology into the agricultural sector depends on the complexity and maturity of technologies such as mobile devices, precision agriculture, remote sensing, big data, climate, analytics, cybersecurity, and intelligent systems [1].

Crop residues, accounting for the largest crop yields of agricultural products for more than half of the phytomass, are a potential source of plant nutrients. Effective utilization of locally generated agricultural residues that are otherwise underutilized or underutilized, causing waste and environmental problems that are very important in green agriculture [2].

Geographic Information Systems (GIS), have seen major improvements in terms of increased cost and expansion of system capacity and scale of their day-to-day implementation in various fields. Remote sensing has been applied in many applications such as flood risk mapping, coastal processes, soil erosion, soil infiltration, agriculture, forestry, and others [3].

The use of GIS applications in agriculture is generally in mapping soil types, climate, and agricultural land use. There are not many GIS applications in animal husbandry in Indonesia so that it can be used as a reference for the carrying capacity of feed from agricultural waste concerning planning the development of future beef cattle farms.
Applications of GIS in agriculture have gained much attention from researchers around the world due to its significance, and considering the power crisis world, it can be beneficial in terms of meeting the energy supply and demand. GIS application is beneficial and may be used by farmers for many benefits, starting from biomass management to renewable energy production. By adopting new technologies of farming, it can solve farmers’ economical problems too. GIS as a tool can bring a tangible impact in the country and may also contribute to energy security at a global level [4].

The GIS-based Ecological Carrying Capacity Model of Nutrition Resources (ECCNR-GIS) software is a new approach based on rangeland assessment and the estimated energy content of the forage. Work with GIS software is easy and with a little education, most experts familiar with GIS can benefit from it. Changing the input data to the ECCNR-GIS, can predict, based on a herd of productive resources, the provision of productive resources based on vegetation change in circumstances such as drought and subsequent ecological capacity of livestock feed resources in different conditions [5].

Beef cattle are an important livestock commodity and are often highlighted by government policy objects because they play an important role in meeting the needs of animal protein (in this case beef and buffalo) of the Indonesian people. Beef production was 0.5 million tons in 2019. This production contributes to the fulfillment of domestic meat needs by 10.2%. The growth of national beef production in recent years was quite low at around 2.29%, originating from cattle at 1.37% [6].

The increase in population will certainly lead to an increase in the need for meat as well. One of these events needs to be anticipated through efforts to increase the cattle population. The population of beef cattle in 2020 in Central Java was 1.8 million heads, while the national population was 17.47 million heads. In 2020 rice productivity was 5.7 tons/ha with a rice harvest area of 1.68 million hectares. The population of beef cattle in Grobogan Regency is 198158 heads. Rice harvested area in 2020 in Grobogan Regency was 131929 ha with a productivity of 6.1 tons/ha, the highest rice production in Central Java was Grobogan Regency, which was 805889.27 tons [7].

Abundant agricultural waste such as rice straw, corn husks, and soybean stover which was abundant in specific locations was an effort to provide feed for beef cattle. The development of the integration pattern of beef cattle with plants was a mutually supportive and beneficial process because it can improve land and plant fertility and increased the availability of feed throughout the year [8].

The purpose of this study was to estimate the feed carrying capacity of agricultural waste for beef cattle feed in Grobogan Regency using geospatial data.

2. Data and Methods

The study area (Grobogan Regency) has blocks (Figure 1). The Regency of Grobogan occupies an area of more than 1975.86 km² and was selected as a case study due to its biomass potentiality of crops, and has their strong interest in growing biomass, and large scale industrial agglomerations.

2.1 Descriptive Analysis.

Descriptive analysis in this study is used to describe the state of beef cattle farm resources in the Grobogan Regency area, descriptive analysis which is sourced from secondary data [7].

2.2 Agricultural Waste Production Analysis.

The analytical method used to calculate agricultural waste production is as follows [9], namely total fresh production, total dry matter production with the following formula:

a. Total Fresh Production = Fresh Production (Tons/Ha) x harvested area (ha)

b. Total BK Production = Production of fresh material from agricultural waste x BK content (%)

c. Carrying capacity of dry matter food crop waste (BK) = Production of dry matter /dry matter requirement (kg/unit of livestock/year).

d. Carrying capacity index of food crop waste (BK) = total BK production (kg) / cattle population (ST) x BK requirement (kg/ST/year).
2.3 Analyses of Geospatial.

To determine the annual mean carrying capacity index agricultural wastes values, we applied the following procedures [10]:

a. Extracted the data of the study area using ArcGis 10.3 software.

b. Used the ordinary kriging technique to interpolate values when data carrying capacity values were missing within the study area.

c. Lastly, we calculated the mean annual carrying capacity using ArcGIS software.

Figure 1. Location map of Grobogan Regency, Central Java, Indonesia.

3. Results and Discussion

3.1 Distribution of Land Use in Grobogan Regency

The use of agricultural land in Grobogan Regency, Central Java Province covers 170,039 ha or about 83.75% of the total area of Grobogan Regency. The most extensive use of agricultural land is rainfed rice fields covering an area of 61,251 ha and mixed gardens covering an area of 46,654 ha. These two types of land are evenly distributed throughout the district. Rice fields in Grobogan Regency are divided into two types, namely irrigated rice fields and rainfed rice fields, each covering an area of 43,148 ha and 61,251 ha. These rice fields spread almost throughout Grobogan Regency. Meanwhile, sugarcane plantations are found in a not-too-wide area, covering an area of 799 ha.

Non-agricultural land in Grobogan Regency covers an area of 32,989 ha, consisting of non-cultivated forest, grasslands, built-up land, and a water body. Non-agricultural land is dominated by built-up land and grassland, covering 22,122 ha and 8,770 ha, respectively, while the smallest area is non-cultivated forest, which is 916 ha. The distribution of agricultural land use and non-agricultural land use in Grobogan Regency, Central Java Province is presented in Table 1 and Figure 2 below.
### Table 1. Distribution of agricultural land use in Grobogan Regency, Central Java Province

| Symbol | Description                        | Area  | %     |
|--------|------------------------------------|-------|-------|
|        |                                    | Ha    | %     |
| **Agricultural land** |                                      |       |       |
| Si     | Irrigated rice fields              | 43,148| 21.25 |
| St     | Rainfed rice fields                | 61,251| 30.17 |
| Hb     | Cultivated forest                 | 4,392 | 2.16  |
| Kc     | Mixed gardens                      | 46,654| 22.98 |
| Tp     | Field/Moor with Palawija           | 13,796| 6.80  |
| Tu     | Sugarcane plantations              | 799   | 0.39  |
| **Sub-Total** |                                  | 170,039| 83.75 |
| **Non-Agricultural land** |                                    |       |       |
| Ha     | Non-cultivated forest              | 916   | 0.45  |
| Pr     | Grassland                          | 8,770 | 4.32  |
| X2     | Built-up land                      | 22,122| 10.90 |
| X3     | Water body                         | 1,181 | 0.58  |
| **Sub-Total** |                                  | 32,989| 16.25 |
| **Total** |                                  | 203,028| 100   |

![Figure 2. Distribution of Agriculture Land Use map of Grobogan Regency, Central Java, Indonesia.](image-url)
3.2 Carrying Capacity Index

A study on the carrying capacity of feed has been carried out in Kutai Kartanegara Regency, East Kalimantan, but the only agricultural waste that counts is rice straw [11]. The study that we did calculates agricultural waste of rice straw, corn stover, and soybean straw in Grobogan Regency, the estimation results show that most of them have a safe carrying capacity index value except for Gabus and Puwodadi Districts in the critical category as in Figure 3. Studies that have been conducted in the District North Minahasa calculate the carrying capacity of food crop waste, but the area is only sub-district and has not used geospatial [9].

A more comprehensive study of the carrying capacity of the environmental ecology approach has been carried out in China. The estimated slope, land use, the land stress index, the habitat quality index, the water network density index, vegetation coverage, the geological hazard index, annual total rainfall, annual total temperature, population density index, the proportion of construction land, the economic development index, the road network density index, the steep slope reclamation rate, and the steep slope reclamation rate were some of the fifteen factors involved [12].

![Figure 3. Geospatial Carrying Capacity Map of Grobogan Regency, Central Java, Indonesia](image)

The agricultural and agro-industrial fields, in hopes of improving their sustainability and adopt a bioeconomic model for the Grobogan economy in this situation, the utilization, and valorization of biomasses, such as by-products, agricultural waste, and agro-industrial waste produced during manufacturing techniques, is the main priority.

In the field of energy production from renewable energy sources, the issue of redefining byproducts and waste from all agro-food production is also relevant. One of the major challenges today is maintaining the lengthy sustainability of energy production [13].

A fall in stocking density on sloping fields is not taken into account in the aforementioned carrying capacity calculation. Our second carrying capacity model, which took into account the need to lower stocking rates to prevent erosion, yielded a stocking density of 6.2 beef cattle per hectare. These statistics are consistent with the Azerbaijani government's recommendation of 2–8 beef cattle per hectare for summer pastures [14].

The model that developed provides information on the spatial variation in carrying capacity, which can help stakeholders decide on more sustainable stocking rates to establish and implement.

The highest feed production in Geyer District is 47933.92 DM tons/year with a livestock capacity of 109289 AU and additional capacity of 97178 AU, the CCI value is 4.5. The lowest feed production in Klambu District is 9143.44 DM tons/year with a livestock capacity of 20847 AU and additional capacity of 20422 AU, the CCI value is 24.6 as shown in Table 2.
Table 2. Carrying Capacity Agricultural Wastes in Grobogan Regency, Central Java, Indonesia

| No. | Districts     | BC (AU) | RS (DM tons/year) | CS (DM tons/year) | SS (DM tons/year) | FP (DM tons/year) | C (AU) | AC (AU) | CCI  |
|-----|---------------|---------|------------------|-------------------|-------------------|------------------|--------|---------|------|
| 1.  | Kedungjati    | 2247    | 1599             | 9650              | 11.76             | 11260.68         | 25674  | 23427   | 5.7  |
| 2.  | Karangrayung  | 914     | 5177             | 21262             | 27.68             | 26467.39         | 60346  | 59432   | 33.0 |
| 3.  | Penawangan    | 2296    | 9721             | 3031              | 72.66             | 12823.92         | 29239  | 26943   | 6.4  |
| 4.  | Toroh         | 13226   | 8003             | 29051             | 1.31              | 37055.96         | 84488  | 71262   | 3.2  |
| 5.  | Geyer         | 12112   | 5873             | 42061             | 0.00              | 47933.92         | 10929  | 97178   | 4.5  |
| 6.  | Pulokulon     | 12360   | 9779             | 28583             | 220.98            | 12823.92         | 38582  | 75610   | 3.6  |
| 7.  | Kradenan      | 7798    | 10043            | 15429             | 96.82             | 25568.35         | 58296  | 50498   | 3.7  |
| 8.  | Gabus         | 20405   | 10388            | 29051             | 1.31              | 37055.96         | 84488  | 71262   | 3.2  |
| 9.  | Ngaringan     | 11113   | 11471            | 8131              | 72.31             | 20322.66         | 46336  | 35223   | 2.1  |
| 10. | Wirosari      | 18552   | 10434            | 21235             | 0.00              | 31668.88         | 72205  | 53653   | 1.9  |
| 11. | Tawangharjo   | 6242    | 6982             | 9300              | 570.55            | 16852.97         | 38425  | 32182   | 3.1  |
| 12. | Grobogan      | 7335    | 7204             | 12931             | 0.00              | 20135.35         | 45909  | 35673   | 3.1  |
| 13. | Purwodadi     | 13969   | 9995             | 4619              | 107.25            | 14720.53         | 33563  | 19594   | 1.2  |
| 14. | Brati         | 3243    | 4908             | 6794              | 0.00              | 11702.59         | 26882  | 23438   | 4.1  |
| 15. | Klambu        | 425     | 4660             | 4484              | 0.00              | 9143.44          | 20847  | 20422   | 24.6 |
| 16. | Godong        | 432     | 15000            | 23                | 1.18              | 15023.61         | 34254  | 33822   | 39.7 |
| 17. | Gubug         | 97      | 8269             | 5040              | 0.00              | 13308.49         | 30343  | 30246   | 156.4|
| 18. | Tegowanu      | 170     | 8122             | 4589              | 0.00              | 12710.96         | 28981  | 28811   | 85.5 |
| 19. | Tanggungharjo | 635     | 2165             | 14394             | 0.55              | 16560.14         | 37757  | 37122   | 29.8 |
|     | Grobogan      | 133569  | 149794           | 253606            | 2128.96           | 405528.81        | 924606 | 791036  | 3.5  |

Source: data analysis [15]

Remarks for carrying capacity index: > 2 = secure; > 1.5 - 2 = vulnerable; > 1 - 1.5 = critical; < 1 = very critical, BC= Beef Cattle Population, RS= Rice straw production, CS= Cora stover production, SS= Soybean straw production, FP= Feed production, C= Capacity, AC= Additional capacity, CCI= Carrying capacity index, AU = Animal Unit, DM= Dry matter (tons/year)

4. Conclusion

From this research, the carrying capacity agricultural wastes value has been successfully quantified. Result of the study showing that Grobogan Regency has a safe carrying capacity value of 3.5, livestock capacity of 924606 AU, and an additional capacity of 791036 AU. These results support agricultural waste management in Grobogan Regency, especially in Geyer District.

The results also show the effort in calculating agricultural waste in Grobogan Regency. So that this effort can be the basis for determining public policy. Furthermore, agricultural waste policies can be encouraged to be more effective and applicable. This study also succeeded in applying GIS as tools which helped the process of calculating agricultural waste through spatial analysis, so it brings an innovation especially in policy of agricultural waste management.

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