Utilisation of remote sensing and geographic information system for compiling of agricultural land resources database in sragen regency

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Abstract. Availability of accurate information on agricultural land resources in Indonesia is important. An alternative method is needed to provide agricultural resource information quickly and accurately. The use of remote sensing and Geographic Information Systems (GIS) is expected to be an alternative method as a basis for compiling a database of agricultural information resources, specifically carrying capacity of agricultural land. Availability of a database of carrying capacity of agricultural land is important, to realise sustainable development, spatial planning must be based on environmental carrying capacity. The research objectives are (1). Compile the database for carrying capacity in Sragen Regency (2). Analysing the utilisation of remote sensing and GIS as the basis for compiling the database for the carrying capacity of the agricultural land in Sragen Regency. The main data source of the research is satellite imagery. Data collection methods used are image interpretation, field observations, interviews, and documentation. The research approach is used spatial description. The results of the study are: (1) The compilation of a database of land carrying capacity of Sragen Regency (2). Remote sensing satellite imagery and GIS can be used as the basis for compiling the database for the carrying capacity of the agricultural land in Sragen Regency.

1. Introduction

The development of remote sensing and GIS technology is very rapid, driven by the increasing demands of application needs to answer various development challenges and problems [1]. Remote sensing technology is one alternative that can help to tap physical information in the area. That is because remote sensing imagery can present a complete picture of objects, regions and symptoms on the surface of the earth with the shape and location of objects that are similar to the actual situation on the terrain [2]. The development of remote sensing makes it easier for users to carry out analysis and extraction of thematic data from imagery for various fields of study, including in the field of land and agricultural resources. [3] In an agrarian country like Indonesia, the availability of accurate and fast agricultural resource information is very important. Remote sensing imagery allows presenting information on agricultural resources that is always ‘up to date’, so it is very helpful for agricultural decision-makers and planners [4]. The remote sensing method can also minimise fieldwork which usually requires a large amount of...
cost. So that in addition to fast and accurate remote sensing methods also tend to be more cost-effective and can cover large areas [5].

One of the important agricultural resource information is land carrying capacity. Carrying capacity and environmental capacity is very important for guiding regional plans and promoting sustainable development of regional economy [6] and should be the basis in the preparation of the National Spatial Plan (RTRW), Provincial RTRW, and City / Regency RTRW. This is reflected in Law number 26 of 2007 which states that the government must draw up a national spatial plan (Article 19 Paragraph 5), the provincial, regional government must draw up a provincial spatial plan (Article 22 Paragraph 4), the district regional government must draw up a district spatial plan (Article 25 Paragraph 4), taking into account the environmental carrying capacity. Preparation of regional spatial plans that do not pay attention to the carrying capacity and capacity of the environment will cause environmental problems such as floods, landslides, drought, and others. Also, regional spatial planning that does not consider the carrying capacity and capacity will also cause problems in spatial use that can trigger conflicts of interest, namely the high need for space for various interests, while the availability of land is very limited.

Carrying Capacity Ratio (CCR) analysis is a development planning tool that provides an overview of the relationship between population, land use, and the environment. Carrying Capacity Ratio (CCR) analysis contains an understanding of the ability of a place to support the life of living things optimally in a long period [7]. Analysis of the carrying capacity of land can be done through 3 approaches, namely: the approach of land capability for the allocation of land use, the comparison between land supply and demand, and the comparison between supply water and demand.

As an agricultural country, most of its population in Indonesia work in the agricultural sector, and most depend on agriculture for their livelihoods. Agricultural land as a place of activity for farmers has decreased over time, which is caused by increasing population pressure on agricultural land. The higher the population pressure on the land, the lower the carrying capacity of the land. Problems in decreasing the carrying capacity of land also occur in Sragen Regency, which is one of the districts that become rice granaries in Central Java Province. Therefore, the compilation of an accurate agricultural database for the analysis of the carrying capacity of agricultural land is important [3]. Remote sensing imagery that can provide up to date agricultural resource information will be used as the main data source for developing agricultural databases more effectively and efficiently.

Remote sensing data processing can be supported with the help of Geographic Information Systems (GIS), which have the ability to input, edit and analyse data, both spatial data and attribute data quickly and accurately. In general, a geographical information system is a collection of tools used to collect, store, activate following the will, transform, and present spatial data from a real phenomenon on the surface of the earth for certain purposes [8]. Geographic Information System (GIS) is a computer-based system that is used to store and manipulate geographic information [9]. Geographic information systems are composed of various interrelated components, including data input, data processing and manipulation, and data output. GIS is currently experiencing very rapid development, this is marked by the emergence of GIS software both raster and vector-based, as well as the ability of spatial analysis functions and attribute analysis functions. Through the integration between remote sensing and GIS, it is expected that optimal spatial analysis results can be obtained for various purposes, one of which is the spatial analysis of agriculture, including the analysis of the carrying capacity of agricultural land and compiling of the agricultural database.
The research objectives are (1). Compile the database for carrying capacity in Sragen Regency (2). Analyzing the utilisation of remote sensing and GIS as the basis for compiling a database of carrying capacity for agricultural land in Sragen Regency

2. Methods

This research is remote sensing research, with the main data source is a remote sensing satellite image. The form of research is spatial descriptive, with land units as units of analysis or mapping units. The research method used was a survey method. The survey was conducted to obtain field data through systematic observation, measurement and recording of symptoms that occur in the research object in the form of data on the physical condition of the study area that will be used for carrying capacity analysis of the land. Data collection methods used are image interpretation, field observations, interviews, and document review. Satellite imagery obtained information on land cover and land use and land used as a basis for analyzing the carrying capacity of agricultural land. The form of research is spatial descriptive, the analysis used is spatial analysis which is processed using GIS.

The research was conducted through three stages, namely: the pre-field stage, the field stage, and the post-field stage. At the pre-field stage, remote sensing imagery is interpreted to obtain information on land use and land cover of the study area, as well as the preparation of a base map and a map of tentative land units as an analysis unit or mapping unit. The use of land units as analysis units or mapping units is based on the consideration that one land unit has the same physical characteristics or characteristics regarding topography, soil type, geological conditions, and land use.

The main data sources of this research are Ikonos satellite imagery and ETM Landsat imagery. From the satellite imagery data obtained from land use and land cover in Sragen Regency, Sragen Regency Year and 2017. Secondary data used in this study are: location data of the study area obtained from the RBI Map, soil type data from the Karanganyar Regency Land Map scale 1: 50,000, rock type data from Geology Map Surakarta sheet and Ponorogo sheet scale 1: 100,000, slope data from slope maps interpreted by RBI Maps scale 1: 25,000, research area, as well as population data obtained from the Central Statistics Agency (BPS) Karanganyar Regency. The research population is the land in Sragen Regency, while the method of determining the sample is the area sampling method and the stratified random sampling method. The equipment used in this research are: (a) Data processing equipment in the form of a set of computers and printers, (b) ENVI (Environment for Vizualyzing Images) software version 4.3, (c) ArcView 3.3 software, (d) SPSS 12.0 software, (e) GARM GPSMap 76CSX GPS Receiver, (f) Field compass, (g) Digital camera, (h) Field fill table, and (i) Writing stationary

The analysis of land carrying capacity uses the model / approach of land capability for the allocation of land use and the land capability index (IKLw) approach. Determination of land capability in the study area, the unit of land is used as a unit of analysis. The land unit is obtained from overlaps maps of slopes, land maps, geological maps and land use maps. Next, determine the land capability class for each of these land units using parameters that have been determined in accordance with LH Regulation No. 17 of 2009, such parameters include slope, soil texture, soil drainage, effective soil depth, erosion, lots of gravel / rocks and the threat of flooding. The determination of the land capability class is done by the matching method. After determining the land capability class, then the land carrying capacity is determined using the land capability index approach (IKLw) uses the following formula: 

\[ IKLw = \frac{LWK \cdot 1-IV}{0.3 \cdot LW} \]
IKLw > 1, shows that the region has the ability to develop its land potential more optimally, especially for various types of cultivation areas while maintaining environmental balance. IKLw <1, shows that the area has more protective functions, especially protection against water systems and interference from problems of flooding, erosion, sedimentation, and water shortages.

3. Results and Discussion

3.1 Compile the data base for carrying capacity in Sragen Regency

The extraction of land use and land cover information used as a basis for the preparation of an agricultural database in Sragen Regency, specifically the analysis of the carrying capacity of agricultural land, was obtained from the interpretation of the IKonos Imagery and the ETM Landsat Imagery. Supported by processing and analyzing data using GIS, various maps are produced which are the results of the spatial analysis of the study area, namely: administrative maps, geological maps, slope maps, land type maps, land use maps, land cover maps, land unit maps, land capability maps, land capability maps, and land carrying capacity map. Based on the results of overlapping geological parameters, soil, slope, and land use, obtained 59 land units in the study area. Next, an analysis of land capability was carried out on 59 land units using parameters of slope, soil texture, drainage, effective depth, erosion, gravel / rock and flood. The land capability classification carried out in this study is grouped up to the land capability subclass. The land capability subclass is a grouping of land capability units that has the same type of dominant constraints or threats if used for agriculture as a result of soil, relief, hydrological and climate characteristics. The method used to classify the land capability sub-class in the research area is the Matching Method. Based on the results of data analysis using this method, there are 8 types of land capability classes at the level of land capability sub-classes in Sragen Regency. The land capability classes include IIes, Ilew, Ile, IIIw, IIIew, IVw, Ivs and VIv. Details of the area of land capability sub-classes in the study area is presented in Table 1:

| Sub Class Land Capability | Area (Ha) | Percentage (%) |
|---------------------------|-----------|----------------|
| IIes                      | 33.175,51 | 76,33          |
| Ilew                      | 1.556,64  | 3,58           |
| Ilesw                     | 285,82    | 0,66           |
| Ile                        | 7.860,01  | 18,09          |
| IIIw                      | 31,62     | 0,07           |
| IIIew                     | 37,68     | 0,09           |
| IVw                       | 284,04    | 0,65           |
| Ivs                       | 230,67    | 0,53           |
| Total                     | 43461,99  | 100            |
Land capability classes in the study area consist of 3 classes, including land capability class II, land capability class III and land capability class IV. The land capability in research area can be seen in figure 1.

The results of the analysis of land capability used as a basis for determining the carrying capacity of the study area. Carrying capacity of land is directly proportional to the ability of land. The higher the land capability class, the better the carrying capacity of the land, conversely the lower the land capability class, the lower the land carrying capacity. Carrying capacity of land is classified into 4 categories: very good, good, medium and low. The classification is based on the table relationship between land capability and land carrying capacity. The results of the classification of land carrying capacity in the study area are presented in table 2:

| Class Land Capability | Area (Ha)  | Percentage (%) | Land Carrying Capacity |
|-----------------------|------------|----------------|-----------------------|
| II                    | 42877,98   | 98,65          | Very Good             |

Figure 1. The Land Capability in Research Area
Based on the analysis of the carrying capacity of the land, there are four classes of land carrying capacity in the study area, which are very good, good, medium and low. Land with a very good carrying capacity is most commonly found with a total area of 42,877.98 hectares or 98.65 percent of the total area of the study. This land with excellent carrying capacity has high suitability for agricultural activities. This excellent agricultural land carrying capacity makes the research area listed as one of the rice barns in Central Java Province. Land with good carrying capacity has an area of 69.3 hectares or 0.16 percent of the total research area, while land with medium carrying capacity has an area of about 284.04 hectares or 0.66 percent of the total area of the study area. The last land class with poor carrying capacity has an area of 230.67 hectares or around 0.53 percent of the total area of the study.

The carrying capacity in research area can be seen in figure 2.
The results of the calculation of the carrying capacity of the land based on the land capability index (IKLw) of the study area have a value of 3.31. This means that Sragen Regency has the ability to develop its land potential more optimally, especially for various types of cultivation areas while maintaining environmental balance (IKLw > 1).

4. Conclusion

As an agrarian country, in Indonesia the availability of accurate and fast agricultural resource information is very important. Remote sensing imagery able to present agricultural resource information that is always up to date can be used as the main data source for the compilation of agricultural databases more effectively and efficiently. so it is very helpful for agricultural decision-makers and planners. The remote sensing method can also minimize fieldwork which usually requires a large amount of cost. So that in addition to fast and accurate remote sensing methods also tend to be more cost-effective and can cover a large area. Remote sensing data processing can be supported with the help of Geographic Information Systems (GIS), which have the ability to input, edit and analyze data, both spatial data and attribute data quickly and accurately.

The use of GIS is important, especially in terms of energy and time efficiency. In addition, GIS is very well used in the management of land resources, especially for monitoring purposes and for algometric databases. With GIS, the information generated will be more easily seen and analyzed in the context of land resource management. Through the integration between remote sensing and GIS it is expected that optimal spatial analysis results can be obtained for various purposes, one of which is spatial analysis of agriculture.

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References

[1] A Skidmore 2017 Environmental modelling with GIS and remote sensing (CRC Press)
[2] Sutanto 1992. Penginderaan Jauh Jilid I (Yogyakarta : Gadjah Mada University Press)
[3] L Somantri and Nandi 2018. Land Use: One of Essential Geography Concept Based on Remote Sensing Technology. IOP Conf. Ser. Earth Environ. Sci. 145 012039
[4] S Khanal, J Fulton, S Shearer 2017 An overview of current and potential applications of thermal remote sensing in precision agriculture Computers and Electronics in Agriculture no 139 pp 22-32
[5] Lillesand T and Kieffer RW 2004. Remote Sensing and Image Interpretation Fourth Edition (New York : John Willey and Sons, Inc.)
[6] B Ma 2017 Literature review on land carrying capacity of the coordinated development of population, resources, environment and economy AIP Conference Proceedings vol 1890, 1 pp 040106 (AIP Publishing LLC)
[7] Muta’ali Lutfi 2012 *Daya Dukung Lingkungan Untuk Perencanaan Pengembangan Wilayah* (Yogyakarta : Badan Penerbit Fakultas Geografi (BPFG) Universitas Gadjah Mada)

[8] Burrough PA 1987 *Principal of Geographic Information System for Land Resources Assessment* (Oxford: Clarenson Press)

[9] Aronoff Stan 1989 *Geographic Information System : A Management Perspective* (Canada: WDI Publications)