Mapping of environmental supporting capacity based on ecosystem services in Wajo Regency 2021

A R Makkasau¹, D Malamassam² and A Umar²

¹Forestry Science Study Program, Graduate School of the University of Hasanuddin
²Faculty of Forestry, Hasanuddin University

Email: rifqimakkasau11@gmail.com

Abstract. Population growth causes an increase in economic activity that occurs all the time. This has an impact on increasing the need for space for settlements and other needs to support human life. The increase in human demand for land encourages changes in land use which have an impact on changes in the ability of nature to support human needs. The increase in population and limited land area will result in an increase in the activity and intensity of the use of natural resources and an increase in the amount of waste that can disrupt the balance of the ecosystem. It can also pose a threat to the decrease in the carrying capacity of the environment. Wajo Regency has the potential of natural resources, especially in the agricultural sector. Most of Wajo Regency is fertile and has potential for agricultural development. This is a special concern for local governments in improving the farmers’ economy and supporting national food security. The rapid development also accelerates the conversion of land functions, and puts pressure on the sustainability of the food supply ecosystem. The results of the interpretation of Sentinel 2 Imagery (2020), Wajo Regency is dominated by rice fields (114,296 Ha). The landscape map of Wajo Regency is dominated by undulating, wavy folds structural plains, made of non-carbonate sedimentary rock. From data analysis using the Analytical Hierarchy Process (AHP) method for food supply, water supply, protection against natural disasters, as well as flow management and flood protection, five classification classes were obtained: very high, high, medium, low and very low.

1. Introduction

Population growth causes an increase in economic activity that occurs all the time. This has an impact on increasing the need for space for settlements and other needs to support human life. The increase in human demand for land encourages changes in land use which have an impact on changes in the ability of nature to support human needs. The increase in population and limited land area will result in an increase in the activity and intensity of the use of natural resources and an increase in the amount of waste that can disrupt the balance of the ecosystem. It can also pose a threat to the decrease in the carrying capacity of the environment. The increase in population and regional development has also led to an increase in the need for space, facilities and infrastructure, while the land area remains constant. This condition will encourage an increase in land use change, especially on agricultural land and forests. The high land conversion on agricultural land can reduce the carrying capacity of agricultural land [1].
Ecosystems have organized and provided natural resources for humans to use to fulfill their needs and welfare. These natural resources include ecosystem services or products that can support economic activities and human development. On the other hand, all economic and development activities that utilize or use natural resources will have an impact on the availability and condition of natural resources [2]. Economic or development processes also influence natural regulatory capacities. Although to some extent the ecosystem has a balance and the ability to recover naturally. The recommended use of the environment is in accordance with the carrying capacity of the environment, this will return the quantity and quality of natural resources to their initial capacity. On the other hand, the wrong use will cause the ecosystem to lose the ability to regulate and provide natural resources [3].

The ecosystem of Wajo Regency has a wealth of natural resources and a very potential environment. This is illustrated by the diversity of complex landscapes ranging from mountains and hills, plains, lakes, and coasts and seas. The great potential of these ecosystems results in a wealth of biotic resources and the culture of the community that upholds local traditions and harmony with the environment. The potential of natural resources, especially in the agricultural sector, is a special concern for local governments in improving the farmers’ economy and supporting national food security. However, the rapid development has resulted in more rapid land conversion, putting pressure on the sustainability of the food supply ecosystem. Therefore, it is necessary to conduct a study of carrying capacity based on ecosystem services in Wajo Regency.

2. Material and methods

2.1. Research site
The research was carried out for 3 (three) months starting from February 2021 to April 2021 in Wajo Regency, South Sulawesi Province. Geographically it is located between 3°39' - 4°16' S and 119°53' - 120°27' E

2.2. Research approach and type
This research is based on mapping with non-experimental research categories using survey methods, assessment by experts (Analytical Hierarchy Process) and GIS analysis. Spatial analysis uses administrative data from Wajo Regency, Wajo Regency land cover and Wajo Regency landforms to produce a map of ecosystem services. Data on ecosystem services becomes the basis for describing the harmony of spatial patterns with ecosystem services for food supply, water supply, flow and flood management and prevention and protection against natural disasters.

2.3. Data collection
Primary data include: (1) expert opinion (AHP), (2) image interpretation to produce land cover maps, (3) direct observation of image interpretation results. Secondary data is collected from several agencies according to what will be studied. The data includes administrative spatial data, land cover maps, and spatial pattern maps of Wajo Regency. The types of data needed and their sources in this study can be seen in table 1.

| No | Type of Data               | Source                                      |
|----|----------------------------|---------------------------------------------|
| 1  | Administration map of Wajo Regency | Indonesia Geospatial Portal 1 : 50,000 (tanahair.indonesia.go.id) |
| 2  | Land cover map              | Sentinel 2 imagery (2020)                    |
| 3  | Land form map               | Directorate of environmental impact prevention for regional and sector policies, Directorate general of forestry planning and environmental |
2.4. Research procedure

2.4.1 Land form mapping. Landform identification through visual interpretation of DEM data obtained from non-optical images [4,5] with the help of geological data, topographic maps [6] and high resolution optical images [7,8]. The image used in this study is a sentinel 2 image recorded in 2020. The landform map was prepared by considering morphology and morphogenesis. Classification of landforms on a scale of 1: 50,000 was carried out by following the ITC classification system [9].

2.4.2. Landcover mapping. Image interpretation is done manually based on the characteristic pattern of color/hue, texture, shape, size, and pattern. The image used in this study is the google earth imagery. The land cover classification used is from the Indonesian National Standard (SNI) 7645-1:2014 on land cover classification. Interpretation is done by manual digitization. Then it is verified through a ground check to determine the accuracy of the interpretation results.

2.4.3. Ecosystem services – based environmental carrying capacity analysis. Assessment of land types and land cover types is carried out using an assessment method carried out by experts who are competent in their fields. The weighting of the role and contribution of landforms and land cover to ecosystem services is carried out using the Analytical Hierarchy Process (AHP) method. AHP itself is a decision-making method using several variables with multilevel analysis [10].

The high value of ecosystem services indicates that the carrying capacity of the environment is also high. To obtain the value of ecosystem services, two methods are used, namely land form and land cover as the basis for mapping the carrying capacity and carrying capacity of the environment. To get the value of ecosystem services, weighting and comparison of land form with land cover is carried out on ecosystem services.

Assessment of land forms and land types is carried out by experts who in this case are Hasanuddin University lecturers. The assessment for each coverage and landform of ecosystem services is carried out by filling out a questionnaire, so that the weighting results of the experts are combined using the geometric average.

\[
f(Land\ Form,\ Land\ Cover) = f(wlt \times slt) + (wlc \times slc)
\]

**Information,**

- \(wlf\) : land form value
- \(slf\) : land form score
- \(wlc\) : landcover value
- \(slc\) : landcover score

The ecosystem services studied are those that are closely related to the priority issue of spatial planning in Wajo Regency. The selected ecosystem services are those related to cultivation areas and protected areas in the Regional Spatial Plan (RTRW). The selected ecosystem services are as follows:

1. Ecosystem services representing the RTRW cultivation area are food supply services and water supply services
2. Ecosystem services representing the RTRW protected area are services for regulating the flow of water and floods, regulating services in the prevention and protection of natural disasters. The value of each ecosystem service is between 0 to 1. Each value has a different class range due to the varying minimum and maximum values. Based on the distribution of the data on the value of ecosystem services obtained, it is further classified into 5 classes, namely very low, low, medium, high, and very high. To determine the classification of ecosystem services, it is based on the classification of natural breaks. The classification of ecosystem services can be seen in Table 2.

| No  | Classification | Description | Class Range |
|-----|----------------|-------------|-------------|
| 1   | Class 1        | Very Low    | Red         |
| 2   | Class 2        | Low         | Orange      |
| 3   | Class 3        | Middle      | Yellow      |
| 4   | Class 4        | High        | Light Green |
| 5   | Class 5        | Very High   | Dark Green  |

3. Result and discussion

3.1. Food supply ecosystem services
Food is a basic need for every living thing to survive. This makes the availability of food in an area an important thing and must always be guaranteed its availability. Nature was created consisting of various ecosystems that also provide various benefits for living things. One of these benefits is food supply services, namely everything that comes from biological sources, both plants and animals that can be used for human consumption.

| No  | Classification | Interval | Total        | %  |
|-----|----------------|----------|--------------|----|
| 1   | Very High      | 1.00     | 4,858.47     | 0.02 |
| 2   | High           | 1.81     | 38,723.68    | 15.53|
| 3   | Medium         | 2.61     | 43,659.84    | 17.51|
| 4   | Low            | 3.41     | 131,167.87   | 52.62|
| 5   | Very Low       | 4.21     | 30,842.94    | 12.37|
|     |                |          | 249,252.81   | 100.00|

Overall food supply ecosystem services in Wajo Regency are dominantly in the high potential class (39.26%), medium potential (28.31%) and very high potential (17.58%). This shows that the carrying capacity of the environment based on food supply in Wajo Regency is still very good, because the supply of food with low to very low potential is only 14.86%.
3.2. Water supply ecosystem services

Water supply ecosystem services are ecosystem services to provide ground water and surface water that can be used for human survival. In addition to food, another thing that is also a major need for humans is the availability of clean water. Clean water is also one of the benefits that can be obtained from the ecosystem. Naturally, clean water can come from surface water, such as rivers and lakes or from ground water.

Table 4. Water supply ecosystem services

| No | Classification  | Interval | Total Ha  | %  |
|----|-----------------|----------|-----------|----|
| 1  | Very High       | 1.00-1.81| 45,845.55 | 18.39 |
| 2  | High            | 1.81-2.60| 187,898   | 75.38 |
| 3  | Medium          | 2.61-3.40| 449.54    | 0.01  |
| 4  | Low             | 3.41-4.20| 1,106.01  | 0.44  |
| 5  | Very Low        | 4.21-5.00| 13,912.67 | 5.58  |
|    | Total           |          | 249,252.81| 100.00 |

Most of the land that has high water supply ecosystem service potential is located in valley landforms used for reservoirs, fluvial valleys, fluvial plains, fluvio-volcanic plains and volcanic foot slopes. The fluvial plain is composed of alluvial material which is capable of forming a potential aquifer, with a flat morphological support. This condition causes the reserves or availability of groundwater to be relatively shallow (< 10 m) which forms a groundwater reservoir or hydrogeological basin. Fluvial plains generally also have rivers that flow throughout the year with large flow rates. This makes the fluvial plain landforms have abundant water availability. Furthermore, fluvio-volcanic plains also have good water supply potential. Pyroclastic materials with the composition of sand, gravel, and gravel are compositions of materials that have high permeability, thus forming a potential aquifer. The flat to concave morphological support in this landform forms a soil reservoir or hydrogeological basin. This makes the fluvio-volcanic plain landform a potential source of clean water. Meanwhile, land that has low potential is mostly located in volcanic crater landforms, upper slopes of volcanic cones, denusadional volcanic cliffs, and marine plains.
3.3. Ecosystem services for flow and flood management
Ecosystem services for flow and flood management is ecosystem services to be able to capture water (infiltration) maximally and release it periodically so that these services are able to store and maintain water properly and control floods and droughts.

| No | Classification | Interval | Total |
|----|----------------|----------|-------|
|    |                | Ha %     |       |
| 1  | Very High      | 1.00 - 1.81 | 10886.79 | 4.36 |
| 2  | High           | 1.81 - 2.60 | 10.376.97 | 4.16 |
| 3  | Medium         | 2.61 - 3.40 | 58.610.85 | 23.51 |
| 4  | Low            | 3.41 - 4.20 | 161.089.89 | 64.63 |
| 5  | Very Low       | 4.21 - 5.00 | 8.247.26 | 3.30 |
|    | **Total**      | **249.252.81** | **100.00** |

Most of the land that has high potential in water management is located on the upper slopes of volcanic cones, denudational volcanic mountains and hills and fluvio-volcanic foot slopes. The landform is an area that is dominated by land cover in the form of extensive vegetation. Areas whose land use is dominated by forests have a high potential to absorb water. Vegetation in forest areas is able to accommodate rainwater and drain it into the ground, so that it becomes a groundwater reserve. The higher the density of vegetation, the more rainwater that can be captured. Most of the land that has low potential for water management is located on marine plains and volcanic craters. Volcanic craters cause low potential because they are not overgrown by vegetation.
3.4 Ecosystem services for prevention and protection against natural disasters

Ecosystem services that can function to prevent and protect humans from certain disaster threats, such as those from erosion, landslides, earthquakes, volcanic eruptions, or tsunamis. Ecosystems contain elements of regulation of natural infrastructure for the prevention and protection of several types of disasters, especially natural disasters. Places that have dense vegetation can prevent the area from erosion, landslides, abrasion, and tsunami disasters. In addition, specific landforms have a direct impact on the source of the disaster, such as erosion and landslide disasters that generally occur in structural and denudational landforms with hilly morphology.

Table 6. Ecosystem services for prevention and protection against natural disasters

| No | Classification | Interval | Total Ha | % |
|----|----------------|----------|----------|---|
| 1  | Very High      | 1.00 -  | 1.81     | 45,845.55 | 18.39 |
| 2  | High           | 1.81 -  | 2.60     | 187898    | 75.39 |
| 3  | Medium         | 2.61 -  | 3.40     | 449.54    | 0.3   |
| 4  | Low            | 3.41 -  | 4.20     | 1,106.02  | 0.40  |
| 5  | Very Low       | 4.21 -  | 5.00     | 13,912.67 | 5.58  |
|    | Total          |          |          | 249,252.81 | 100.00 |

Wajo Regency with dense vegetation cover. This makes this area able to prevent disasters such as landslides and erosion. Even so, efforts to keep this area from being damaged must continue, especially from the dangers of logging and forest burning. Most of the land that has low potential for prevention and protection from natural disasters is located on the middle and lower slopes of volcanic cones, foot slopes and fluvio-volcanic plains. Most of the land that has low potential is in the cover of paddy fields, industrial buildings, and settlements.
4. Conclusions

Wajo Regency is dominated by landforms originating from volcanic processes with the most dominant landforms being wavy folds structural plains made of non-carbonate sedimentary rocks (45.10%) and structural hills folds made of non-carbonate sedimentary rocks (21.44%). The main land cover in Wajo Regency in terms of area dominance, respectively, is rice field and dry land mixed with bush agriculture. The environmental carrying capacity based on ecosystem services in the 4 ecosystem services studied in Wajo Regency is dominated by high and medium classes. The environmental carrying capacity based on ecosystem services can be used as material to evaluate and improve the regional spatial plan (RTRW) of Wajo Regency.

Reference

[1] Wijaya I M H, Prasetyo L B and Rusdiana O 2015 Evaluasi Kesesuaian Dan Kemampuan Lahan Terhadap Rtrw Kabupaten Kotabaru, Kalimantan Selatan J. Pengelolaan Sumberd. Alam dan Lingkung. (Journal Nat. Resour. Environ. Manag. 5 148

[2] Rossiter D G 1996 A theoretical framework for land evaluation Geoderma 72 165–90

[3] Rachmawati T, Muta’ali L and Santosa W 2016 Kajian Daya Dukung Bioekologi Kawasan Puncak Kabupaten Bogor Maj. Geogr. Indones. 28 180–97

[4] Smith M J and Clark C D 2005 Methods for the visualization of digital elevation models for landform mapping Earth Surf. Process. Landforms 30 885–900

[5] Norris S L, Margold M and Froese D G 2017 Glacial landforms of northwest Saskatchewan J. Maps 13 600–7

[6] Mahardi R and Tjahjono B 2014 Penilaian bahaya lahar Gunung Salak (Suatu pendekatan morfometri) J. Lingkung. Dan Bencana Geol. 5 93–110

[7] Handayani L D W, Tjahjono B and Trisasonko B H 2013 interpretasi bentuklahan gunungapi guntur menggunakan citra ikonos J. Ilmu Tanah dan Lingkung. 15 76–83

[8] Handayani L D, Trisasonko B H and Tjahjono B 2015 Geomorphology analysis of lava flow of Mt. Guntur in West Java using Synthetic Aperture Radar (SAR) with fully polarimetry Procedia Environ. Sci. 24 303–7

[9] HTh V and RA van Z 1975 ITC-system of Geomorphological Survey. Enschede:
International Insitute for Aerial Survey and Earth Sciences *Int. Institute Aer. Surv. Earth Sci.*

[10] Saaty Thomas L 1993 Pengambilan Keputusan Bagi Para Pemimpin: Proses Hierarki Analitik Untuk Pengambilan Keputusan Dalam Situasi Yang Kompleks *Alih Bhs. Lili Setiono. Pustaka Binaman Press. Jakarta*