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# Mapping of Food Supply Ecosystem Services in Malang Regency

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**Abstract:** The increase in population is in line with the increase in resource use, including the need for land as a space for human activities to meet their needs. Land conversion, primarily agricultural land, into non-agricultural land can reduce the ability of land ecosystems to provide food. This research aims to assess the performance of ecosystem services for providing rice food in Malang Regency. The study used the Simple Additive Weighting (SAW) method, a simple weighting and scoring method of land use parameters, landform ecoregions, natural vegetation types, soil types, and rainfall to determine ecosystem services for food provision. The results showed that the Malang Regency area consists of 5 classes of Ecosystem Service Performance Index (ESPI) for rice food providers, including Very High, High, Medium, Low, and Very Low. The Medium class is the ESPI class with the highest area of 117,452.85 hectares or 34% of the total area. Followed by Low ESPI class 99,980.31 hectares (29%), High ESPI class 90,742.14 hectares (26%), Very Low ESPI class 19,191.28 hectares (6%), and Very High ESPI class 17,442.59 (5%).

**Keywords:** Ecosystem Services, Food Supply, Malang

## Introduction

Ecosystems, as providers of natural resources, can provide various benefits to support the needs of living things. The benefits humans receive directly or indirectly from ecosystems are called ecosystem services (Costanza R., et al., 1998). Ecosystem services act as a link between natural ecosystems and social systems that can be influenced by various factors of the natural environment, socio-economic, and human needs in the process of formation and development (Dade et al., 2019). Muta'ali (2019), argue that all living things depend on the resources and services the geosphere, biosphere, and ecosystems provide. The support of all human livelihood needs offered by nature in the form of food, water, energy, and so on is then referred to as the concept of ecosystem services.

The preservation of ecosystem services requires a balance in the quantity and spatial distribution of different land use types aligned with the needs of diverse stakeholders (Zou et al., 2021). Irrational or unbalanced land use can lead to changes in ecosystem structure and function, posing threats to ecological security and sustainable development (Du et al., 2023; Wang et al., 2019). It is reported that about 60% of the world's ecosystem services have been degraded or lost, and ecosystems are undergoing significant changes (MEA, 2005).

Along with the progress of society, human demand for ecosystem services is increasing (Cumming., et al., 2014). Therefore, the improvement of ecosystem services has become an urgent matter.

There are four ecosystem services overall as functional ecosystem services: provisioning services, supporting services, regulating services, and cultural services. As provisioning services, ecosystem services provide tangible products such as food, fiber, raw materials, water, genetic resources, minerals, and medicinal resources. The need for food from year to year is increasing because the number of humans continues to increase. The problem that often arises is that the increase in population causes a higher level of food consumption and is not balanced by the level of food production, which can threaten food security.

Malang Regency is an area that continues to experience development. Located directly adjacent to Malang City and Batu City, Malang Regency is also experiencing rapid trade, services, and tourism development. This has triggered a high increase in population growth. In the last decade, the population in Malang Regency has continued to increase yearly. In 2014, the population of this regency was recorded at 2,527,087 people, while in 2023, it was recorded at 2,730,601 people. This data shows that in the last 10 years, the population of this regency has increased by 203,514 people, with a population growth rate of 1.64 per year. The increasing population growth aligns with the increasing use of resources, including the need for land as an activity space (Septory et al., 2023; Hidayat & Rofiqoh, 2020). According to Malang Regency Regional Regulation No. 6 of 2015 concerning Sustainable Food Crop Land Protection, agricultural land in Malang Regency has shrunk by an average of 10-15 hectares per year in the last five years.

Land conversion, primarily agricultural land, into non-agricultural land can reduce the ability of land ecosystems to provide food. Currently, the role of ecosystem services is increasingly taken into account in the decision-making process to support the achievement of sustainable development. There has been much research on ecosystem services, especially as an approach to identifying the carrying capacity and capacity of the environment. Identification and analysis of carrying capacity and capacity has an approach where the higher the value of ecosystem services, the higher the capacity and capacity of the environment (MEA, 2005; Direktorat Pencegahan Dampak Lingkungan Kebijakan Wilayah dan Sektor, 2019). The ecosystem service valuation approach is a habitat determined by endogenous factors and exogenous factor dynamics characterized by ecoregion components and land cover (land use) as a value estimator (Muta'ali, 2015).

Ecosystem service assessment research generally focuses on ecoregion parameters, natural vegetation, and land cover (Ramadhani, 2024; Holik et al., 2022; Kurniawan, 2018). However, rainfall and soil type aspects have not explicitly been considered when assessing ecosystem services as food providers. These factors significantly influence agricultural productivity, especially in determining water availability, soil fertility, and environmental conditions that support the growth of food crops. In addition, this study utilizes spatial mapping technology to analyze the distribution and variation of ecosystem services in more detail. Therefore, this study proposes a more comprehensive approach by including rainfall and soil type parameters and integrating the Geographic Information System (GIS) method to produce a more accurate, holistic, and geospatial data-based spatial analysis.

Data and information on ecosystem services serve as a reference in natural resource management, environment, and development planning. In food provision, ecosystem services are essential to maintain the sustainability of ecosystems that support food production, such as soil fertility, water availability, and biodiversity balance. This study aims to determine the performance of ecosystem services for providing rice agricultural food in Malang Regency. Information on the performance of ecosystem services helps policymakers determine priority areas for restoring degraded ecosystems but still plays a role in providing food for the population.

## Methods

### A. Location

Malang Regency has the second largest area in East Java Province after Banyuwangi Regency, with an area of approximately 3,473.50 km2. Malang Regency consists of 33 sub-districts, with the district's capital city being Kepanjen Sub-district (**Figure 1**). Astronomically, Malang Regency is located between 112° 17', 10.90" East longitude to 112° 57', 00.00" East longitude and between 7° 44', 55.11" South latitude to 8° 26', 35.45" South latitude. Malang Regency borders seven regencies. The boundaries of Malang Regency are as follows:

1. north : Jombang, Mojokerjo, Pasuruan and Probolinggo
2. east : Lumajang
3. south : Indonesian Ocean
4. west : Blitar and Kabupaten Kediri
5. center (inner ring) : Malang City and Batu City

Together with Batu City and Malang City, Malang Regency is part of a regional unit known as Malang Raya (Malang Metropolitan Area). Such a geographical location causes Kabupaten Malang to occupy a strategic location, marked by the increasing transportation flow on the north and south routes that cross this region. In addition, the sub-districts directly adjacent to Malang City and Batu City continue to experience rapid development. Infrastructure development and rapid urbanization have the potential to put pressure on ecosystems. Therefore, ecosystem service valuation is important to understand the impact of these changes and ensure a balance between development and ecosystem sustainability.

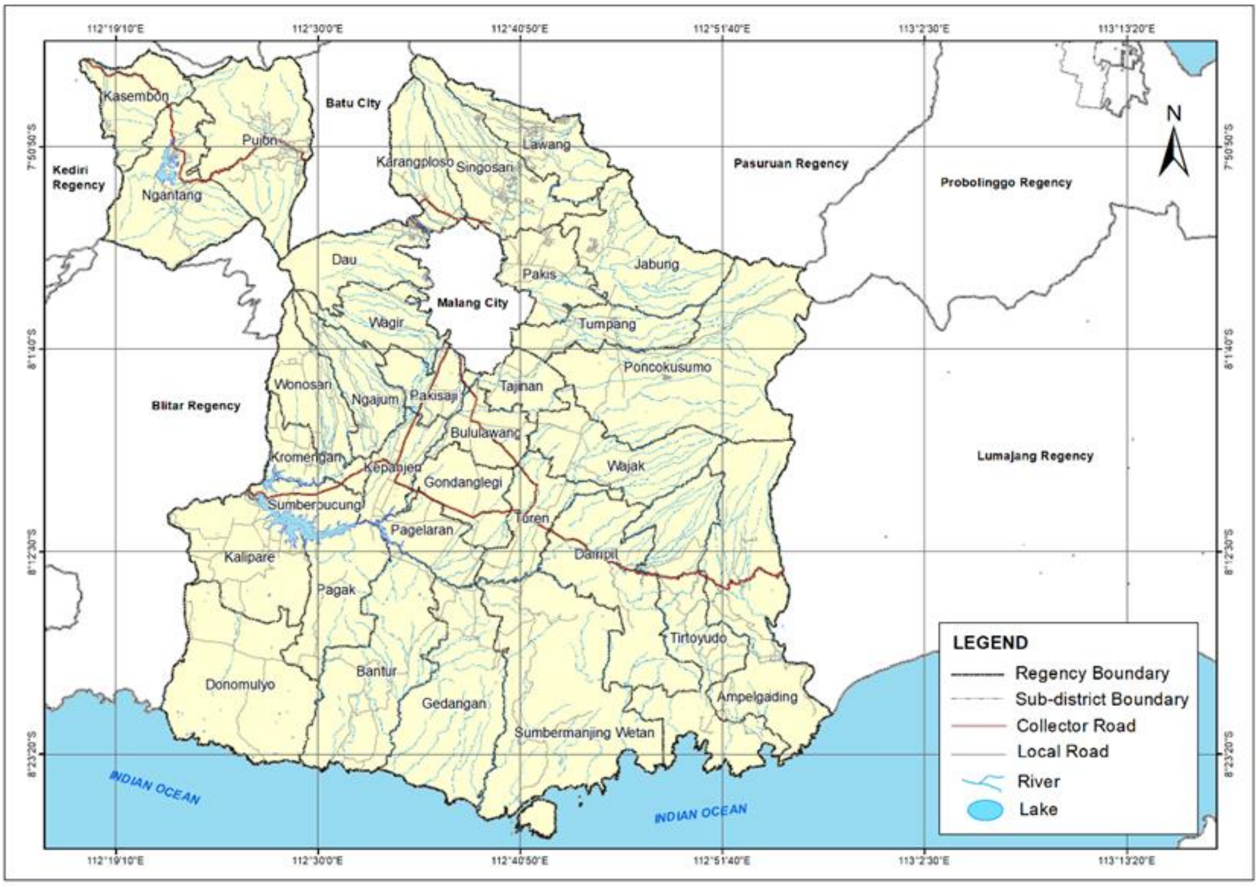


**Figure 1.** Research Location Map

## B. Methods

The stages and methods of data processing carried out in this study generally consist of three stages, namely: (1) typological inventory of each parameter, the purpose of which is to provide information on the condition of the studied area; (2) determination of scores and weights on each parameter; (3) spatial analysis and calculation of ecosystem service performance index, as well as visualization of results.

In the first stage, data inventory was carried out by collecting data in the form of secondary data obtained from the Directorate General of Planology, Ministry of Environment and Forestry of the Republic of Indonesia for landform ecoregion parameters and natural vegetation types; Geospatial Information Agency for land cover/use parameters; Agricultural Land Resources Instrument Standard Testing Center for soil type parameters; and Geophysical Meteorology and Climatology Agency for rainfall parameters. The secondary data are spatial data and tabular data.

The second stage of assessing and weighing ecosystem service parameters obtained from expert assessments from multiple disciplines can produce a comprehensive assessment (Maynard, et al., 2010). The experts involved in the assessment process comprised geomorphology, environmental, and agricultural experts. The assessment was carried out by filling in a questionnaire table arranged using a scale of 1 - 5 with the explanation that the greater the score, the greater the value, role, and contribution of each parameter to the potential carrying capacity of ecosystem services for food provision (Muta'ali, 2019). The weight of each parameter in this study is assumed to have the same value or importance.

Then, in the third stage, the ecosystem service performance index is calculated using the Simple Additive Weighting (SAW) method. The SAW method is often chosen in multi-criteria analysis because its calculations are simple, transparent, and easy to apply. In the SAW method, the value of each alternative is calculated by adding up the results of multiplying the criteria weights by the normalized values, so the process is easier than other methods, such as AHP or TOPSIS (K. Paul Yoon, 1995). The SAW method allows fast data normalization and can handle various criteria without complex calculations (Triantaphyllou, 2000). In addition, this method provides results that directly show the ranking of alternatives, making it easier for decision-makers to understand (Kusumadewi S. et al., 2006; Yudhistira, 2024). With its flexibility in various fields, the SAW method is ideal for decision support systems requiring fast and efficient processes. The mathematical modeling of the Simple Additive Weighting method is as follows.

**Ecosystem Service Performance Index** = Σ [(Ecoregion score + Natural vegetation type score + Land cover score + Soil type score + Rainfall score]

The calculation results from the equation above will produce a class interval grouping, which is then given a color based on the class of ecosystem services for food provision. Data processing, spatial analysis, and visualization of results using ArcGIS Desktop software and Microsoft Excel. The results will illustrate the spatial distribution of food provisioning ecosystem services in Malang Regency with five classes: low, low, medium, high, and very high.

## Results and Discussion

The potential of ecosystem services for food provision in Malang Regency shows the ability of an environment to provide food services, especially rice farming. The ecosystem service index of food provision is obtained based on the scoring approach of several parameters: landscape ecoregion, natural vegetation type, land use, soil type, and rainfall.

The link with food provisioning ecosystem services is that each parameter will have a different contribution or ability to provide food in Malang Regency.

**A. Ecoregions**

Malang Regency has a diverse landscape: highlands, lowlands, and hills. This diversity is influenced by its location, surrounded by several active and inactive mountains. In the east, the Tengger-Semeru plateau stretches from north to south at between 500 and 3,600m above sea level, while in the west, the Kawi-Arjuno plateau slopes at between 500 and 3,300m above sea level. This also reflects the various ecoregions that influence environmental conditions and ecosystems in the region. Malang Regency consists of 14 ecoregion units.

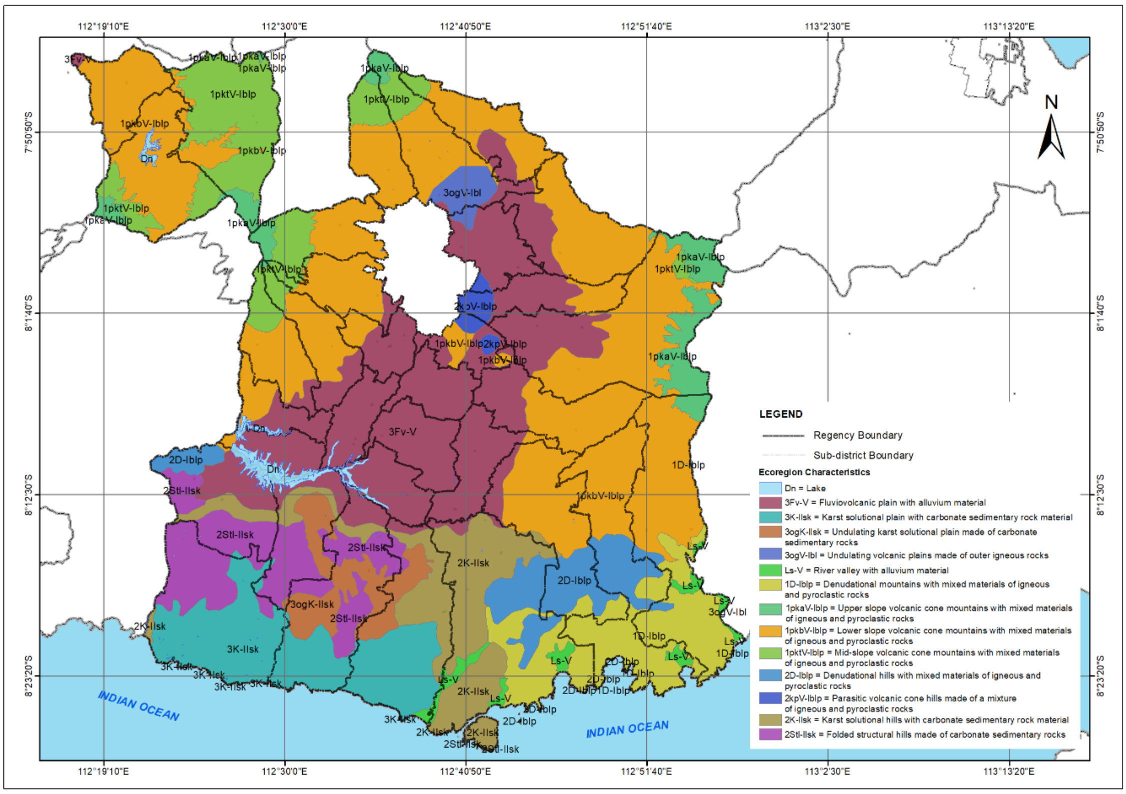


**Figure 2.** Ecoregion Map of Malang Regency

The lower slope volcanic cone mountain ecoregion, with a mixture of igneous and pyroclastic rocks, has the most extensive coverage in Malang Regency, 112,937.94 hectares. The fluviovolcanic plain ecoregion with alluvium and the river valley ecoregion with alluvium have the highest scores, meaning that these ecoregions have the most important contribution or role to food provision ecosystem services. Alluvium material has a gelatinous texture, crumbly structure, and very thick solum, and with abundant water availability. These conditions make this land fertile and suitable for agricultural land development (Kurniawan & Sadali, 2018). **Figure 2** presents the ecoregion distribution of Malang Regency; details of the area and ecoregion scores are in **Table 1**.

**Table 1**. Ecoregion area and scores

| Ecoregion | Area (hectares) | Score |
|---|---|---|
| Denudational mountains with mixed materials of igneous and pyroclastic rocks | 22,010.58 | 2 |
| Upper-slope volcanic cone mountains with mixed materials of igneous and pyroclastic rocks | 10,396.97 | 0 |
| Lower slope volcanic cone mountains with mixed materials of igneous and pyroclastic rocks | 112,937.94 | 4 |
| Mid-slope volcanic cone mountains with mixed materials of igneous and pyroclastic rocks | 24,654.99 | 2 |
| Denudational hills with mixed materials of igneous and pyroclastic rocks | 14,173.39 | 2 |
| Karst solutional hills with carbonate sedimentary rock material | 23,142.77 | 2 |
| Parasitic volcanic cone hills made of a mixture of igneous and pyroclastic rocks | 2,194.27 | 2 |
| Folded structural hills made of carbonate sedimentary rocks | 20,264.90 | 3 |
| Fluviovolcanic plain with alluvium material | 72,889.63 | 5 |
| Karst solutional plain with carbonate sedimentary rock material | 24,078.18 | 1 |
| Undulating karst solutional plain made of carbonate sedimentary rocks | 9,794.01 | 2 |
| Undulating volcanic plains made of outer igneous rocks | 3,012.20 | 3 |
| Lake | 2,397.03 | 3 |
| River valley with alluvium material | 3,115.69 | 5 |

## B. Types of Natural Vegetation

Natural vegetation is an important element in identifying and providing ecosystem services. Natural vegetation refers to native plants that grow naturally in an area without significant human intervention (Kartawinata, 2016). The existence of natural vegetation is an indicator of environmental quality and serves as a provider of various ecosystem services that support human life and other living things. There are 16 types of natural vegetation spread across Malang Regency. Pamah (nondipterocarp) forest vegetation has the widest distribution in Malang Regency, mainly in the central and southeastern parts of Kasembon and Ngantang Sub-districts. This vegetation develops in lowland drylands, characterized by leaves that fall or dry out during the dry season. This community consists of trees with a 30-45 meter height growing on yellow-red podzolic soils and various complex soils at 0-1,000 meters above sea level.

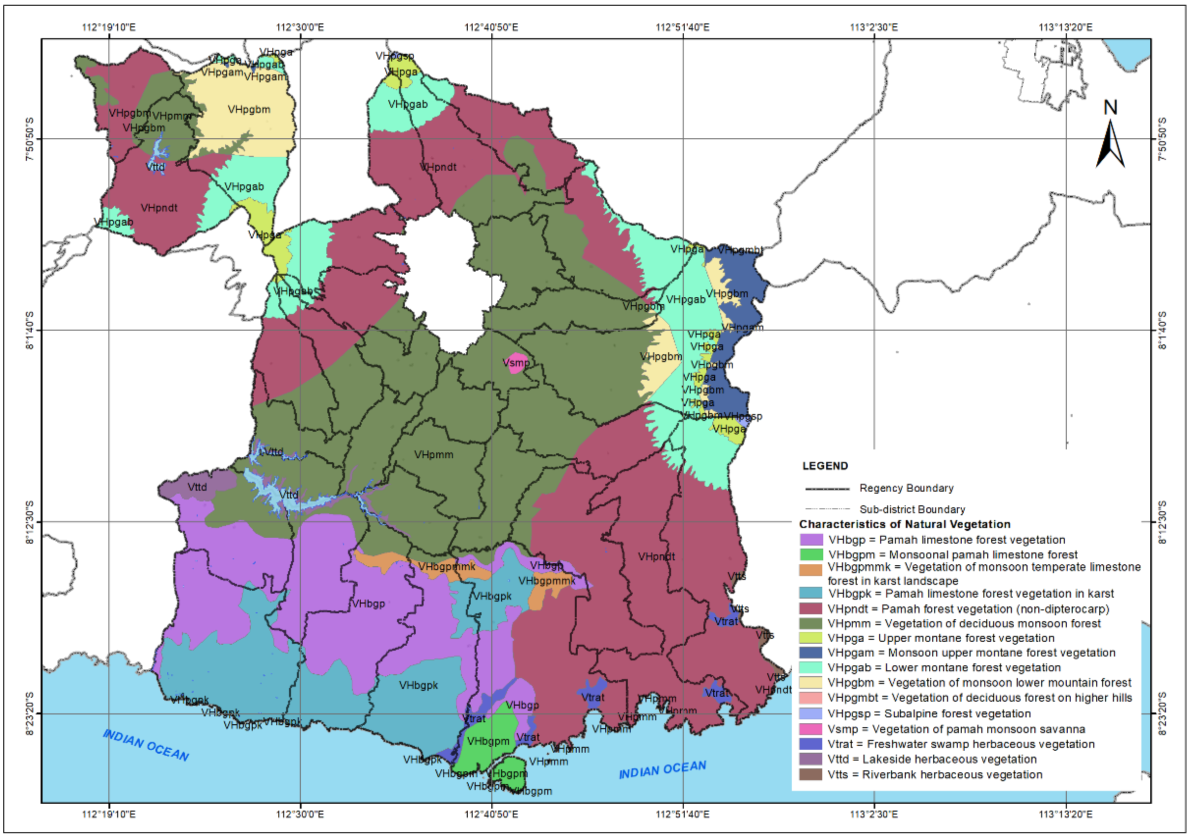


**Figure 3.** Map of Natural Vegetation Types of Malang Regency

**Table 2**. Area and score of natural vegetation types

| Natural Vegetation Types | Area (hectares) | Score |
|---|---|---|
| Pamah limestone forest vegetation | 41,945.08 | 2 |
| Pamah limestone forest vegetation in karst landscape | 28,566.36 | 2 |
| Vegetation of monsoonal Pamah limestone forest | 3,876.55 | 2 |
| Vegetation of monsoon temperate limestone forest in karst landscape | 2,891.87 | 2 |
| Upper montane forest vegetation | 4,289.52 | 0 |
| Lower montane forest vegetation | 28,347.67 | 0 |
| Monsoon upper montane forest vegetation | 5,526.10 | 0 |
| Vegetation of monsoon lower mountain forest | 12,224.96 | 1 |
| Vegetation of deciduous forest on higher hills | 2.40 | 2 |
| Subalpine forest vegetation | 195.00 | 1 |
| Vegetation of deciduous monsoon forest | 100,914.19 | 3 |
| Pamah forest vegetation (non-dipterocarp) | 108,645.07 | 4 |
| Vegetation of pamah monsoon savanna | 370.04 | 3 |
| Freshwater swamp herbaceous vegetation | 2,688.29 | 4 |
| Lakeside herbaceous vegetation | 4,146.69 | 4 |
| Riverbank herbaceous vegetation | 432.75 | 5 |

## C. Land Use/Land Cover

Land use plays an important role in ecosystem services because it reflects the potential result of any human intervention. Each type of land use has a beneficial value for ecosystem balance. In food provision, especially rice, the function value or contribution of benefits from each land use type is often related to food productivity, water conservation, and supporting ecosystems for wetland agriculture. Based on the land use/land cover map (**Figure 4**), moor/field is the land cover with the most extensive area coverage. Moor/field is a type of dry agricultural land usually used to grow secondary crops (such as corn, peanuts, and cassava) or horticultural crops (vegetables and fruits). Moor/field does not require waterlogging like paddy fields and relies on rainfall as the primary source of irrigation.

Most paddy fields in Malang Regency are located in the central part of the fluviovolcanic plain. According to Hardjowigeno et al. (2004), from the perspective of soil formation, areas with flatter slope classes tend to have shallower groundwater tables, so the soil is more often waterlogged. Therefore, areas with flatter slopes are more widely utilized as paddy fields. Conversely, the steeper the slope class, the deeper the water table tends to be. If the land's topography is on a slope of more than 15%, bench terraces must first be made for paddy fields. The detailed area and score of land use types can be seen in **Table 3**.

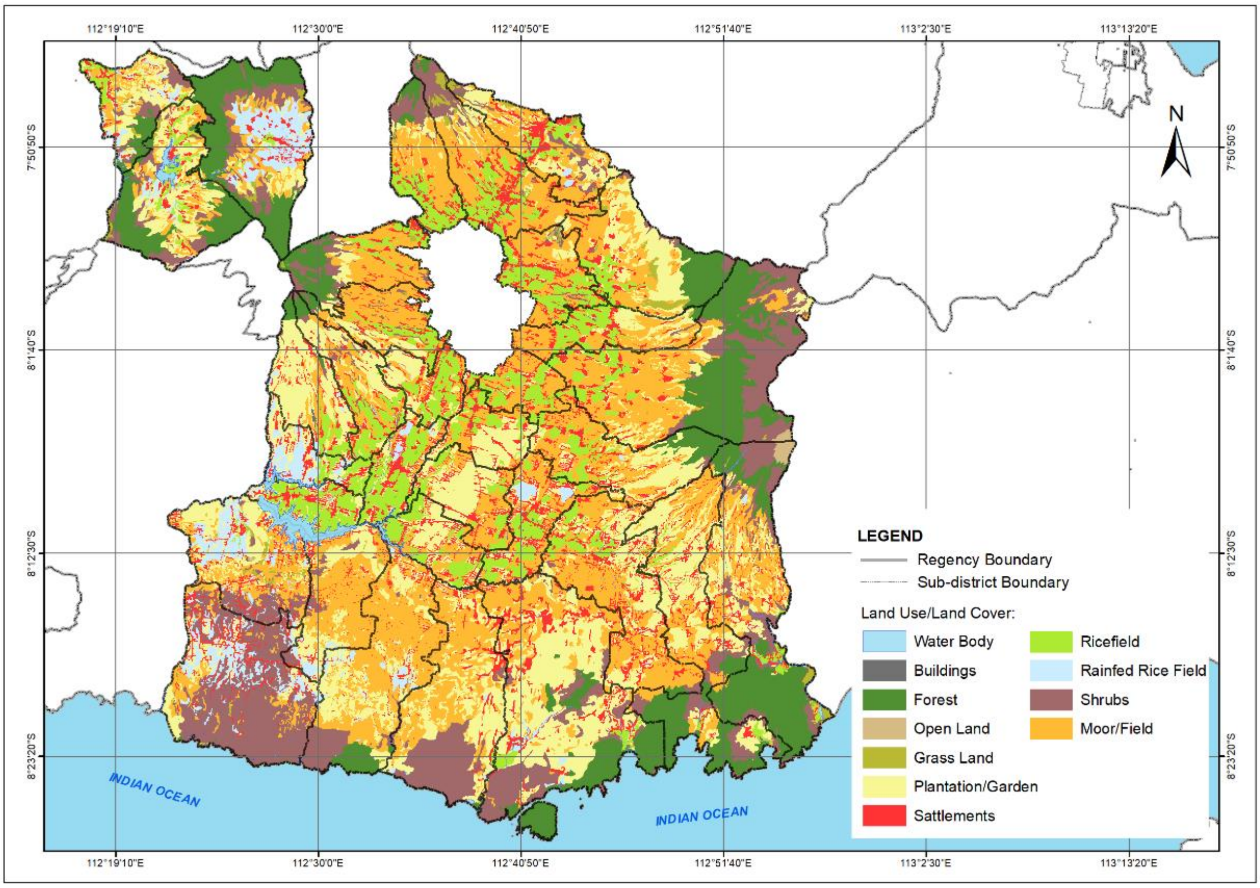


**Figure 4.** Land Use/Land Cover Map of Malang Regency

**Table 3**. Area and score of land cover/land use types of Malang Regency

| Land Use/Land Cover | Area (hectares) | Score |
|---|---|---|
| Settlements | 31,233.16 | 0 |
| Shrubs | 44,960.39 | 3 |
| Forest | 41,250.41 | 1 |
| Glassland | 3,034.74 | 3 |
| Water Body | 2,758.17 | 3 |
| Industrial/Office/Commerce Buildings | 148.50 | 0 |
| Open Land | 559.09 | 1 |
| Rainfed Rice Field | 11,708.69 | 5 |
| Ricefield | 32,227.46 | 5 |
| Moor/Field | 95,865.30 | 4 |
| Plantation/Garden | 81,832.51 | 2 |

**D. Soil Type**

Soil types play a vital role in ecosystem services because soil is the basis for various life-sustaining ecosystem processes. Soil type determines the level of fertility and nutrient availability that directly affects agricultural productivity (Sasongko, 2023). Fertile soils support plant growth and are a food source for humans and animals. According to data from the Center for Agricultural Land Resources, there are 14 soil types in Malang Regency.

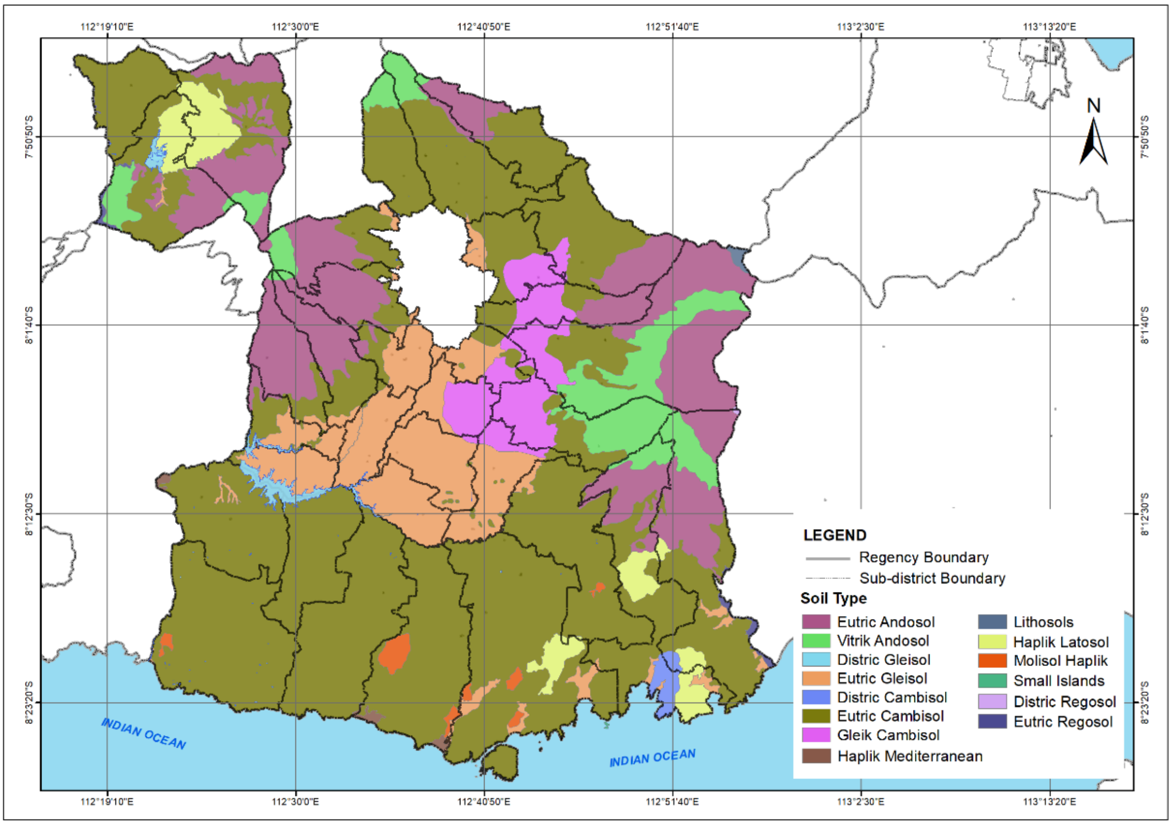


**Figure 5.** Soil Type Map Malang Regency

**Figure 5** shows the distribution of soil types in Malang Regency. The soil type with the highest score is the gleisol. This soil is scattered in the central part and has a flat, low-elevation topography. It is suitable for rice fields because it has a high organic matter content and can naturally retain standing water. However, these soils have labor-intensive drainage that requires proper drainage management.

**Table 4**. Area and score of soil type map Malang Regency

| Soil Type | Area (hectares) | Score |
|---|---|---|
| Eutric Andosol | 59,786.60 | 2 |
| Vitrik Andosol | 21,205.28 | 1 |
| Distric Gleisol | 100.91 | 5 |
| Eutric Gleisol | 38,226.41 | 5 |
| Distric Cambisol | 1,573.90 | 3 |
| Eutric Cambisol | 191,835.86 | 3 |
| Gleik Cambisol | 15,808.31 | 3 |
| Haplik Latosol | 10,921.54 | 1 |
| Lithosols | 310.69 | 1 |
| Haplik Mediterranean | 614.80 | 0 |
| Molisol Haplik | 2,029.06 | 0 |
| Small Islands | 46.82 | 0 |
| Distric Regosol | 45.95 | 0 |
| Eutric Regosol | 820.33 | 0 |

**E. Rainfall**

Rainfall is one of the factors that play a role in regulating ecological balance and supporting the various services provided by the ecosystem. The analysis of rainfall in Malang Regency was obtained from the interpolation of rainfall using the Inverse Distance Weighting method with the help of ArcGIS 10.8 software. The rainfall data used comes from 18 rainfall stations spread across Malang Regency. With more data from various rainfall stations, the spatial distribution of rainfall can be mapped more accurately, especially in areas with high topographic variations, such as Malang Regency. From the interpolation results in **Figure 6**, it can be seen that most areas of Malang Regency have annual rainfall of 1500-200 mm/year. Areas with this amount of rain have the potential to support increased biodiversity and agricultural productivity.

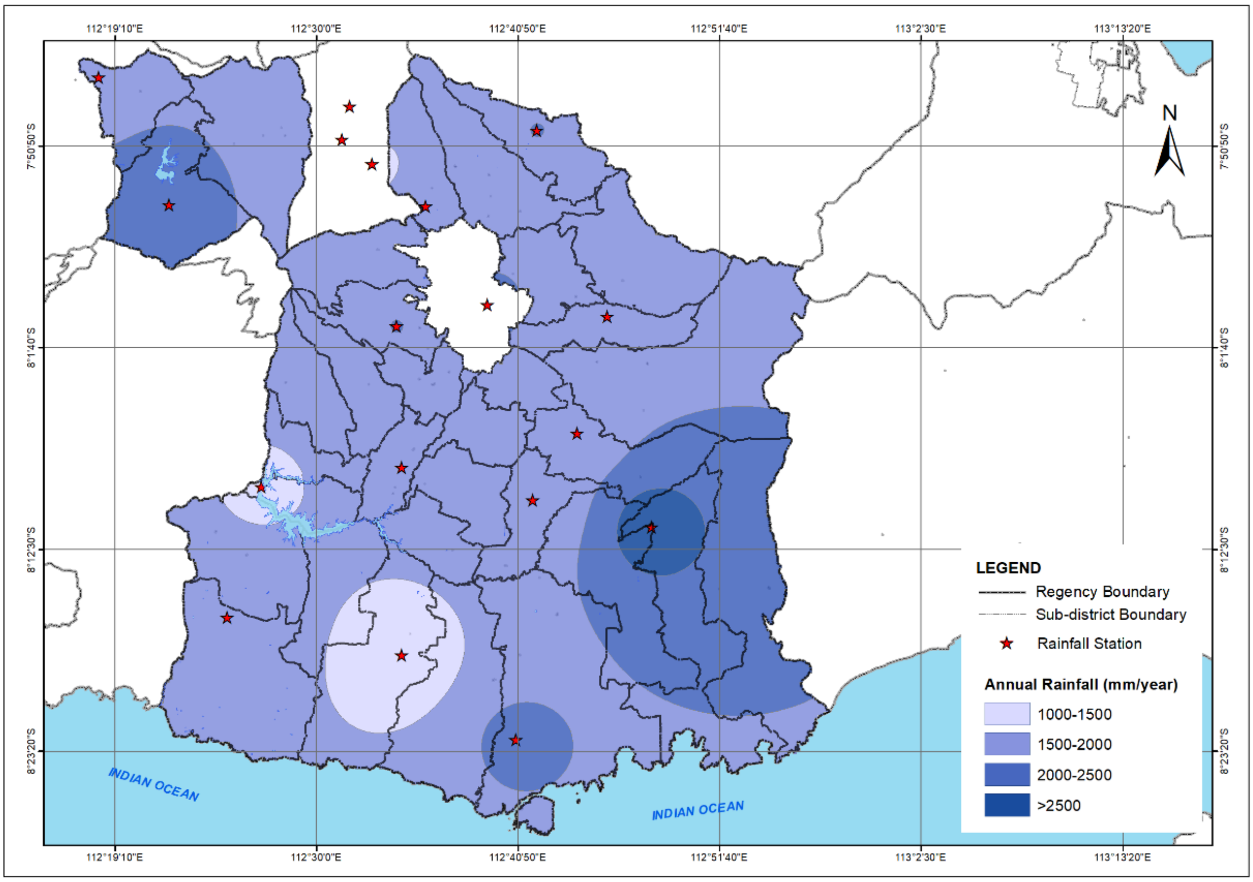


**Figure 6.** Rainfall Interpolation Map of Malang Regency

**Table 5**. Area and score of rainfall interpolation Malang Regency

| Rainfall (mm/year) | Area (hectare) | Score |
|---|---|---|
| 1000-1500 | 20,125.00 | 4 |
| 1500-2000 | 254,219.79 | 5 |
| 2000-2500 | 65,321.10 | 2 |
| >2500 | 5,953.62 | 0 |

## F. Ecosystem Services Mapping

Based on the analysis and calculation of the performance index of ecosystem services for food provision in Malang Regency, there are five classes: very low, low, medium, high, and very high. Each sub-district in Malang Regency has varied characteristics and environmental conditions. The characteristics of each parameter, including ecoregion, land use, vegetation, rainfall, and soil type, determine the class of ecosystem services that provide food in Malang Regency. Spatially, the ecosystem services providing food class are visualized in the map in **Figure 7**.

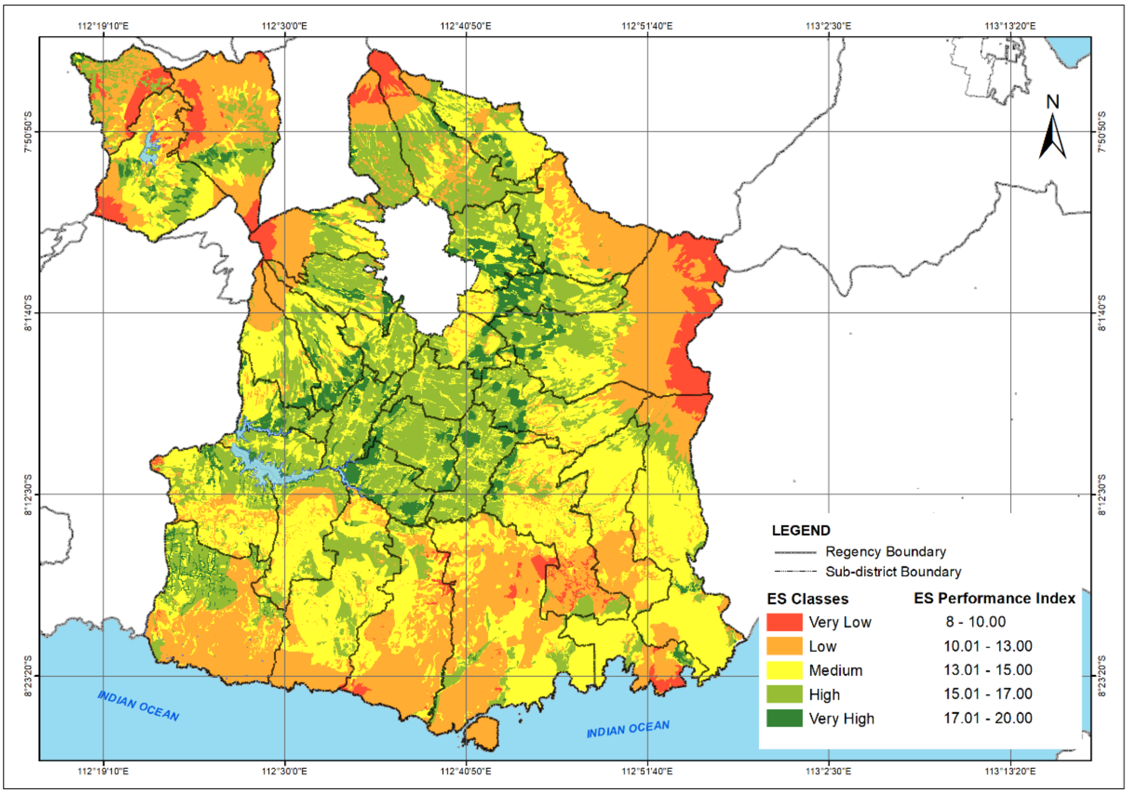


**Figure 7.** Map of Food Supply Ecosystem Services in Malang Regency

The Medium Ecosystem Services Performance Index (ESPI) class is the ESPI class with the highest area of 117,452.85 hectares or 34% of the total sub-district area. Followed by Low ESPI class 99,980.31 hectares (29%), High ESPI class 90,742.14 hectares (26%), Very Low ESPI class 19,191.28 hectares (6%), and Very High ESPI class 17,442.59 (5%). ESPI Class High to Very High is most widely spread in the fluviovolcanic plain ecoregion unit with alluvium material. This condition is very supportive for rice plants to grow optimally because the soil is fertile, rich in nutrients, and highly able to retain water. Alluvium material comes from river deposits carrying volcanic minerals, supporting rice growth. This is in line with the research of Febriarta & Oktama, (2020) and Sabila, (2020), the distribution pattern of ecosystem service performance with high values is mainly spread in the fluviovolcanic plain ecoregion unit.

Ecosystem service performance is relatively low in volcanic cone mountain ecoregion units with upper slopes and middle slopes consisting of mixed materials of outer igneous and pyroclastic rocks. This is due to the steep to very steep slope morphology that puts it at risk of soil erosion and makes it difficult to retain water. At upper slope elevations, water sources for irrigation may be limited, while rice requires adequate water supply during its growing period. Therefore, appropriate land management techniques, such as terracing and sound irrigation systems, are needed. Each class has a distribution of ecosystem service values with different areas in each sub-district presented in **Table 6**.

**Table 6**. Area of food supply ecosystem services based on sub-districts in Malang Regency

| No. | Sub-district | Area of Ecosystem Services Performance Index (hectares) | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Very Low | Low | Medium | High | Very High | |
| 1 | Donomulyo | 64.00 | 9,330.74 | 3,158.87 | 4,344.53 | 1,108.63 | 18.006,76 |
| 2 | Kalipare | 56.62 | 1,698.25 | 6,312.70 | 3,314.48 | 439.79 | 11.821,84 |
| 3 | Pagak | 191.62 | 1,281.52 | 5,230.68 | 2,258.92 | 95.4 | 9.058,15 |
| 4 | Bantur | 26.43 | 4,131.63 | 9,005.04 | 3,321.30 | 62.58 | 16.546,99 |
| 5 | Gedangan | 541.43 | 9,262.24 | 5,359.50 | 1,204.38 | 23.12 | 16.390,67 |
| 6 | Sumbermanjing | 650.22 | 14,743.59 | 10,185.53 | 1,684.19 | 67.1 | 27.330,64 |
| 7 | Dampit | 1,251.05 | 4,492.02 | 6,789.90 | 2,511.85 | 365.85 | 15.410,66 |
| 8 | Tirtoyudo | 539.52 | 4,921.17 | 10929.27 | 1,309.14 | 161.43 | 17.860,53 |
| 9 | Ampelgading | 732.43 | 3,757.10 | 13,202.04 | 1,949.58 | 163.61 | 19.804,77 |
| 10 | Poncokusumo | 5,087.04 | 10,017.66 | 4,876.26 | 4,515.11 | 1,111.04 | 25.607,11 |
| 11 | Wajak | 693.75 | 1,574.92 | 3,764.73 | 3,349.04 | 915.09 | 10.297,53 |
| 12 | Turen | 250.70 | 76.27 | 1,297.04 | 4,391.08 | 635.63 | 6.650,72 |
| 13 | Bululawang | 326.37 | 5.41 | 367.55 | 4,031.15 | 1.32 | 4.731,79 |
| 14 | Gondanglegi | 80.26 | 0.17 | 851.91 | 4,397.67 | 960.65 | 6.290,67 |
| 15 | Pagelaran | 94.08 | 0 | 831.39 | 2,581.16 | 1,608.45 | 5.115,09 |
| 16 | Kepanjen | 98.86 | 0.21 | 879.65 | 3,033.01 | 721.51 | 4.733,24 |
| 17 | Sumber Pucung | 114.58 | 43.96 | 1,183.43 | 2,535.11 | 274.99 | 4.152,07 |
| 18 | Kromengan | 368.92 | 206.74 | 1,461.22 | 1,618.47 | 773.46 | 4.428,80 |
| 19 | Ngajum | 156.74 | 949.69 | 2,418.42 | 2,141.65 | 1,157.39 | 6.823,89 |
| 20 | Wonosari | 26.06 | 1,636.73 | 2,939.81 | 1,941.85 | 298.77 | 6.843,22 |
| 21 | Wagir | 99.50 | 512.54 | 1,525.23 | 3,267.44 | 667.69 | 6.072,40 |
| 22 | Pakisaji | 16.17 | 53.22 | 1,657.90 | 2,494.54 | 84 | 4.305,82 |
| 23 | Tajinan | 49.68 | 231.51 | 1,863.60 | 1,407.54 | 513 | 4.065,33 |
| 24 | Tumpang | 143.04 | 8.39 | 2,321.17 | 2,529.11 | 1,309.83 | 6.311,54 |
| 25 | Pakis | 369.40 | 601.91 | 1,218.43 | 2,392.01 | 1,754.62 | 6.336,36 |
| 26 | Jabung | 158.13 | 6,220.48 | 3,053.91 | 2,147.13 | 354.92 | 11.934,57 |
| 27 | Lawang | 545.30 | 1,206.22 | 3,990.17 | 2,164.28 | 231.68 | 8.137,65 |
| 28 | Singosari | 1,114.86 | 2,414.65 | 1,864.41 | 5,627.42 | 256.88 | 11.278,22 |
| 29 | Karangploso | 550.05 | 1,888.42 | 265.71 | 3,730.85 | 76.84 | 6.511,87 |
| 30 | Dau | 752.96 | 3,022.66 | 2,060.79 | 1,614.92 | 128.67 | 7.580,01 |
| 31 | Pujon | 1,790.55 | 8,725.83 | 1,564.79 | 2,559.53 | 431.43 | 15.072,13 |
| 32 | Ngantang | 863.76 | 4,071.00 | 4,719.40 | 2,621.44 | 620.59 | 12.896,19 |
| 33 | Kasembon | 1,387.17 | 2,893.44 | 302.39 | 1,752.27 | 66.65 | 6.401,93 |
| **Total** | | **19,191.28** | **99.980,31** | 99,980.31 | 117,452.85 | 90,742.14 | 17,442.59 |

Sumbermanjing Wetan, Gedangan, and Donomulyo Sub-districts are located in the southern part, dominated by the landscape characteristics of plains to karst solutional hills with carbonate sedimentary rock material with considerable limestone mining potential. In this landscape, natural vegetation is dominated by pamah limestone forests and plants that can adapt to dry conditions. Crops, especially rice, are generally less suitable to grow in karst solutional areas with carbonate sedimentary rocks because these areas have low water retention, minimal soil fertility, high pH (alkaline), and shallow and rocky soil layers. Rice requires soils that can retain water and are rich in nutrients, while karst soils quickly absorb water and are poor in essential nutrients. So that these sub-districts have areas with low to very low ecosystem service classes that are pretty extensive. Similarly, research by Nugroho et al. (2020), in Gunung Kidul Regency is dominated by karst hilly areas that are difficult to store groundwater, making it difficult for agricultural land to get water. However, the community gets around this problem by planting crops in an intercropping manner to anticipate crop failure.

Most sub-districts with High to Very High grades are located in the central part of Malang Regency. This area is a unit of the fluviovolcanic plains ecoregion with alluvium and the plains of the foothills or lower slopes of volcanic mountains with pyroclastic materials. In addition, this plain generally has a relatively flat topography, making it easier for irrigation systems and land management. This area is also the Groundwater Basin of the Brantas watershed, which has a potential groundwater discharge of 5 to >10 liters per second (Poespowardoyo, 1984). This potential is the primary irrigation source, especially in the dry season. Abundant groundwater supports plant growth by providing sufficient moisture and maintaining soil fertility. In areas with High to Very High ecosystem service potential, there is a need for sustainable preservation of ecosystem functions because the challenges of land conversion due to the expansion of settlements, industry, and infrastructure can reduce the area of productive agricultural land.

In terms of area, the ecosystem service potential for food provision in Malang Regency is dominated by the Medium class. However, natural resources in the form of agricultural food products obtained from the High and Very High ecosystem service classes can provide benefits and help ensure food availability, especially rice. Rice is the leading agricultural commodity in Malang Regency, as seen from the high production of other food crops. Malang Regency can produce 484,613 tons of GKG rice, the highest produced by Donomulyo and Kepanjen Sub-districts. The total rice production in 2023 has decreased from the previous year; namely, in 2022 and 2021, the total rice production was 501,697 tons and 503,428 tons, respectively. Meanwhile, other commodities, such as corn, recorded a production value of 322,355 tons. Cassava production recorded a production value of 104,629 tons.

The potential for food production based on ecosystem services can be measured by multiplying the land area by ecosystem service class with productivity and planting frequency according to the ecosystem service class, where the Very High class, which is the majority of paddy fields, has the potential to be planted with rice 3 times while the High class, which is the majority of horticultural/secondary crop fields, has the potential to be planted with rice one planting period. The determination of planting potential is based on the type of land use and field observations. Potential calculations are only carried out on very high and high ecosystem service classes, considering that other ecosystem service classes have environmental risks if they are maximized to produce rice. Land in the Very High ecosystem service class is mainly utilized as a rice producer, while High-class land is developed for horticulture and secondary crops. The planting frequency, according to the ecosystem service class, is the potential of the land when planted with rice. The results of the calculation of food production potential with ecosystem services can be seen in **Table 7**.

**Table 7**. Rice production potential based on food supply ecosystem service class in Malang Regency

| No. | Sub-district | Ecosystem Services Classes | Planting Frequency per year | Area (ha) | Productivity (Kw/Ha) | Potential Rice Production (Ton) | Total |
|---|---|---|---|---|---|---|---|
| 1 | Donomulyo | Very High | 3 | 1,108.63 | 61 | 20,287.90 | 46,789.51 |
| | | High | 1 | 4,344.53 | 61 | 26,501.61 | |
| 2 | Kalipare | Very High | 3 | 439.79 | 61 | 8,048.09 | 28,266.43 |
| | | High | 1 | 3,314.48 | 61 | 20,218.34 | |
| 3 | Pagak | Very High | 3 | 95.4 | 61 | 1,745.82 | 15,525.26 |
| | | High | 1 | 2,258.92 | 61 | 13,779.44 | |
| 4 | Bantur | Very High | 3 | 62.58 | 64 | 1,201.63 | 22,457.98 |
| | | High | 1 | 3,321.30 | 64 | 21,256.35 | |
| 5 | Gedangan | Very High | 3 | 23.12 | 61 | 423.01 | 7,769.72 |
| | | High | 1 | 1,204.38 | 61 | 7,346.71 | |
| 6 | Sumbermanjing | Very High | 3 | 67.1 | 60 | 1,207.84 | 11,312.99 |
| | | High | 1 | 1,684.19 | 60 | 10,105.14 | |
| 7 | Dampit | Very High | 3 | 365.85 | 69 | 7,573.01 | 24,904.76 |
| | | High | 1 | 2,511.85 | 69 | 17,331.76 | |
| 8 | Tirtoyudo | Very High | 3 | 161.43 | 62 | 3,002.56 | 11,119.20 |
| | | High | 1 | 1,309.14 | 62 | 8,116.64 | |
| 9 | Ampelgading | Very High | 3 | 163.61 | 62 | 3,043.19 | 15,130.61 |
| | | High | 1 | 1,949.58 | 62 | 12,087.42 | |
| 10 | Poncokusumo | Very High | 3 | 1,111.04 | 65 | 21,665.23 | 51,013.43 |
| | | High | 1 | 4,515.11 | 65 | 29,348.20 | |
| 11 | Wajak | Very High | 3 | 915.09 | 64 | 17,569.75 | 39,003.62 |
| | | High | 1 | 3,349.04 | 64 | 21,433.86 | |
| 12 | Turen | Very High | 3 | 635.63 | 70 | 13,348.18 | 44,085.76 |
| | | High | 1 | 4,391.08 | 70 | 30,737.58 | |
| 13 | Bululawang | Very High | 3 | 1.32 | 68 | 26.85 | 27,438.66 |
| | | High | 1 | 4,031.15 | 68 | 27,411.81 | |
| 14 | Gondanglegi | Very High | 3 | 960.65 | 67 | 19,309.08 | 48,773.49 |
| | | High | 1 | 4,397.67 | 67 | 29,464.41 | |
| 15 | Pagelaran | Very High | 3 | 1,608.45 | 68 | 32,812.41 | 50,364.31 |
| | | High | 1 | 2,581.16 | 68 | 17,551.90 | |

| No. | Sub-district | Ecosystem Services Classes | Planting Frequency per year | Area (ha) | Productivity (Kw/Ha) | Potential Rice Production (Ton) | Total |
|---|---|---|---|---|---|---|---|
| 16 | Kepanjen | Very High | 3 | 721.51 | 71 | 15,368.18 | 36,902.54 |
| | | High | 1 | 3,033.01 | 71 | 21,534.36 | |
| 17 | Sumber Pucung | Very High | 3 | 274.99 | 68 | 5,609.87 | 22,848.59 |
| | | High | 1 | 2,535.11 | 68 | 17,238.72 | |
| 18 | Kromengan | Very High | 3 | 773.46 | 69 | 16,010.65 | 27,178.07 |
| | | High | 1 | 1,618.47 | 69 | 11,167.42 | |
| 19 | Ngajum | Very High | 3 | 1,157.39 | 65 | 22,569.07 | 36,489.77 |
| | | High | 1 | 2,141.65 | 65 | 13,920.70 | |
| 20 | Wonosari | Very High | 3 | 298.77 | 65 | 5,826.07 | 18,448.09 |
| | | High | 1 | 1,941.85 | 65 | 12,622.02 | |
| 21 | Wagir | Very High | 3 | 667.69 | 63 | 12,619.32 | 33,204.21 |
| | | High | 1 | 3,267.44 | 63 | 20,584.90 | |
| 22 | Pakisaji | Very High | 3 | 84 | 69 | 1,738.71 | 18,951.01 |
| | | High | 1 | 2,494.54 | 69 | 17,212.30 | |
| 23 | Tajinan | Very High | 3 | 513 | 63 | 9,695.70 | 18,563.20 |
| | | High | 1 | 1,407.54 | 63 | 8,867.50 | |
| 24 | Tumpang | Very High | 3 | 1,309.83 | 68 | 26,720.45 | 43,918.42 |
| | | High | 1 | 2,529.11 | 68 | 17,197.97 | |
| 25 | Pakis | Very High | 3 | 1,754.62 | 68 | 35,794.28 | 52,059.93 |
| | | High | 1 | 2,392.01 | 68 | 16,265.65 | |
| 26 | Jabung | Very High | 3 | 354.92 | 66 | 7,027.41 | 21,198.45 |
| | | High | 1 | 2,147.13 | 66 | 14,171.04 | |
| 27 | Lawang | Very High | 3 | 231.68 | 65 | 4,517.67 | 18,585.48 |
| | | High | 1 | 2,164.28 | 65 | 14,067.81 | |
| 28 | Singosari | Very High | 3 | 256.88 | 65 | 5,009.14 | 41,587.40 |
| | | High | 1 | 5,627.42 | 65 | 36,578.26 | |
| 29 | Karangploso | Very High | 3 | 76.84 | 65 | 1,498.41 | 25,748.94 |
| | | High | 1 | 3,730.85 | 65 | 24,250.53 | |
| 30 | Dau | Very High | 3 | 128.67 | 61 | 2,354.69 | 12,205.69 |
| | | High | 1 | 1,614.92 | 61 | 9,851.00 | |
| 31 | Pujon | Very High | 3 | 431.43 | 60 | 7,765.66 | 23,122.83 |
| | | High | 1 | 2,559.53 | 60 | 15,357.17 | |
| 32 | Ngantang | Very High | 3 | 620.59 | 64 | 11,915.33 | 28,692.54 |
| | | High | 1 | 2,621.44 | 64 | 16,777.21 | |
| 33 | Kasembon | Very High | 3 | 66.65 | 68 | 1,359.75 | 13,275.18 |
| | | High | 1 | 1,752.27 | 68 | 11,915.43 | |
| **Total** | | | | | | | **936,936.08** |

The potential for rice production based on the performance of ecosystem services for food provision in Malang Regency shows considerable potential. The total potential for rice production is almost twice the potential for existing rice, which is 936,936.08 tons. It is important to utilize this agricultural potential properly to improve food security, farmers' welfare, and regional economic growth, as well as to prevent various threats to the agricultural sector. Some of the threats faced by Malang Regency include the threat of a decrease in the area of wet-rice agricultural land due to land conversion for other purposes. An example is the case of agricultural land in Karangwidoro Village, Dau Sub-district, which has experienced land conversion. The results of the analysis of Kawirian., (2020), this shows that in the period of 9 years (2019-2019), there has been a decrease in the area of agricultural land in Karangwidoro Village. 14.48% of the village's agricultural land decreases yearly, and 6.8% turns into settlements. The high demand for space for urban activities also drives land conversion in Malang Regency. As a result, the growth of Malang City began to expand from the city center (urban sprawl) and spread to peripheral areas, including the Karangploso Urban Area in Malang Regency. Research by Aprildahani et al. (2014), showed that between 2010 and 2013, the area of irrigated rice fields decreased by 60.7 hectares, while that of fields decreased by 0.93 hectares. This conversion of agricultural land occurred for the development of residential areas, trade, services, and industry.

In addition, land use change is also rampant in the Dau Sub-district, which is close to Malang City and the campus of Muhammadiyah University of Malang. As the number of students in Malang City increases, the need for space to study, discuss, or socialize also increases. Since 2015, many agricultural lands have been converted into cafes. The contributing factor is that the rental price of land for cafes can be 2 to 3 times greater than the results of farming with one harvest. So many rice field owners choose to rent their land for cafes rather than for the agricultural sector (Samsi et al., 2022).

Challenges in rice production are also caused by climate change in Malang Regency. The results of research by Ruminta & Nurmala (2018), shows an increase in air temperature of 0.7-0.8°C, and the Oldeman climate classification has shifted from class C3 to C2. Climate shifts greatly affect the availability of water, the growth period, and the types of plants that can be cultivated. This also significantly impacts the risk of decreased rice production in the Greater Malang area. In the dry season of 2024, farmers in Donomulyo and Sumbermanjing Wetan sub-districts will find it difficult to grow rice due to the drying up of rivers caused by the long dry season. Of the approximately 1,600 hectares of paddy fields, 245 hectares in Tulungrejo Village, Donomulyo Sub-district, stopped production because the water available from cave sources was only enough for daily needs.

## Conclusion

The development of a map of ecosystem services as food providers in Malang Regency using landscape ecoregion parameters, natural vegetation types, land cover/use, soil types, rainfall, and simple additive weighting analysis resulted in five classifications of ecosystem service performance. The high capacity of food provisioning ecosystem services is mainly shown in areas with mountainous lower slope ecoregions and fluviovolcanic plains. These areas are characterized by sloping to flat morphology, fertile soil, and good water storage, resulting in high productivity potential for rice cultivation. Low to very low food provisioning ecosystem services capacity is distributed in areas with mountainous upper slope ecoregions and karst solutional plains. Based on the results of this study, cooperation between the government and the community is needed to pay more attention to ecosystem security, especially food-providing land such as rice fields from land conversion. In addition, there is a need for land conservation in areas with low ecosystem capacity and efforts to utilize and apply agricultural cultivation technology innovations to increase ecosystem capacity to produce food.

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