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WATER CARRYING CAPACITY BASED ON ECOSYSTEM SERVICES IN URBAN AGRICULTURE OF PALU

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ABSTRACT

Urban agriculture grows increasingly in tropical countries. It develops not only to feed the growth of the population but also to provide green space, biodiversity, and recreational landscaping. However, developing urban agriculture is facing the problem of water provision. This study examines the existence of agricultural land in Palu, investigates the distribution of agricultural land use in each district, and analyzes the status of environmental carrying capacity for provisioning water. The environmental carrying capacity for provisioning water was assessed based on ecosystem services analysis. The total area of agricultural land in Palu is 5,892.06 ha or about 16.52% of the total area, which spreads in all districts. Three districts recorded have the more extensive agricultural lands, Mantikulore, Tawaeli, and North Palu, of each, has 2188.12 ha (14%), 1090.89 ha (18.51%), and 723.88 ha (12.29%) respectively. The status of water carrying capacity ranged from moderate to high levels, covering an area of 5,189.95 ha or 88.08% of the total area of agricultural land. The low carrying capacity of water provision covers 689.31 ha or about 11.84% of the total agricultural land. The district of West and South Palu calculated to have the highest carrying capacity. However, both districts experienced a decrease in agricultural land space due to urban development. This study's finding contributes to essential data for relevant authorities in decisions making for sustainable development of urban agriculture in Palu.

Keywords: Agriculture, Palu, Provision, Water.

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INTRODUCTION

Apart from being used for drinking and household purposes, water is also used in other life aspects, namely for agriculture, plantation, housing, industry, and tourism (Hoekstra, 2015; Saccon, 2018; Winkler, 2019). The concept of water carrying capacity (WCC) has been defined. For instance, WCC status shows the area's estimated water level with existing needs and their socio-economics activities (Liu et al., 2012; Qin et al., 2016). Improper management can harm the water. This can also pose challenges to the environment that require support for the exceeded. See, for example, few flood case in Indonesia (Fulazzaky, 2014; Marfai et al., 2015; Siswanto and Francés, 2019). This requires an area to be able to maintain adequate water resources.

As the capital of the province of Central Sulawesi, Palu is one of the cities that continues to grow, which is accompanied by a significant population growth each year. The increasing population in Palu has differences between activities and needs related to water use, which has an impact on the water carrying capacity in the area of Palu. One form of utilization of water supply ecosystem services in Palu is to fulfill irrigation needs on agricultural land, which until now has maintained its existence as productive land, and some of it has the status of sustainable food agriculture land.

According to Regulation of the Minister for the Environment Number 17 of 2009 Article 1, the environment's carrying capacity is the ability of the environment to support the lives of humans and other living creatures. The carrying capacity of the environment that comes from nature, such as the carrying capacity of water, is a factor that takes part in ordering the community's welfare. Determination of the amount of environmental carrying capacity is carried out by looking at the environment's capacity to fulfill and support human space activities to ensure their survival (Hui, 2006; Pulselli and Coscieme, 2014; Grunewald and Bastian, 2015).

One approach that can be used in determining the carrying capacity of the environment is the ecosystem services approach. In this case, the provision of water by the natural environment is a form of ecosystem service, and the assumption is that the higher the value of ecosystem services in an area, the higher the carrying capacity of the environment (Ash et al., 2010; Grunewald and Bastian, 2015). Analysis of ecosystem services is an alternative approach in determining the status of the water carrying capacity that is easier, cheaper, and specifically based on existing conditions by referring to the ecoregion, land cover, and the type of native vegetation around agricultural land in Palu.

So far, in determining the carrying capacity of water for agricultural activities, climate data is commonly used (Ramirez-Villegas and Challinor, 2012; Parkes et al., 2019), especially in rainfall data obtained from weather observation stations. In this research, in determining the carrying capacity of water. The ecosystem services approach can be an alternative or complement to existing methods or is often used to determine the natural carrying capacity of water supply based on the character of the landscape, land cover, and native vegetation types. The most common form of presenting information on ecosystem services is in the map. The ecosystem services map is a tool for policymakers to identify ecosystem services' spatial distribution and the linkages or relationships between one ecosystem service and another (Maes et al., 2012; Vorstius and Spray, 2015; Stępniewska, 2016). The map can be used for special needs in environmental management and spatial planning based on the environment's carrying capacity. A map has advantages on visualizing the carrying capacity of the environment based on ecosystem services. This study analyzed the water carrying capacity status based on water supply ecosystem services on agricultural land Palu and plotted in maps.

MATERIALS AND METHODS

Study Site

This study was conducted from December 2019 to April 2020, located in the city of Palu's administrative area. Palu is located around the equator. Geographically it is located at coordinates 0° 36"- 0° 56" south latitude and 119° 45"- 121° 1" east longitude. Based on data from the meteorological station of Palu, the average rainfall of Palu is 48.58 mm year^{-1}, the highest rainfall occurs in July, namely 94 mm, the number of rainy days is 11 days with 76% irradiation time, the lowest rainfall occurs in December is 9 mm, the number of rainy days is 19 days with a long exposure to 47%. The average air temperature is between 28.0°C - 30.8°C where the minimum temperature is in November 22.6°C, and the maximum temperature is in October and December which is 33.9°C (Statistics of Palu City, 2020).

Stage of analysis and Data Sources

The following stages were used in analyzing the carrying capacity of water-based on ecosystem services in Palu.

1. Identification of the distribution of agricultural land in Palu based on spatial data using a geographic information system.
2. Calculation and production of service/performance map of environmental services as an indicative carrying capacity status for water supply on agricultural land in Palu.

The following data were used in this study.

1. Map of Palu's ecoregion with an information scale of 1:50,000, source from the Environmental Office of Palu City.
2. Map of Palu's natural vegetation types, information scale of 1:250,000, source from the Directorate of Environmental Impact Prevention for Regional and Sector Policy, Directorate General of Forestry Planning and Environmental Planning, Ministry of Environment and Forestry, 2017.
3. Land cover map of Palu with an information scale of 1:50,000 in 2018. The source of the updating of the land cover data on the thematic map of the land cover of Palu provided in the Regional Spatial Planning document of Palu.
4. Map administration boundary of Palu with information scale 1:50,000. Sources from the revised Regional Spatial Planning document of Palu.
5. Map of sustainable food agriculture land. Sourced from the revised Regional Spatial Planning document of Central Sulawesi Province.
6. Map of rice fields sourced from the Cipta Karya and Water Resources of Central Sulawesi Province.
7. The score of landscape classification types, vegetation types, and land cover for each environmental services—source: Directorate General of Forestry Planning and Environmental Management, Ministry of Environment and Forestry, 2017.
8. Ecoregion, vegetation type, and land cover weight in each environmental service. Source: Directorate General of Forestry Planning and Environmental Management, Ministry of Environment and Forestry, 2017.

Calculation of Ecosystem Services Index and Water Support Capacity

The ecosystem services index is calculated based on ecosystem services' performance to determine the nature supply (availability). The calculation of environmental service performance uses three parameters: ecoregion, vegetation type, and land cover. The mathematical model used in spatial analysis to determine environmental services' performance is the simple additive weighting method (Regulation of the State Minister for the Environment No. 17/2009).

Performance of Ecosystem Services
= f {Ecoregion, Vegetation, Land Cover}
= (WEc × EcS) + (WVeg × VegS) + (WLC × LCS)

Where WEc is the weight of the ecoregion, EcS is ecoregiom score, WVeg is weight of vegetation, VegS is vegetation score, WLC is weight of land cover, and LCS = land cover score.

The scoring and weights used in calculating the performance of water supply ecosystem services in Palu were sourced from the Directorate of Environmental Impact Prevention of Regional and Sector Policies, Directorate General of Forestry Planning and Environmental Planning, Ministry of Environment and Forestry, 2017, with a predetermined depth of spatial analysis of 1: 250,000 for the scoring and weight of Sulawesi Island.

Table 1. Weight of Environmental Services for Water Supply for Landscapes Components, Weight.

Assessment Components	Weight
Ecoregion	0.28
Native vegetation type	0.12
Land cover	0.6

The carrying capacity of water is represented in the form of an index. Namely, the ecosystem services index, which is the result of calculating the performance of ecosystem services based on the three parameters mentioned above (Regulation of the State Minister for the Environment No. 17/2009). The results of the qualitative calculation of the environmental services index will have a value range from one to five, namely:

- Very high = 4.21 - 5.00
- Height = 3.41 - 4.20
- Moderate = 2.61 - 3.40
- Low = 1.81 - 2.60
- Very low = 1.00 - 1.80

RESULTS AND DISCUSSION

Results

Agricultural Land of Palu

Data on the distribution and area of agricultural land in this study were obtained from the analysis of geographic information systems by overlaying several spatial data sources, namely the land cover, agriculture land, and sustainable food, and rice field maps. Data on the distribution and area of agricultural land in Palu is provided in Table 2. The spatial distribution data can be seen in Figure 1.

Based on the data presented above, agricultural land in Palu covers an area of 5,892.06 ha or around 16.52% of the total area of Palu. The agricultural land is spread across all districts in the city of Palu. Approximately 67.94% of the total agricultural land area in Palu are located in three districts that have the highest agricultural land area, namely Mantikulore District, Tawaeli District, and North Palu Subdistricts. Each of has 2,188.12 ha (37.14%), 1,090.89 ha (18.51%), and 723.88 ha (12.29%) of agricultural lands respectively.

Table 2. Distribution and Area of Agricultural Land in Palu.

District	Land Area	
	Ha	%
Mantikulore	2,188.12	37.14
West Palu	462.35	7.85
South Palu	537.19	9.12
East Palu	39.39	0.67
North Palu	723.88	12.29
Tatanga	216.43	3.67
Tawaeli	1,090.89	18.51
Ulujadi	633.81	10.76
Total	5,892.06	100.00

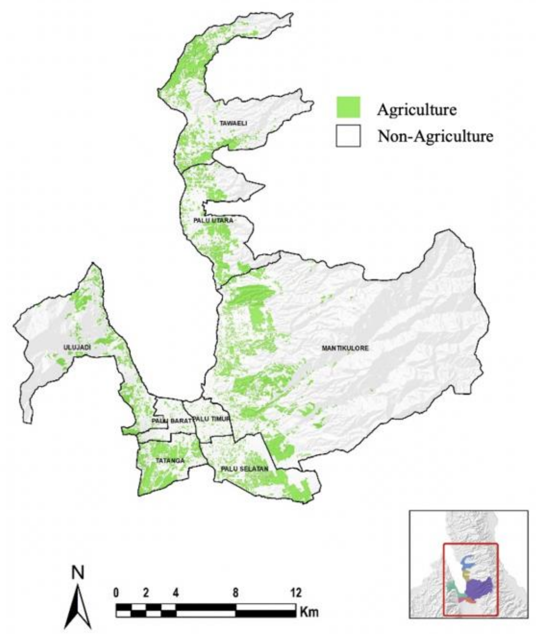

Figure 1. Distribution of agricultural land in Palu

The Carrying Capacity of Water based on Water Supply Ecosystem Services

Based on the data presented above, agricultural land in Palu covers an area of 5,892.06 ha or around 16.52% of the total area of Palu. The agricultural land is spread across all districts in the city of Palu. Approximately 67.94% of the total agricultural land area in Palu are located in three districts that have the highest agricultural land area, namely Mantikulore District, Tawaeli District, and North Palu Subdistricts. Each of has 2,188.12 ha (37.14%), 1,090.89 ha (18.51%), and 723.88 ha (12.29%) of agricultural lands respectively.

The Carrying Capacity of Water based on Water Supply Ecosystem Services

Based on spatial analysis, water provision in Palu's city was very low to very high in agricultural land. Only eleven percent area has low and very low capacity, while the rest showed moderate to high water provision (Figure 2 and Table 3).

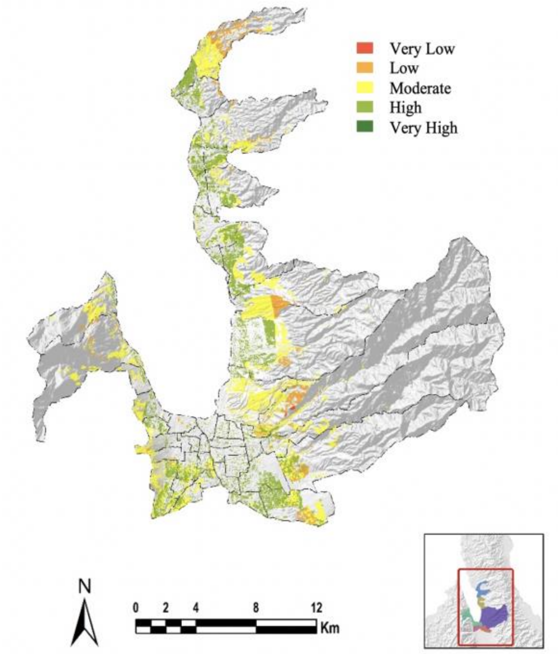

Figure 2. Distribution of water supply ecosystem service classes on agricultural land.

Agricultural Land with Low and Very Low of Water Provision

The distribution of water carrying capacity and data on the area of ecosystem services that provide water with very low-performance categories on agricultural land in Palu are presented in graphical form in Figure 3.

Table 3. Extent of Agricultural Land by Water Supply Ecosystem Service Class.

Water Provider Ecosystem Service Class	Area in Ha	Area in %
Low and very low	697.76	11.84
Moderate	2,812.40	47.73
High and very high	2,382.06	40.43
Total	5,892.22	100

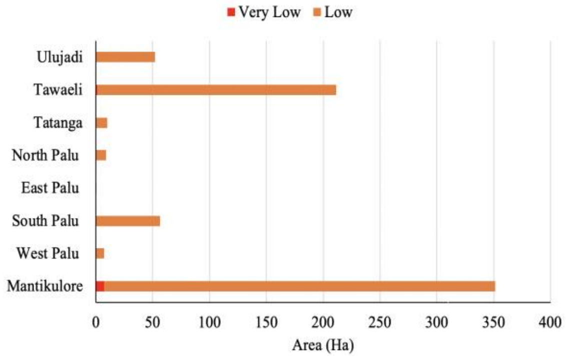

Figure 3. The area of agricultural land with low and very low water supply ecosystem services in each district in Palu.

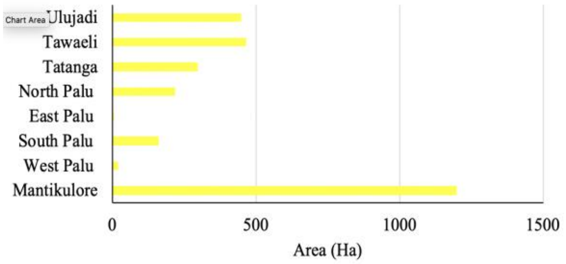

Figure 4. The agricultural land area with moderate water supply in each district of Palu.

The distribution of agricultural land area which has low and very low water carrying capacity or the performance of ecosystem services that provide water was found on agricultural land in each district of Palu with a relatively diverse area. Status with low and very low water supply mostly found on agricultural land in the Mantikulore and Tawaeli with area of 351.17 and 211.53 ha.

Agricultural Land with Moderate Water Provision

The distribution of water carrying capacity with moderate categories is shown in Figure 4.

The water supply with moderate status with an area greater than 400 Ha found Ulujadi and Tawaeli districts, covering 448.49 hectares and 465.89 ha, respectively. Meanwhile, an area greater than 1000 ha, agricultural land in the Mantikulore district, about 1198.41 ha.

Agricultural Land with High and Very High Water Provision

The distribution of water carrying capacity with high and very high-performance categories on agricultural land in Palu is shown in Figure 5.

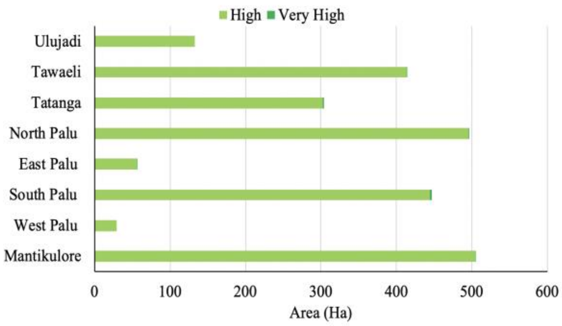

Figure 5. The agricultural land area with a high and very high performance of water supply ecosystem services in each sub-district in Palu.

The water supply greater than 400 ha, was found on agricultural land in Tawaeli, North Palu, and South Palu, each covering an area of 413.48, 495.96, and 446.73 ha, respectively. Meanwhile, with an area greater than 500 ha was only in Mantikulore.

Discussion

The ecosystem provides the benefits of clean water, both from surface and groundwater (including storage capacity), even rainwater, which can be used for domestic, agricultural, industrial, and other purposes. The provision of clean water services is strongly influenced by rainfall conditions and soil or rock layers that can store water (aquifers) as well as factors that can affect groundwater storage systems, such as the shape of the landscape and the type of land cover (Muta'ali, 2019)

The ability of the natural environment in Palu to provide water, ranged from very low to very high categories. Furthermore, based on the value of the ecosystem services index, it is known that the carrying capacity of water in Palu is dominated by agricultural land, which is included in the moderate, high, and low water carrying capacity. Which spatially also shows that the three categories of water carrying capacity are spread across agricultural land in each district in Palu.

On agricultural land with low and very low water carrying capacity, it is known that the ecoregion dominated by denudational hills, sandstones, mudstones, marl, and coral limestone (FAO, 1979; Bishop, 2000; Idrus et al., 2011; Husein, 2015). This indicates that the type of rock layer formed from conglomerates, sandstones, mudstones, marl, and coral limestones has a low capacity to maintain and maintain water availability. Further, it is clarified by the data on land cover types found in the top layer of the landscape around the agricultural land, which is known dominated by the cover as shrubs and open land. This type of land cover is generally known to have very low capacity to hold and capture rainfall so that it can be retained and available as groundwater in the hydrological cycle.

Meanwhile, agricultural land with moderate water carrying capacity is known to be mostly located in ecoregion units or landscapes in the form of denudational hills, sandstones, mudstone, marl, and coral limestone. Based on the land cover data in the revised Spatial Planning Document for Palu (2019), agricultural land in the water supply is dominated by agricultural land types with land cover in the form of mixed gardens and crops and dryland crops.

Agricultural land that has a high and very high performance of water supply is an indication of agricultural land which naturally has high and very high water carrying capacity. Mostly, the landscape characteristic formed by alluvial plain, crust, gravel, igneous rock, and metasediments open-packed with coarse to fine sand and alluvial plains. Coarse sand, fine sand, and loam contain unevenly distributed igneous rock crusts. Moreover, based on the land cover map, it can be seen that several locations of agricultural land with high and very high water carrying capacity are close to water sources or land cover in the form of water bodies.

CONCLUSION

Palu's agricultural land covers an area of 5892.06 ha or about 16.52% of Palu's total area. The agricultural land is spread across all districts in the city of Palu. Approximately 67.94% of the total agricultural land area in Palu is located in three districts that have the highest agricultural land area, namely Mantikulore, Tawaeli, and North Palu districts, of which has 2188.12 (37.14%), 1090.89 ha (18.51%) and 723.88 ha (12.29%), respectively.

The status of water carrying capacity based on the ecosystem services dominated by moderate-class, which covers an area of 2812.40 ha or 47.73% of the total area of existing agricultural land, and distributed in all district areas.

Water carrying capacity on agricultural land with a high and very high class cover an area of 2382.06 ha or 40.43% of the total agricultural land, especially in West Palu and South Palu districts.

Water carrying capacity on agricultural land with a low and very low class covers an area of 697.76 ha or 11.84% of the total agricultural land, especially in agricultural land in Mantikulore and Tawaeli districts.

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