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Wetland Landscape Management Analysis for Sustainability of Makassar City, Indonesia

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ABSTRACT

Wetland area is a combination of green open space and blue open space. Wetlands in Makassar City are vulnerable to land conversion into built-up spaces due to the rapid development of urban facilities and infrastructures. This study aims to analyze wetland landscape management for sustainability of Makassar City. The spatial analysis method with GIS was used for mapping the wetland area in Makassar City in 2019. The wetland landscape management analysis was conducted using a descriptive analysis based on SDGs and CO_2 uptake. The mapping results show that recently, there are 3635.92 hectares of wetland in Makassar City covering up 20.7% of the total area of the City. Analysis of wetland landscape management in Makassar City produces five management concepts that need to be carried out, namely (1) maintaining the existence of wetland areas from land use change through the implementation of more stringent local government policies and regulations, (2) expanding mangrove areas, especially in coastal areas for coastal conservation and disaster mitigation, (3) build greenbelt around the wetland area for soil and water conservation, (4) developing wetland ecotourism for the purpose of education and improving the economy of the surrounding community, and (5) involving community participation together with government and private parties in wetland conservation activities in Makassar City.

Key words *: Wetland, Makassar, Landscape management, Sustainability, SDGs*

Introduction

Makassar City, the capital of South Sulawesi Province, Indonesia, is located in the western coastal area of the province with an area of 17,577 ha. Similar to other metropolitan cities in Indonesia, the development in Makassar City is very fast. Population growth encourages the needs of various urban infrastructure facilities, hence the development in various sectors continue to be implemented. Consequently, there are many inevitable land use changes where natural green open space (GOS) is converted into built-up space (Hairuddin *et al*., 2017).

One form of the natural GOS vulnerable to land conversion in Makassar City as in other cities, is the wetland area (Pifu, *et al*., 2019; Das and Bhattacharjee, 2020). The wetland area in Makassar City consists of five types of land cover, namely paddy fields, mangroves, fishponds, swamps, and lakes. So this wetland area is not only in the form of GOS such as paddy fields and mangroves, but also in the form of blue open space (BOS) which is cov-

ered with water such as swamps, fish ponds and lakes. Data on agricultural land conversion that occurred in Makassar City showed a decrease in land area in 2006 - 2016, from 4,648 ha to 4,287 ha. (Hakim *et al*., 2020). The decline in agricultural land in the past 10 years is quite large at around 361 ha (7.77%) had been changed into developed land.

Changes in land use which make a decrease in the area of GOS and BOS will have a negative impact on the quality of the environment in urban areas. The impacts include micro-climate change, increased air temperature, increased CO_2 gas emissions, vulnerability to flooding in the rainy season, lack of food sources, and other social and economic impacts. Therefore, an environmentally sound urban development plan is needed. Indonesia and other United Nation member countries have agreed on Sustainable Development Goals (SDGs). SDGs aim to keep improving the welfare of society sustainable economy, ensuring the sustainability of social life, maintain environmental quality and inclusive development and implementation of governance that is able to keep improving the quality of life from one generation to the next (Sachs, 2012).

There were 17 goals in the SDGs consist of (1) No Poverty, (2) Zero Hunger, (3) Good Health and Well-being, (4) Quality Education, (5) Gender Equality, (6) Clean Water and Sanitation, (7) Affordable and Clean Energy, (8) Decent Work and Economic Growth, (9) Industry, Innovation and Infrastructure, (10) Reducing Inequality, (11) Sustainable Cities and Communities, (12) Responsible Consumption and Production, (13) Climate Action, (14) Life Below Water, (15) Life On Land, (16) Peace, Justice, and Strong Institutions, (17) Partnerships for the Goals (Alisjahbana and Murniningtyas, 2018). Based on the goals to be achieved from the SDGs, the sustainability of the development of Makassar City in the future must be realized by referring to the SDGs. The development of wetland areas, especially in conservation and restoration efforts, is also in line with the SDGs goals (Samaneh Seifollahi-Aghmiuni, 2019). Thus, it is necessary to analyze the landscape management of wetland areas that are vulnerable to changes in land use with a review from the SDGs aspect.

Materials and Methods

This study was conducted from June to November 2020 in Makassar City. The methodology of this landscape management analysis was based on spatial analysis with Geographic Information System (GIS) to obtain the map of wetland area in Makassar City. The materials used are the image of Makassar City data in 2019, Google Earth maps, and *Rupabumi Indonesia* maps from Geospatial Information Agency. In addition, field surveys was carried out to ensure wetland land cover types that exist in Makassar for further digitization on a screen.

Wetland Landscape Management analysis was carried out using a descriptive analysis referring to SDGs, especially in the objectives of zero hunger (SDG 2), sustainable cities and communities (SDG 11), climate action (SDG 13), life below water (SDG 14), and life on land(SDG 15). Analysis of CO_2 uptake was conducted on rice and mangrove plants, i.e. *Nypafruticans* and *Rhizophoramucronate*. The allometric equation proposed by by Prasetyo (Pradiptiyas *et al*., 2012; Laksono and Damayanti, 2014) was used to calculate the CO_2 absorption from rice, namely:

$$A = L \times 32.88 \text{ kg/ha/day} \quad .. (1)$$

Meanwhile, CO_2 absorption in mangrove plants refers to the allometric equation from Rahman *et al*. (2017) for *Nypafruticans* plants, namely:

$$A = L \times 80.02 \text{ton/ha} \quad .. (2)$$

and for *Rhizophoramucronate* plants, namely:

$$A = L \times 73.17 \text{ ton/ha} \quad .. (3)$$

Where the total CO_2 absorption (A) is the multiplication of the area of vegetation (L) with the absorption capacity of CO_2 for each type of plant.

Results and Discussion

Wetland Area of Makassar City

The results of the study in the form of a wetland map in Makassar City (Figure 1) were obtained through spatial analysis carried out on the 2019 image of Makassar City using ArcMap 10.6. Figure 1 show that the wetland area is spread across 8 districts, namely Biringkanaya, Manggala, Mariso, Panakkukang, Rappocini, Tallo, Tamalanrea and Tamalate.

The types of land cover in the wetland area and its area are shown in Table 1. The area of the wetland in 2019 is 3635.92 ha or 20.7% of the area of Makassar City. The type of land cover in the form of

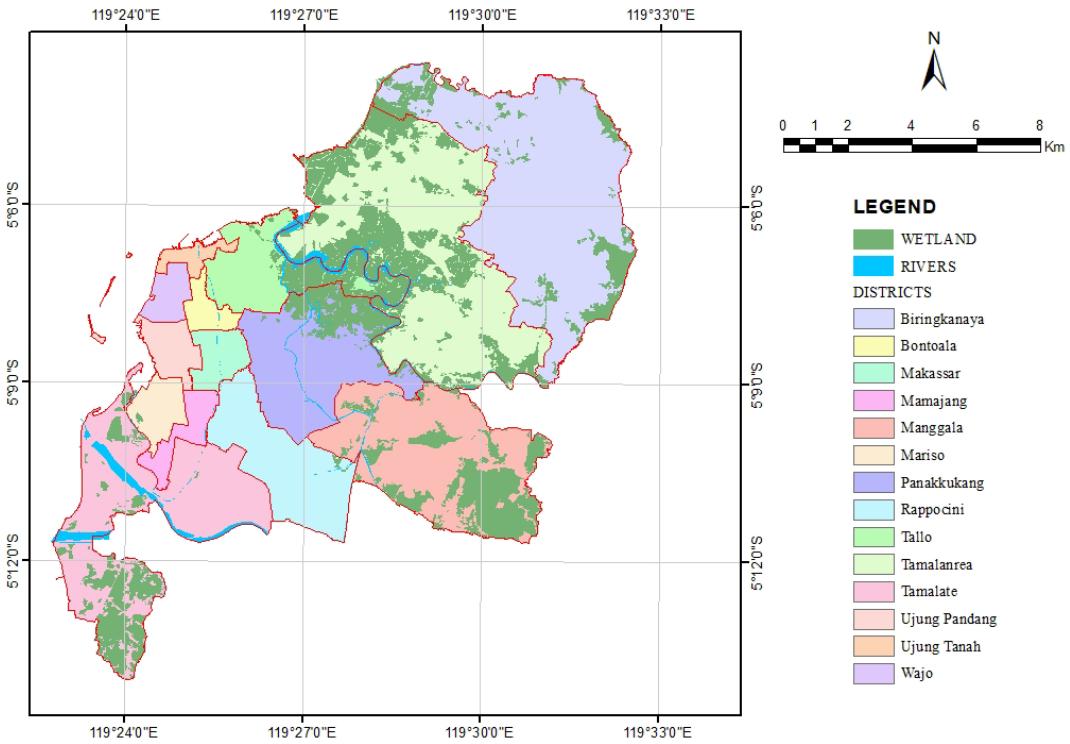

Fig. 1. Wetland of Makassar City 2019

paddy fields and fishponds dominates the wetland area in Makassar City. The largest wetland area is in Tamalanrea District with the dominant type of land cover in the form of fishponds covering an area of 676.74 ha.

The Makassar city with 20.7% of the wetland area is an area that requires wise and precise management so that the wetland area can provide high value benefits for the sustainability of Makassar City. The dominant wetland area located within watershed Tallo especially near river mouths. Tallo River headwaters in the mountains Kallapolompo with 61.5 km length of the river ranges (Arifuddin *et al*., 2013).This river flows through the City of Makassar which then discharged into the Makassar Strait. This river flow tends to be slow due to the sloping topography and causes the sedimentation process to be quite high. The topographic map of Makassar City can be seen in Figure 2.

Wetland Landscape Management Analysis

The sustainable development planning for Makassar

Table 1. The spread of wetland land cover type in Makassar and City and its area (ha) in 2019.

Districts	Area of land cover type (ha)					Total Area (ha)
	Paddy Fields	Fishponds	Mangroves	Swamps	Lakes	
Biringkanaya	285.52	137.98	24.66	19.04	6.44	473.64
Manggala	427.45	3.31	13.01	228.09	75.15	747.01
Mariso	0.00	5.09	0.00	0.00	0.00	5.09
Panakkukang	27.81	144.28	140.03	11.74	0.94	324.80
Rappocini	6.25	0.95	0.00	0.52	0.00	7.72
Tallo	18.40	216.83	36.56	9.08	0.00	280.87
Tamalanrea	298.57	676.74	220.58	81.25	6.53	1283.67
Tamalate	409.58	81.08	4.26	7.85	10.35	513.12
Total Area (Ha)	1473.58	1266.26	439.10	357.57	99.41	3635.92

Source: Spatial Analysis results, 2020.

City should be based on the 17 objectives contained in the SDGs. Thus, the Wetland landscape management in Makassar City is also made based on the SDGs. There are 5 goals in the SDGs related to the wetland landscape management analysis, namely zero hunger (SDG 2), sustainable cities and communities (SDG 11), climate action (SDG 13), life below water (SDG 14), and life on land (SDG 15).

Wetland landscape management based on zero hunger (SDG 2)

The types of land cover in the wetland in Makassar City that are related to food security are paddy fields, fishponds and mangroves. The paddy fields in Biringkanaya, Manggala, and Tamalate Districts are paddy fields that have irrigation facilities so that rice planting can be done twice a year. Meanwhile, paddy fields in other sub-districts, namely Panakkukang, Rappocini, Tallo, and Tamalanrea are rainfed fields that can only be planted with rice once a year. Production obtained from paddy fields and fishponds in the city of Makassar in 2019 can be seen in Table 2.

Total rice production data in the form of milled dry unhulled rice in 2019 shows a large enough production value to meet the food needs of the people in Makassar City. Likewise with the results of fishponds in the form of shrimp and milkfish based on 2019 data from the Marine and Fisheries Service of South Sulawesi Province. Henceforth it is necessary that all paddy fields can get irrigation facilities in order to grow rice twice a year so that the production of rice obtained can be improved and sustained (Mucharam *et al.*, 2020). In addition, it needs the support of various parties, both government and private sectors in facilitating and educating people related efforts to increase food production from wetland areas with environmentally friendly concepts. Through the development of organic farming it can avoid water in wetland areas of chemical pesticides and fertilizer pollution (Verhoeven and Setter, 2009).

Table 2. Production from paddy fields and fish ponds in Makassar City in 2019

Wetland Type	Product Type	Production (ton)*
Paddy fields	Rice	27357.13
Fishponds	Shrimp	367
Milkfish	313.4	

*)Source : BPS 2020 and DKP SulSel Province 2019

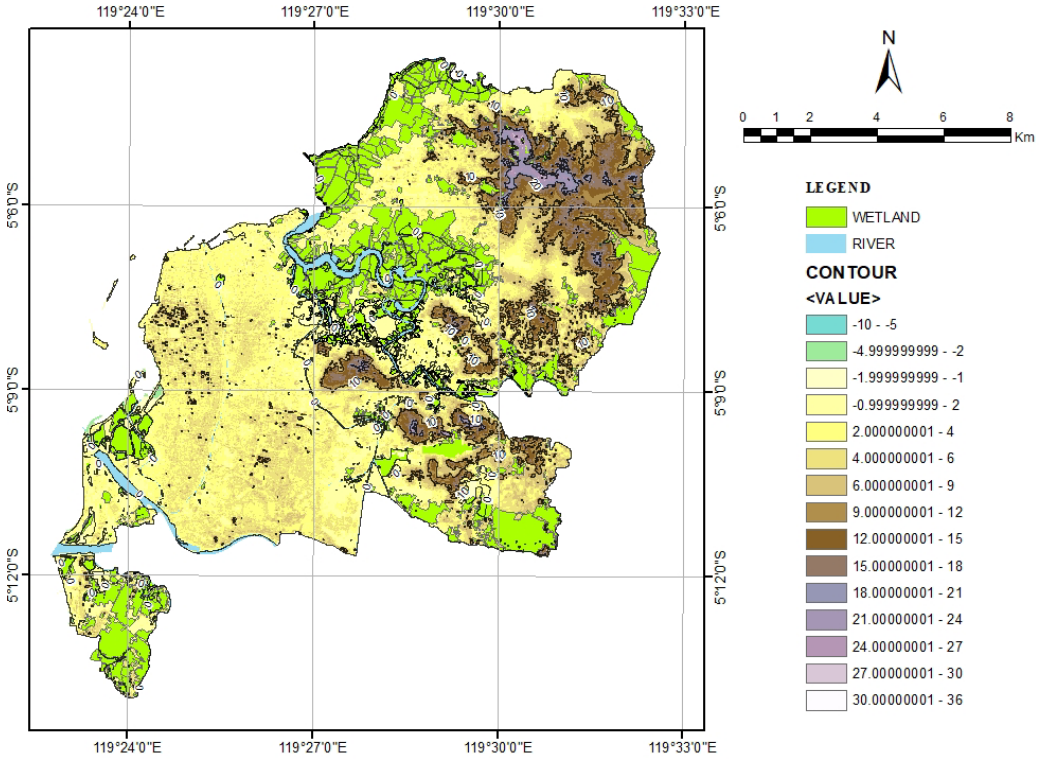

Fig. 2. Topographic map of Makassar City

Other food sources that can be obtained from the wetland area are mangroves, especially *Nypa fruticans*, namely sugar sap and fruit. The sap is tapped from fruit bunches of *Nypa fruticans* trees which can be drunk directly because of its sweet taste and can also be processed into palm sugar, vinegar, and ethanol (Cheablam and Chanklap, 2020). Young *Nypa fruticans* fruit can be consumed directly while the old ones can be processed into flour with high fiber and carbohydrate content, as well as protein, fat and vitamin C (Subiandono *et al*., 2011). For food diversification, various innovations in food processing from *Nypa fruticans* are needed. Regarding the potential for food sources from the wetland area, in managing the wetland landscape, the existence of paddy fields, fishponds and mangroves must be maintained in order to support food security and realize food sovereignty in Makassar City, which has a population of 1,526,677 people.

Wetland landscape management based on sustainable cities and communities (SDG 11)

Sustainable urban and residential development is currently more focused on building green infrastructure as a counterweight to the environment (Budoni and Ricci, 2020). One of the facilities of green infrastructure is urban GOS (Benton-Short *et al*., 2019). Urban GOS must be provided to give a healthy, beautiful and comfortable environment for city residents. Physically, the form of urban GOS can be divided into two, namely natural GOS and non-natural or man-made GOS. One form of natural GOS in the wetland area is paddy fields and mangrove land which we can call wetland GOS.

Wetland GOS in Makassar City must be protected or maintained because it has a very important ecological function. The ecological function of the wetland GOS, among others, is to mitigate climate change, especially in the absorption of CO_2 (Ward, 2020; Were *et al*., 2019), produce O_2, reduce air pollution, conserve water and soil, and prevent sea water intrusion and abrasion. Vegetation in the wetland area is able to absorb CO_2 gas and produce O_2 through the photosynthesis process. In addition, pollutant particles will also be absorbed by vegetation so that the air quality becomes cleaner. The presence of mangrove vegetation on the coast and the estuary of the Tallo river has an important role in preventing sea water intrusion and coastal abrasion by waves. Therefore, the existence of mangrove areas along the coast and around the mouth of the Tallo river must be conserved and even need to be improved its range.

The existence of wetland vegetation also plays a role in infiltrating rainwater, thereby reducing surface runoff, preventing flooding, and increasing the volume of groundwater (Patenaude *et al*., 2015). The existence of a predominantly water-covered wetland area such as lakes, swamps and fishponds also acts as a water storage container during the rainy season so as to prevent flooding in Makassar City. Therefore, the conversion of land use wetlands into developed land must be prevented. Henceforth, it is necessary to make a greenbelt plan that surrounds the wetland area as well as the arrangement of the contour of the soil an effort to slow down surface runoff, reduce sedimentation, and increase the infiltration of rainwater into the soil. Related to the greenbelt planning further research is needed, especially in determining the type of vegetation and the right land contours setting.

Wetland landscape management based on climate action (SDG 13)

Climate change and the phenomenon of global warming that are currently occurring are experienced in all regions of the world. The increase in CO_2 in the atmosphere is the cause of global warming (Pratiwi *et al*., 2020) which results in an unstable climate. Therefore, the role of green open space in mitigating climate change is very important. The existence of green open space with the dominance of plants in addition to providing a more comfortable microclimate condition, is also able to reduce CO_2 in

Table 3. CO_2 absorption in the wetland area of Makassar City in 2019

Vegetation Type	Land Cover Area (ha)*	CO_2 Absorption (ton/year)*
Rice (*Oryza sativa*)	1,473.58	10,243.19
Nipah (*Nypa fruticans*)	291.08	23,292.45
Bakau (*Rhizophora mucronata*)	123.35	9,020.55
TOTAL		42,556.19

*Source: Analysis results, 2020.

the atmosphere. Every plant has the ability to absorb CO_2. Likewise, the vegetation in the wetland, namely rice plants and mangroves on the coast and river basins (Rahman *et al*., 2020). In Table 3, the potential of wetland vegetation in mitigating CO_2 gas in Makassar City is presented.

Based on the results of the analysis, the potential for wetland vegetation to absorb CO_2 gas related to climate change mitigation is quite large (42,556.19 tons per year). Therefore, the existence of the wetland area must be maintained. The conversion of wetland to built-up areas should be prevented as much as possible in the midst of development in Makassar City through the implementation of stricter government policies and regulations.

Wetland landscape management based on life below water (SDG 14) and life on land (SDG 15)

The wetland ecosystem can be said to be part of the marine and land ecosystem where part of the wetland area is adjacent to the sea and partly on land, especially in river basins. Biodiversity of flora and fauna in the wetland ecosystem is very rich and unique (Sun *et al*., 2019) so that this ecosystem needs to be conserved to prevent its extinction due to uncontrolled urban development. The wetland ecosystem in Makassar City has an important role in maintaining environmental stability and also acts as an educational forum for the development of natural and environmental science.

Conservation efforts of the wetland ecosystem can also be carried out through the development of its ecotourism potential. Through the ecotourism program, the wetland area can be preserved and maintained its existence (Massiseng *et al*., 2020; Sukuryadi *et al*., 2020). Besides that, it can also add value to the benefits of improving the economy of the surrounding community (Hsu, 2019). Therefore, wetland conservation activities must consider the triple helix relationship involving the participation of the community, government and the private sector to ensure the area to run sustainably.

Conclusion

The area of wetland in Makassar City in 2019 is 3635.92 ha or 20.7% of the total area of Makassar City. SDGs-based wetland landscape management in Makassar City includes five things, namely (1) maintain the existence of the wetland area from land use change through the implementation of more stringent local government policies and regulations, (2) expanding mangrove areas, especially in coastal areas for coastal conservation and disaster mitigation, (3) build a greenbelt around the wetland area for soil and water conservation, (4) developing wetland ecotourism to improve the economy of the surrounding community and educational purposes, and (5) involving the community together with government and private parties in wetland conservation activities.

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Declaration of interests

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