Existence of paddy fields in Makassar city as a part of green open space: Ecological perspective on urban farming

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Abstract. Paddy fields are part of urban green open space which is now rarely found in big cities because it has been converted into built-up land. This study aims to study the existence of paddy fields in Makassar City in 2019 and to review their ecological function in CO2 absorption. Spatial analysis using the GIS method was used to map paddy fields that are still productive in 2019 in Makassar City. Analysis of CO2 uptake from the rice cultivation in this urban paddy fields was carried out using allometric equations. Mapping results show that recently, there are 1,473.58 hectares of paddy fields in Makassar City. These paddy fields are spread across seven districts, namely Tamalate, Rappocini, Tallo, Panakukkang, Manggala, Biringkanaya and Tamalanrea. Makassar City must provide a minimum of 5,273 ha of green open space. The existence of this paddy field contributes about 8.38% of the total minimum required green open space (30%) for Makassar City. The paddy fields in Makassar City, planted with rice as much as one to two times a year, will be able to absorb CO2 in the range of 5,814.16 to 10,243 tons per year. Thus, the existence of paddy fields in urban areas needs to be maintained to improve the quality of the urban environment.

1. Introduction
Due to increasingly advanced development, Makassar City also has a problem like another metropolitan cities in terms of to be sufficient the requirement of Green Open Space (GOS). Conversion of green land into developed land is often unavoidable which is attributed to the increase in population every year, hence it requires the construction of various infrastructure facilities [1, 2]. In general, changes of the GOS is mostly in the form of agricultural land which is converted into housing and business centers [3]. Agricultural land in the form of paddy fields has begun to decrease in urban areas. The area of agricultural land in Makassar City has decreased from 4,648 ha in 2006 to 4,287 in 2016 due to conversion of this type of land into developed land [4]. If this land conversion occurs continuously, the GOS of Makassar City will be depleted and the quality of the city environment will get worse.

Green open space is a green infrastructure that must exist in every urban area to protect the value and function of natural ecosystems [5]. Green open space has various functions, from the aspects of
ecological, socio-cultural, architectural, and economic functions [6]. The ecological functions of urban green open space include mitigating global warming, reducing air pollution, improving groundwater quality, preventing floods, reducing city temperatures, and preserving biodiversity [7].

The phenomenon of global warming or the greenhouse effect in cities can be overcome by providing green open space [8,9]. This is because the main element of green open space is vegetation which has the ability to absorb CO$_2$ gas and emit O$_2$ gas through the photosynthesis process. CO$_2$ gas emission is the main element causing the greenhouse effect which must be minimized [10].

All plants can absorb CO$_2$ gas even though the amount of absorption varies depending on the type. Rice plants in paddy fields also have the ability to absorb CO$_2$ gas. Therefore, the existing paddy fields in Makassar City need to be assessed for their existence as part of urban green open space and to assess how much its contribute to reducing CO$_2$ gas emissions to create a better urban environment.

2. Materials and methods

This research was conducted from June to September 2020 in Makassar City. The method used was spatial analysis with Geographic Information System (GIS) to map the paddy fields in Makassar City. The materials used were Sentinel 2 imagery for Makassar City as well as Google Earth maps and Rupabumi Indonesian maps (RBI) from the Geospatial Information Agency (BIG). The first stage was to classify paddy fields coverage in Makassar City in 2019 through digitization onscreen process. Furthermore, contribution of the paddy fields to the GOS of Makassar City was calculated in terms of the area of the city and the population of Makassar City. The area of urban green open space is based on the rules stipulated in Permen PU No. 5 of 2008 which is 30% of the total area of the city. While the area of urban green open space based on population refers to the Kepmen PU No. 387 of 1987 which is 17.3 m$^2$/capita.

Furthermore, analysis is carried out from the aspect of ecological functions, especially in terms of absorption of CO$_2$ gas. The amount of CO$_2$ absorption from the existing rice plants was calculated using the allometric equation proposed by Prasetyo et.al [11, 12], as follows:

$$ A = L \times 32.88 \text{ kg/ha/day} $$

The total CO$_2$ uptake (A) is the multiplication of the paddy fields area (L) with the CO$_2$ absorption capacity of rice plants (32.88 kg/ha/day).

3. Results and discussion

3.1. Paddy field as a part of city GOS.

Spatial analysis was performed using ArcMap 10.6 on Sentinel 2 imagery combined with google earth map and the Indonesian Rupabumi map. Based on the results of the analysis, a map of paddy fields cover in Makassar City in 2019 was obtained as shown in figure 1.

The paddy fields in Makassar City are spread across seven districts, namely Tamalate, Rappocini, Tallo, Panakukkang, Manggala, Biringkanaya, and Tamalanrea. Figure 1 also shows that the dominant paddy fields area are mostly located in the border districts adjacent to the other regencies so that the paddy fields also function as the green belt of Makassar City. Green Belt is a public green open space which has the main objective of limiting the development of a land use and has a function of protecting the surrounding environmental factors [13,14]. Green belt is needed to overcome air pollution that occurs in urban areas [15]. Therefore, paddy fields that function as green belts must be maintained.
3.1.1. The area of GOS for paddy fields based on the area. The area of urban green open space is at least 30% which consisting of 20% public green open space and 10% private green open space. Public GOS is green open space whose provision and management is the responsibility of the government. Meanwhile, private green open space is green open space whose provision and management is borne by the private sector, individuals and the community [16]. Makassar City has an area of 175.77 km$^2$ so it must provide green open space of at least 5,273.1 ha.

One form of urban green open space is urban agricultural land [17] including the urban paddy fields. The results of the analysis from the mapping of paddy fields in Makassar City 2019 show that the total paddy fields in Makassar City is 1473.58 ha (table 1). The largest paddy field area is in Manggala District, which is 427.45 ha, and the smallest area is in Rappocini District, which is 6.25 ha.

| Districts    | Area (ha) | Area of GOS required$^*$ (ha) | Area of paddy fields (ha) | Percentage of GOS of paddy fields (%) |
|--------------|-----------|-------------------------------|---------------------------|--------------------------------------|
| Tamalate     | 2021      | 606.3                         | 409.58                    | 20.27                                |
| Rappocini    | 923       | 276.9                         | 6.25                      | 0.68                                 |
| Tallo        | 583       | 174.9                         | 18.40                     | 3.16                                 |
| Panakukang   | 1705      | 511.5                         | 27.81                     | 1.63                                 |
| Manggala     | 2414      | 724.2                         | 427.45                    | 17.71                                |
| Biringkanaya | 4822      | 1446.6                        | 285.52                    | 5.92                                 |
| Tamalanrea   | 3184      | 955.2                         | 298.57                    | 9.38                                 |
| **TOTAL**    |           |                                | **1473.58**               |                                       |

Source: Analysis results, 2020.
GOS = Green Open Space
$^*$ 30% of the total area (Permen PU No.5 of 2008)

Table 1 shows that the largest percentage of GOS for paddy fields based on the area is in the District of Tamalate, namely 20.27%. Meanwhile, paddy fields in Manggala district (17.71%) rank second in terms of their percentage of total area. The percentage of green open space for paddy fields in Tamalate
District has met the minimum area of public green open space (20%) so it is not too difficult to achieve the 30% GOS target in this district.

Paddy fields covering an area of 1473.58 ha in Makassar City have contributed as urban green open space by 8.38% of the total 30% targeted. Based on 2018 data on the area of GOS for Makassar City recorded in the Makassar City Environmental Service, there was a paddy fields area of 1398.94 ha that was not included in it or 7.96% of the city area. This data shows that the target area of GOS 30% is of course still very far to be achieved even though paddy fields are included in the calculation of GOS for Makassar City. Therefore, the existence of paddy fields must be considered as part of urban green open space to protect its existence so that it is not converted into developed land. This consideration will be supported by the Makassar City government policy whereby everyone who controls and/or owns land or cultivators in the green open space is prohibited from carrying out development activities in any form, unless the building actually functions to support the function of green open space [18].

3.1.2. The area of GOS for paddy fields based on the population. Efforts must be made to ensure that paddy fields are not degraded into built-up land, given that the population and the need for facilities and infrastructure are increasing from year to year. The total population of Makassar City in 2019 is 1,526,677 people [19]. Calculation of area requirement of GOS for Makassar City based on the population is referring to the Kepmen PU No. 387/1987 is 2641.15 ha. The calculation of green open space requirement provides smaller results than the standardization based on area size. However, increased population growth will result in wider area of green open space needed. This shows that the calculation of urban green open space needs based on the area is more stable because it rarely changes the area of a city. Table 2, shows the area needed for green open space based on the population in the seven districts in Makassar City that have paddy fields.

### Table 2. The area of GOS based on the population in seven districts of Makassar City 2019.

| Districts         | Population | Area of GOS required* (ha) | Area of paddy fields (ha) |
|-------------------|------------|----------------------------|---------------------------|
| Tamalate          | 205,541    | 355.59                     | 409.58                    |
| Rappocini         | 170,121    | 294.31                     | 6.25                      |
| Tallo             | 140,330    | 242.77                     | 18.40                     |
| Panakukang        | 149,664    | 258.92                     | 27.81                     |
| Manggala          | 149,487    | 258.61                     | 427.45                    |
| Biringkanaya      | 220,456    | 381.39                     | 285.52                    |
| Tamalanrea        | 115,843    | 200.41                     | 298.57                    |

*Source: Analysis results, 2020.
GOS = Green Open Space.
*)17.3 m²/capita (Kepmen PU No. 387/1987)

The current paddy field area in Tamalate, Manggala and Tamalanrea Districts shows that the size has exceeded the green open space based on the population in the area. Meanwhile, in the other four districts, they still need additional forms of GOS to be able to meet the needs of GOS in their regions. Therefore, the existence of paddy fields as part of urban green open space needs to be maintained, not to change the land function.

Besides being part of urban green open space, the existence of paddy fields also plays a role in supporting the availability of food for the people of Makassar City. Based on data from the Makassar City Central Statistics Agency, rice production in Makassar City in 2019 reached 27,357.13 tons (table 3). This is certainly an added value for the City of Makassar towards food sovereignty.

Table 3 shows that Manggala District is the region with the highest rice production in the form of milled dry unhulled rice, namely 11,468.57 tons. Two other districts that also provide high rice production are Tamalate (6,575.31 tons) and Biringkanaya (5,015.57 tons), respectively. The paddy
fields in the three districts can provide higher rice production because some of the paddy fields have already received irrigation facilities. Irrigated paddy fields can be planted with rice twice a year so that the annual production is higher. Unlike the case with the other four districts, namely Rappocini, Tallo, Panakukang, and Tamalanrea, all of which are rainfed so that rice can only be planted once a year.

Table 3. Rice production in Makassar City 2019.

| Districts   | Rice Production* (ton) |
|-------------|------------------------|
| Tamalate    | 6575.31                |
| Rappocini   | 111.36                 |
| Tallo       | 91.75                  |
| Panakukang  | 122.33                 |
| Manggala    | 11468.57               |
| Biringkanaya| 5015.57                |
| Tamalanrea  | 3972.24                |
| **TOTAL**   | **27357.13**           |

*Source: BPS [18].

The existing paddy fields are natural food-producing resources that must be maintained to support food security and food sovereignty in Makassar City. To achieve this, it is necessary to increase the provision of irrigation facilities and other supporting production facilities such as the use of superior varieties, the right type and amount of fertilizer, good fertilization techniques, and efforts to control pests and diseases that are environmentally friendly. In the Republic of Indonesia Law number 41 of 2008 concerning the Protection of Sustainable Food Agricultural Land, it is stated that irrigated and non-irrigated paddy fields are included in the category of sustainable food agricultural land whose existence is protected.

3.2. Ecological function for GOS of paddy fields in Makassar City

The greenhouse gas phenomenon that occurs globally makes urban green open space a very important functional value from an ecological perspective. This is because plants are the main element of green open space. Plants in the photosynthesis process will absorb CO$_2$ gas so that plants have a function in mitigating carbon emissions which are the cause of the greenhouse effect.

All plants can absorb CO$_2$ gas in the air although the amount of absorption varies according to the type of plant [19]. Rice plants are able to absorb as much as 32.88 kg/ha/day of CO$_2$. Makassar City with a paddy fields area of 1,473.58 ha will contribute to CO$_2$ absorption in the range of 5,814.16 tons/year to 10,243 tons/year (table 4) depending on how many times the rice is planted in a year. In this calculation, the basic 120 day life cycle of rice plants in paddy fields is used.

Table 4. Uptake of CO$_2$ by rice plants in the paddy fields of Makassar City.

| Districts     | Area of paddy fields (ha) | Uptake of CO$_2$ by rice plants (ton/year) |
|---------------|---------------------------|------------------------------------------|
|               |                           | Planted once per year | Planted twice per year |
| Tamalate      | 409.58                    | 1616.04                   | 3232.08                |
| Rappocini     | 6.25                      | 24.66                     | 24.66                  |
| Tallo         | 18.40                     | 72.60                     | 72.60                  |
| Panakukang    | 27.81                     | 109.73                    | 109.73                 |
| Manggala      | 427.45                    | 1686.55                   | 3373.09                |
| Biringkanaya  | 285.52                    | 1126.55                   | 2253.10                |
| Tamalanrea    | 298.57                    | 1178.04                   | 1178.04                |
| **TOTAL**     | **1473.58**               | **5814.16**               | **10243**              |

Source: Analysis results, 2020.
The contribution of rice cultivation in paddy fields in absorbing CO\(_2\) gas will be even greater if all paddy fields in Makassar City are provided with irrigation facilities so that rice planting can be done twice a year. In addition, if land use is carried out optimally by planting other commodities when the land is not planted with rice, it will increase the contribution of the land in efforts to mitigate global warming. Besides being able to reduce carbon emissions, urban agriculture can also provide oxygen and a source of food for the lives of city residents. Therefore, urban agriculture must be maintained and developed to participate in efforts to reduce carbon emissions and improve the quality of the urban environment.

4. Conclusion
The paddy fields in Makassar City are spread across seven districts, namely Tamalate, Rappocini, Tallo, Panakukkang, Manggala, Biriringkana, and Tamalanrea. The total area of paddy fields is 1473.58 ha, thus contributing as GOS for urban agricultural land by 8.38%. The area of paddy fields in the Districts of Tamalate, Manggala, and Tamalanrea has exceeded the need for green open space based on the population in each district. Rice cultivation in paddy fields also contributes to mitigating global warming in Makassar City with its ability to absorb CO\(_2\) gas ranging from 5,814.16 tons/year to 10,243 tons/year. Therefore, the existence of paddy fields as part of urban green open space in Makassar City must be protected and maintained.

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