The Utilization of Sentinel-2A and ASTER Imagery for Monitoring the Changes of Public Green Open Space and Oxygen Needs in Sukoharjo Regency in 2004-2019

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Abstract. High land requirements have an impact on land conversion. This study aims to calculate the accuracy of the results of mapping public green open space from ASTER and Sentinel-2A imagery, know the changes in green public space, calculate oxygen demand and the needs of green space in 2004 and 2019. The types of green open spaces that are interpreted visually include urban forests, river borders, cemeteries, fields, and city park. Oxygen demand is calculated by the gerrarkis method including livestock, industry, population, and motor vehicles. The mapping accuracy with the ASTER is 96% while the Sentinel-2A imagery is 90%. The mapping of changes in public green open space show that 17.62 km² public green open space has not changed, increased 1.15 km², and decreased 2.61 km². Oxygen demand in 2004 was 1053531.92 kg/day with green open space needs covering 10,41 km², while in 2019 it was 1923959.31 kg/day with Green Open Space needs covering 19 km². The need for green space in 2004 has been fulfilled from public green space of 20.22 km². In 2019 the area of public open green space is 18.77 km², so that public open green space has not been able to fulfill the needs of overall green open space.

Keyword: Green Open Space, ASTER Imagery, Sentinel-2A Imagery, Oxygen Needed

1. Introduction

Sukoharjo Regency as one of the pillars of economic growth in Central Java has a rapid economic development. This has an impact on increasing the population significantly. Data from BPS Sukoharjo Regency in 2019 states that the population of Sukoharjo Regency has continued to increase from 2004-2019. In 2018 the population density reached 1,897 people / km² with an area of 466.66 km² [1]. Economic development has an impact on increasing the need for space and land. High land requirements, not accompanied by adequate land availability. This has resulted in a tendency to change the function of green open space land into a built-up area. Change of land function is a change in land function from one function to another and generally occurs in the suburbs. Data from the Sukoharjo Regency Agriculture Office states that the area of paddy fields decreases every year while built-up land increases by 50-100 hectares per year [11].

The Minister of Public Works Regulation in 2008 states that every city area must provide a Green Open Space of 30% of the total area, namely 20% for Public Green Open Space and 10% for private Green Open Space. The main functions of green open space are as an ecological function, socio-cultural function, economic function, and aesthetic function. Green Open Space also plays a role in providing oxygen for living things and the combustion process [2]. The increase in population, livestock,
motorized vehicles, and industry has an impact on increasing oxygen demand. Oxygen is very important to sustain ecological life. Oxygen plays a fundamental role in preserving the life of living things in the world. With this very important role, the balance between consumption and production needs to be fulfilled [9]. The increase in oxygen demand continues to increase while the availability of green open space is decreasing every year.

Previous research regarding the estimation of green open space needs has been carried out by D. Purba, S. Subiyanto, and Haniyah, 2018 [3]. In this research, the calculation of the area of green open space was carried out with a visual interpretation of the 2015 Quickbird Image and updated using the Sentinel-2A image in 2018. Oxygen demand parameters based on this research used parameters of population, number of motorized vehicles, and number of livestock only. The research only focuses on estimating the need for green open space and its oxygen demand. While in this study the research included monitoring related to the availability of green open spaces and oxygen demand within 15 years. In addition, this study uses the parameters of the number of residents, the number of motorized vehicles, the number of livestock, and the number of industries for the calculation of oxygen demand.

Monitoring of green open space changes is carried out to determine the environmental degradation that has occurred. Remote sensing can be used as a tool in overcoming urban problems. This is because remote sensing has advantages in time, cost efficiency and is environmentally friendly. The availability of Sentinel-2A images and ASTER images which are obtained for free and have good temporal resolution can make changes and the extent of green open space availability can be monitored properly. The aim of this research is:

a. Calculating the accuracy of the mapping results of the public green open space from the ASTER image and the Sentinel-2A image
b. Knowing the changes in public green open space in Sukoharjo Regency from 2004-2019
c. Calculating the oxygen demand in Sukoharjo Regency in 2004 and 2019
d. Calculating the estimated green open space requirement based on oxygen demand in Sukoharjo Regency in 2004 and 2019.

2. Methods

2.1 Data source

Image processing was carried out on the ASTER image recorded on July 7, 2004 and the Sentinel-2A image recorded on September 26, 2019. Both images used were geometrically and radiometrically corrected. The area of green open space availability was obtained from on-screen digitization and visual interpretation of images in the two different years. The tools and materials used in this research are:

a. Handheld GPS; Camera; Laptop;
b. ArcGIS software; ENVI Software; RStudio software; Microsoft Office;
c. Stationary; Field checklist;
d. ASTER image recording year 2004 and Citra Sentinel-2A in 2019;
e. Graphic data (shp format) administrative boundaries of Sukoharjo Regency;
f. Map of the City Spatial Patterns of Sukoharjo Regency 2011-2031;
g. Secondary data on oxygen demand variables in 2004 and 2019 in Sukoharjo Regency:
   - Population Data
   - Data on the number of livestock
   - Data on the number of motorized vehicles
   - Data on the number of industries
h. Regulation of the Minister of Public Works Number 05 / PRT / M / 2008 concerning Guidelines for the Provision and Utilization of Green Open Space in Urban Areas.

2.2 Analysis

The two images have different resolutions. The ASTER image on the band appears to have a spatial resolution of 15 m while the Sentinel-2A image has a spatial resolution of 10 m. Resampling needs to be done on the image, to overcome the difference in spatial resolution. Image resampling was done using RStudio software. The resampling method used is bilinear interpolation. The advantage of this method is that the time required for processing tends to be fast with smooth image results [10]. The
interpretation of Green Open Space is carried out by referring to the Regulation of the Minister of Public Works Number 05 / PRT / M / 2008. The classification of Green Open Space types can be seen in Table 1

| No  | Type of Green Open Space                        |
|-----|------------------------------------------------|
| 1   | Yard Green Open Space                          |
|     | - Home yard                                    |
|     | - Office and shop yard                         |
|     | - Rooftop garden                               |
| 2   | Green Open Space Parks and Urban Forests       |
|     | - RT Park; RW                                  |
|     | - Taman kelurahan; sub-district                |
|     | - City Park                                    |
|     | - Urban Forest                                 |
|     | - Green Belt                                   |
| 3   | Green Line Green Open Space Road               |
|     | - Island roads and road medians                |
|     | - Pedestrian path                              |
|     | - Space under the flyover                      |
| 4   | Green Open Space Specific Functions            |
|     | - Railroad Green Open Space border             |
|     | - The green line of the power grid             |
|     | - Green Open Space for river borders           |
|     | - Green Open Space on the beach                |
|     | - Green Open Space safety source of air springs|
|     | - funeral                                      |

Based on this classification, not all types of green open space can be interpreted. Interpretation is only carried out on the type of Public Green Open Space, while Private Green Open Space such as office pages is not interpreted. This is due to the spatial resolution factor of the two images used. The types of green open space that were interpreted were river borders, fields, city parks, funeral, and urban forests. Interpreted appearance is one with a size exceeding the Minimum Mapping Unit (MMU) used. The determination of the MMU size is adjusted from the appearance of the object, where the appearance of the expanding area uses MMU 3mm x 3mm, while in areas that tend to lengthen using a minimum width of 1 mm.

The two interpreted images have different spectral characteristics. The VNIR band on the ASTER image starts with the green band (0.556 μm), red band (0.661 μm), and near NIR / Infrared band (0.807 μm). The difference with the Sentinel-2A image is that the blue band has a wavelength of 0.49 μm, the green band is 0.56 μm, the red band is 0.665 μm, and the NIR band is 0.842 μm. The interpretation was carried out by utilizing a standard false color composite (NIR, red, and green bands), namely band 321 in the 2004 ASTER image and band 843 in the 2019 Sentinel-2A image.

Monitoring of changes in public green open space is carried out by comparing the results of reinterpretation of the ASTER image and the Sentinel-2A image. The area of change in public green open space in 2004 and 2019 was obtained from processing using a pivot table. Accuracy test is done by using confusion matrix to determine the ability of ASTER image and Sentinel-2A image in mapping public Green Open Space. Determination of field samples is to use the simple random sampling method with a total sample of 50 samples. Field checks are carried out in two different ways. Field checks in 2004 made use of Google Earth imagery, while field checks in 2019 were conducted live.

Oxygen demand is calculated using the gerrarks method. The calculation of oxygen demand uses variables in the form of oxygen demand from the population, the number of livestock, the number of industries, and the number of motorized vehicles. The formula for calculating the need for green open space based on oxygen demand is:

\[
L_t = \frac{Pt + Kt + Tt + It}{(54)(0.9375)(2)}
\]
Lt : City green open space in year t (m$^2$)
Pt : The amount of oxygen needed by the population
Kt : The amount of oxygen needed for motor vehicles
Tt : The amount of oxygen needed for livestock
It : Amount of industrial oxygen demand
54 : A determination which shows that 1 m$^2$ of land area produces 54 grams of plant dry weight per day.
0.9375 : The rule indicating that 1 gram of plant dry weight is equivalent to the production of oxygen 0.9375 grams
2 : Number of seasons in Indonesia

3. Result and Discussion

3.1 Preprocessing

In the resampling process, each band will experience a change in pixel size. The result of the resampling process is changing the Sentinel-2A image resolution from 10 m to 15 m. Image cutting is done on ENVI software using ROItool (Region of Interest). The study area includes 12 sub-districts in Sukoharjo Regency.

3.2 Interpretation

Types of public green open space that can be interpreted are the field, river border, and urban forest, while the funeral and city park only appear to have more than MMU size which are interpreted. The dominant elements of interpretation are form, color, pattern and site.

The type of public green open space in the form of a funeral can be identified by looking at the visible shapes and patterns. The pattern is grouped with features that tend to be unique and distinctive from a collection of tombstones. Cemeteries are social facilities where this object is able to provide green open space reserves, as a water catchment area, as well as a microclimate creator. There are two burial objects that have been successfully interpreted, namely the funeral in Kartasura District, where this funeral has a very large size of 0.13 km$^2$.

The field is built with its use that is open, public, and capable of being a water catchment area. The key interpretations of this type of green space are shape, color, and site. Most of the forms of Green Open Space are square or rectangular. The color that appears in both images is clearly visible from the reflection of the soil and the surrounding vegetation. In addition, field interpretation can be related to its location in the middle or near the settlement. This is because the social function of the field is to accommodate community activities.

City parks are in the form of parks open to the public that function as micro-climate creators. This type of green space is difficult to interpret without the help of local knowledge from the manufacturer. This is because most of the city parks are located in the middle of dense settlements with a park area that is not too large. City parks that can be interpreted are Satya Negara Square Sukoharjo Regency and Ananda City Park. The two city parks can be interpreted due to their size which is more than the specified MMU.

River border in the form of green lines on either side of the river to protect the river and maintain its sustainability. This green space interpretation uses key interpretations in the form of patterns, colors, and sites. This green space has an elongated, linear pattern along the river. In addition, their appearance is easily recognizable by the red, clustered reflection of the vegetation. This appearance can also be related to its location on the right and left of the river.

Based on the classification of urban forests listed in the Minister of Public Works Regulation Number: 05 / PRT / M / 2008, green open space in the form of urban forest can be in the form of clustered urban forest, urban forest spread, the area planted with an area of 90% - 100%, and urban forest in the form of a path. Urban forest is clustered in the form of clustered vegetation in one area, with a minimum of 100 trees and irregularly dense spacing. The urban forest spreads out without a pattern, and the growing vegetation spreads out in clumps with minimum area of 2500 meters. The urban forest in the form of a lane has a minimum width of 30 meters with a pattern following the formation of rivers, roads, channels and others.
The interpretation carried out in Sukoharjo Regency shows that the form of urban forest in this area tends to be clustered and spread. The clustered form of urban forest can be found in production forest in Polokarto District, while urban forest that spreads out is found in protected forest in Bulu District. The process of interpreting urban forest is a little difficult to interpret, so assistance is needed in the form of a map of the spatial pattern of Sukoharjo Regency 2011-2031 [7]. The map of the spatial pattern of Sukoharjo Regency 2011-2031 is shown in Figure 1.

![Figure 1. Map of the 2011-2031 Spatial Pattern Plan (PUSDATARU, 2017)](image)

The urban forest spreads out in a protected area. The morphology tends to be unique and has certain ecological functions with an area of up to 3 km². In addition to being seen from the spatial pattern map of Sukoharjo Regency in 2011-2031, urban forest is clustered in shape, it can also be identified from the appearance of vegetation with clustering patterns and tree shapes that tend to be uniform. This type of urban forest that can be interpreted is rubber and teak production forest. The results of the map of public green open space in Sukoharjo Regency in 2004 and 2019 are shown in Figure 2.

![Figure 2. (a) Map of Public Green Open Space 2004 (b) Map of Public Green Open Space 2019](image)

3.3. Determination of samples and field checks
The total sample used was 50 samples that were evenly distributed in each study area. The results of the field check in 2004 showed two wrong interpretation results, namely the type of green open space for city parks and the field, while in the field survey in 2019 it was found that there were five wrong interpretation results, namely on the river and field boundaries. Field green open space
has been mistaken because this object is similar to unplanted agricultural land or dry agricultural land. In addition, this green open space is also similar to a garden owned by residents. Borders of rivers and city parks experience errors in interpretation because of their proximity to each other so that they are difficult to distinguish from one another. Urban forest samples located in mountainous areas are difficult to reach. This results in a shift in the sample point to a place that is more easily accessible, without changing the type of green space to be checked for conditions in the field.

3.4. Test accuracy

The accuracy test is carried out by comparing the interpretation of ASTER images with google earth. The overall accuracy results in 2004 can be seen in Table 2. Mapping public green open space using the ASTER image, the accuracy is 96% with a kappa coefficient value of 0.94. Based on the accuracy of the manufacturer and the accuracy of the user, all types of public green open space can be identified properly.

The accuracy test of public green space mapping in 2019 was carried out by comparing the interpretation of Sentinel-2A images with field surveys. The results of the creator's accuracy and user accuracy are more varied, as shown in Table 3. The overall mapping using the Sentinel-2A image produces an overall accuracy of 90% with a kappa coefficient value of 0.86. Based on the accuracy of the maker and the user, there are four types of public green open space that can be identified properly.

The accuracy produced by the two images exceeds 85%, which according to Sutanto (1986) states that if the accuracy rate exceeds 85% then it is feasible for further analysis [8]. The kappa value produced by the two images ranges from 0.8 to 1, where according to Altman (1991) this value is in the very strong or very good category [5]. Based on this, the mapping of public green open space with both images can be further analyzed because the higher the overall accuracy value and the kappa coefficient value, the better the mapping results can be.

### Table 2 Confussion Matrix 2004

| Interpretation                  | Urban Forest | Field | Non Public Green Open | Funeral | River Border | City Park | Total | User's Accuracy |
|--------------------------------|--------------|-------|-----------------------|---------|--------------|-----------|-------|------------------|
| Field                          | 7            | 0     | 0                     | 0       | 0            | 0         | 7     | 100%             |
| Non Public Green Open Space    | 0            | 18    | 0                     | 0       | 0            | 0         | 18    | 95%              |
| Funeral                        | 0            | 0     | 0                     | 0       | 0            | 0         | 0     | 0%               |
| River Border                   | 0            | 0     | 0                     | 0       | 0            | 0         | 0     | 0%               |
| City Park                      | 0            | 0     | 1                     | 1       | 0            | 0         | 1     | 50%              |
| Total                          | 7            | 18    | 1                     | 2       | 2            | 1         | 50    | 96%              |

### Table 3 Confussion Matrix 2019

| Interpretation                  | Urban Forest | Field | Non Public Green Open | Funeral | River Border | City Park | Total | User's Accuracy |
|--------------------------------|--------------|-------|-----------------------|---------|--------------|-----------|-------|------------------|
| Field                          | 7            | 0     | 0                     | 0       | 0            | 0         | 7     | 100%             |
| Non Public Green Open Space    | 0            | 17    | 0                     | 0       | 0            | 0         | 17    | 89%              |
| Funeral                        | 0            | 0     | 0                     | 0       | 0            | 0         | 0     | 0%               |
| River Border                   | 0            | 0     | 0                     | 0       | 0            | 0         | 0     | 0%               |
| City Park                      | 0            | 0     | 1                     | 17      | 2            | 2         | 20    | 100%             |
| Total                          | 7            | 17    | 1                     | 17      | 4            | 2         | 20    | 90%              |

3.5. Monitoring of Public Green Open Space

a. Public Green Open Space in 2004

The results of the mapping of green open space in 2004 that have been reinterpreted indicate that the identified public open green space is a funeral, city park, field, river border, and urban forest. The area of public green open space in 2004 reached 20.22 km² where this area is 0.043 of the total area. If viewed from the Regulation of the Minister of Public Works Number: 05 / PRT / M / 2008, which states that the percentage of public Green Open Space is 20% of the area, then the area of public Green Open Space available is still inadequate.
Urban forest has the largest area, reaching 10.06 km$^2$. The river border has the second largest area, namely 9.43 km$^2$. These two types of public green open space are able to have the largest area because this type of green open space is the easiest to recognize and most of them have a sufficient size for interpretation. The lowest area of all types of green open space is a city park, which is only 0.02 km$^2$. This is because it is very rare for city parks to have an area that exceeds the smallest mapping unit used. The area of public green open space for each type of green open space in 2004 is shown in Figure 3.

**Figure 3.** Area of Public Green Open Space in Sukoharjo Regency in 2019

Based on the distribution of public green open space in 2004, it was found that the sub-districts with the widest public green open space were Polokarto District with an area of 7.25 km$^2$ and Bulu District 4.82 km$^2$, while the sub-district with the lowest area of green open space was Tawangsari District with an area of 0.42 km$^2$. Polokarto and Bulu Subdistricts have a high area of public green open space because in these two sub-districts there are quite large urban forests in the form of protected forests and production forests. In addition, Polokarto District has the largest area among the 11 other sub-districts. Tawangsari sub-district has very few public green open spaces because this sub-district is dominated by agricultural land in the form of large irrigated rice fields.

b. Public Green Open Space in 2019

The public green space that has been identified in 2019 are cemeteries, city parks, fields, river borders, and urban forests. The area of this public green open space reaches 18.77 km$^2$. If this area is calculated based on the need for public green open space of 20% of the area, namely 93.33 km$^2$, then the area of public green open space available in 2019 is still inadequate. The area of public green open space for each type of green open space in 2019 can be seen at Figure 4.

**Figure 4.** Area of Public Green Open Space in Sukoharjo Regency in 2019
Based on Figure 4, it is known that there is a change in the area of the river border and there is an additional area in the types of green open space for city parks and urban forests. This is because from 2004-2019 the construction of several city parks such as Ananda City Park and Grogol Indah City Park were carried out in order to meet the needs of the community’s green open space. The sub-district with the largest public green open space is in Polokarto District, covering an area of 7.14 km², while the sub-district with the lowest public green open space is in Sukoharjo District with an area of 0.34 km². The two sub-districts both experienced a decrease in the amount of green open space when compared to 2004.

c. Monitoring Change in Public Green Open Space

Monitoring of changes in green open space that occurs is carried out by looking at the extent of changes using a pivot table. In this process, a comparison of the green open space map in 2004 and 2019 will be carried out where the results will be obtained from a matrix of changes in the area of green open space for each type of green open space. The results of the green open space change matrix show that the highest change in the area of public green open space occurred on river boundaries which turned into non-public green open space, namely an area of 2.48 km². The extent of changes in each type of public green open space can be seen in Table 4.

| Green Open Space 2019 (km²) | Urban Forest | Field | Non Public Green Open Space | Funeral | River Border | City Park | Total |
|-----------------------------|--------------|-------|----------------------------|---------|--------------|----------|-------|
| Urban Forest                | 10,073.558   |       |                            |         |              |          |       |
| Field                       | 0.348521     | 0.13165381 |                            |         |              |          |       |
| Non Public Green Open Space | 0.810241     | 0.029377 | 4.72,343.3487             |         |              |          |       |
| Funeral                     |              | 0.22211852 |                            |         |              |          |       |
| River Border                | 2.48376461   | 0.0034593 | 6.943,471,103             |         |              |          |       |
| City Park                   |              |         |                            | 0.0031197 | 9.428849   |          |       |
| Total                       | 10.156892    | 0.377896 | 4.72,958.0771             | 0.22557802 | 7.876312056 | 0.1348538 | 491,725971 |

Changes in public green open space as a whole during 2004-2019, namely public green open space covering an area of 17.62 km² did not change or remain permanent. Over the past 15 years, there has been an increase in the area of public green open space to an area of 1.15 km², but during that period there was also a reduction in the area of public green open space by 2.61 km². The increase in the area of public green open space has occurred due to the construction of several city parks in order to meet the needs of public green open space, including the Ananda City Park, Masdulkabi City Park, and Grogol Indah City Park. The highest reduction in public green open space occurred at river boundaries. The reduction in the area of river borders has occurred in many river border areas adjacent to residential areas. This is due to the increasing population and increasingly varied community activities, so that more space is needed to live or do activities. Vegetation on the border of the river also turns into a dwelling for the community.

Monitoring can also be done by overlaying the map of green open space in 2019 and 2004. The result can be seen the addition or reduction of public green open space in Sukoharjo Regency, as shown in Figure 5. Most of the Sukoharjo area is a flat area consisting of Kartasura, Sukoharjo, Baki, Mojolaban, Tawangsari, Gatak, and Grogol, while Nguter, Polokarto, Bulu, Bendosari and Weru sub-districts tend to have a bumpy to mountainous topography. Flat areas are dominated by agricultural land in the form of irrigated rice fields and people's fields so that there are still few public green open spaces. In addition, kecamatan with flat relief tend to be used for industrial estates.

The western part of Sukoharjo Regency which includes Polokarto, Bendosari and Nguter Districts is bordered by Karanganyar Regency, so the relief tends to be bumpy to hilly. These three districts are still dominated by the use of agricultural land in the form of terraced rice fields and gardens owned by residents, and in some areas used for rubber plantations. This is different from the situation in Karanganyar Regency, which is dominated by standing trees.
Based on the map of changes in public green open space in Sukoharjo Regency, it can be seen that the area of change in public green open space per district is shown in Table 5. The most additional public green open spaces were added in Grogol District, but the highest reduction in public green open space was also found in Grogol District. This addition occurs because there is a development of urban parks, while the reduction in the area of public green space occurs due to residential areas that are increasingly densely populated and also the development of industrial areas.

Table 5 Area of Change in Public Green Open Space

| No | District     | Area of Change in Public Green Open Space (km²) |
|----|--------------|-----------------------------------------------|
|    |              | Not change | Increase | Decrease | Non Public Green Open Space |
| 1. | Weru         | 0.88       | 0.10     | 0.11     | 43.57                          |
| 2. | Buda         | 4.71       | 0.02     | 0.11     | 41.42                          |
| 3. | Tawangtani   | 0.33       | 0.03     | 0.09     | 39.19                          |
| 4. | Sukoharjo    | 0.28       | 0.06     | 0.26     | 46.05                          |
| 5. | Ngawen       | 0.72       | 0.14     | 0.10     | 54.64                          |
| 6. | Bendosari    | 0.88       | 0.13     | 0.31     | 56.56                          |
| 7. | Polokarto    | 7.00       | 0.14     | 0.26     | 59.51                          |
| 8. | Mojolaban    | 0.70       | 0.15     | 0.27     | 37.10                          |
| 9. | Grogol       | 0.96       | 0.23     | 0.47     | 29.93                          |
| 10. | Baki         | 0.38       | 0.08     | 0.22     | 22.50                          |
| 11. | Gatala       | 0.40       | 0.03     | 0.26     | 19.26                          |
| 12. | Kartasura    | 0.37       | 0.04     | 0.15     | 20.50                          |

The addition of public green open space indicates that at these locations there was an increase in the area of public green open space in 2019 compared to the area available in 2004. This could be in the form of the construction of new types of public green open space or an increase in the area of the existing public green open space. The reduction in public green open space illustrates that at these locations there has been a reduction in the area of public green open space compared to the area in 2004. The reduction in public green open space that occurs is only in the form of a reduction in the area of public green open space that has been there before.

Public green open space in the form of urban forest has experienced the least change, its area has even increased by 0.08 km² in Polokarto District. This is different from other types of public Green Open Space, such as river borders and fields. The two types of green open space had the most changes in area, either praying or not. In this type of public green open space, all sub-districts in Sukoharjo district experienced a reduction in their area compared to their area in 2004. However, at several points in all sub-districts there was also an increase in the area of this public green open space, although the additional area was not too large. This is due to land conversion due to human settlements. An additional area of green open space in the form of construction of new types of public green open space is available in Grogol and Baki Districts. The development of city parks is aimed at meeting the need for green open space, this is because this sub-district has a large industrial area.
3.6. Oxygen Needs

a. Oxygen Needs for Population

In 2004 the population in Sukoharjo Regency was 815,089 people with the largest population in Grogol District (97,273 people) and the lowest was in Gatak District (46,581 people). The population in 2019 has increased to reach 891,912 people with the highest population in Grogol District (141,407 people), while the lowest number is located in Bulu District (27,575 people). According to White et al. (1959) the need for oxygen per person in one day can reach 0.864 kg of oxygen / day [6]. Based on the calculation of oxygen demand, it is known that the total oxygen demand based on the population in 2004 was 704,236.90 kg / day, while in 2019 it reached 770,611.97 kg / day.

b. Oxygen Needs for Livestock

The difference in the number of livestock was clearly visible between 2004 and 2019, this was due to an increase in the livestock sector that was developing in Sukoharjo. In 2004, the number of livestock was 1,307,279, while in 2019 it was 5,604,339. The livestock sector is dominated by poultry, both in 2004 and 2019. During the past 15 years, there has been an increase in the number of livestock by 4,297,060 heads. In 2004, there were gaps in data on native chicken types, while in 2019 the number of dairy cows was unknown.

The total oxygen demand for livestock is not limited to the boundaries of each district, but is analyzed at the district level. This is because there is no specific data in each district. Oxygen requirements for large livestock have greater oxygen requirements than small livestock and poultry. According to Muis (2005) the oxygen demand for cows and buffaloes reaches 1.70 kg / day while 2.86 kg / day for horses. Small livestock types such as goats and sheep require oxygen of 0.314 kg / day while poultry is 0.17 kg / day [3]. The oxygen demand for pigs is based on the research of Hannon et al. (1989) which is equal to 1.24 kg / day [4]. The oxygen needs of each type of livestock and their numbers in 2004 and 2019 are detailed in Table 6. The increase in livestock numbers also has an impact on increasing the amount of oxygen demanded. This can be seen in the oxygen demand in 2019 which reached 1,014,770.48 kg / day while in 2004 it was only 279,325.70 kg / day.
Table 6 Oxygen requirements for each type of livestock

| No | Types of Livestock | Need for Oxygen (kg/day) | Total 2004 | Total 2019 | Total Need for Oxygen (kg/day) |
|----|--------------------|-------------------------|-----------|-----------|-------------------------------|
| 1  | Cow                | 1.7                     | 25582     | 29745     | 43540.56                      |
| 2  | Buffalo            | 1.7                     | 2398      | 597       | 4081.4                        |
| 3  | Horse              | 2.86                    | 209       | 243       | 597.74                        |
| 4  | Goat               | 0.314                   | 36076     | 49626     | 11327.86                      |
| 5  | Sheep              | 0.314                   | 33337     | 46247     | 10467.82                      |
| 6  | Pig                | 1.24                    | 6798      | 16331     | 8429.52                       |
| 7  | Chicken            | 0.167                   | 1171447   | 5224425   | 186613.65                     |
| 8  | Duck               | 0.167                   | 85432     | 237125    | 14267.14                      |
|    | **TOTAL**          |                         | 279325.7  |           | 1014770.48                    |

c. **Oxygen Needs for Industry**

The calculation of oxygen demand based on the number of industries is not limited to the boundaries of each district, but is analyzed based on district administrative boundaries. This is because there is no specific data in each district. The division of industrial types is classified into the agro and forest products industry, the textile and various industries, and the electro-machine metal chemical industry. The calculation of oxygen demand based on industry uses a large number of industries. This is based on the assumption that large industries use a large number of machines and for a longer period of time than small and medium industries. In 2004, the total number of large industries was 25 industries, while in 2019 it grew to 129 industries. This development mostly occurred in the electro-machine metal chemical industry.

The use of large industries for the calculation of oxygen demand is based on research by Ryadi (1984). The research states that the average fuel requirement for the engine is 185.76 kg/day, while each kg of diesel motor fuel requires 2.86 kg of oxygen [6]. Based on this formula, the oxygen demand in 2004 was 13,281.77 kg/day and in 2019 was 68,533.92 kg/day.

d. **Oxygen Needs for Motor Vehicle**

The number of motorized vehicles in 2004 was 169,968 units and in 2019 801,581 units. Over the past 15 years, there has been an increase in motor vehicle consumption by 631,613 units of vehicles. The number of motorized vehicles is obtained from BPS data from Sukoharjo Regency which is derived from vehicle tax revenue data collection in Sukoharjo Regency. The assumption used in calculating oxygen demand is the number of vehicles originating from Sukoharjo Regency, while vehicles originating from outside the area are ignored. The total oxygen demand is not limited to the boundaries of each sub-district, but is calculated at the district level.

The largest number of motorized vehicles is dominated by motorbikes. Bus cars have the smallest number and the number continues to decrease every year. This is followed by an increase in the number of passenger cars and motorbikes, indicating that the use of private vehicles is increasing every year. The fuel and oxygen requirements for each type of vehicle are detailed in Table 7.

Table 7. Oxygen Needs of Each Type of Vehicle

| No | Motor Vehicle | Fuel Requirements (kg/PS) | Oxygen Needs Per Liter of Fuel (kg) | Oxygen Needs (kg/hours) |
|----|---------------|---------------------------|------------------------------------|-------------------------|
| 1  | Motorcycle    | gasoline                  | 0.21                               | 2.77                    | 0.58                    |
| 2  | Passenger car | gasoline                  | 0.21                               | 2.77                    | 11.63                   |
| 3  | Bus Car       | diesel fuel               | 0.16                               | 2.86                    | 44.32                   |
| 4  | Load Car      | diesel fuel               | 0.16                               | 2.86                    | 22.88                   |

Source: (Wisesa, 1988 in Putrajaya, 2017)

The total oxygen demand of each type of motorized vehicle in each year can be seen in Table 8. The calculation results show that there is an increase in oxygen demand from motorized vehicles, namely in 2004 of 56,687.56 kg/day while in 2019 it was 70,042.94 kg/day.
### 3.7. Need for green open space

The need for green open space is calculated using the Gerrachic approach. This method shows that green open space in every m$^2$ will produce 54 grams of dry weight, wherein one gram of dry weight is equivalent to oxygen production of 0.9375 grams / day [6]. The total oxygen demand of the population, livestock, industry, and motor vehicles in 2004 was 1,053,531.92 kg / day, while in 2019 it was 1,923,959.31 kg / day.

This can be seen from the available open green space area of 20.22 km$^2$ from the need for green space that is only 10.41 km$^2$. The increase in population, industry, motorized vehicles, and livestock has an impact on increasing the need for green open space. This can be seen in the oxygen demand in 2019 which increased by 870,473.9 kg / day from 2004. The green space available in 2019 was 18.77 km$^2$, where this area experienced a reduction of 1.45 km$^2$ from the previous 15 years. The reduction in the area of green open space is inversely proportional to the need for green open space in 2019 which has increased to 19 km$^2$. Based on the number of requirements, it can be said that the availability of green open space in 2019 is still not fulfilled by the available public open green space.

### 4. Conclusion

The conclusions obtained from this study are ASTER imagery and Sentinel-2A imagery can be used for visual interpretation in mapping public open space in the form of fields, river borders, and urban forests while for public open green space in the form of cemeteries and city parks can only be interpreted if the size is more than MMU. The overall accuracy value produced by the ASTER image reaches 96%, while the accuracy of the Sentinel-2A image is 90%. Mapping changes in public green open space in 2004-2019 shows that 17.62 km$^2$ of public green open space has not changed. Changes in the area of public green open space, namely an addition of 1.15 km$^2$ of green open space and a reduction of 2.61 km$^2$ of green open space, which was dominated by changes in the area of the riverbank to non-public green open space of 2.48 km$^2$.

Based on the population, industry, livestock, and motorized vehicles, it was found that the estimated total oxygen demand in Sukoharjo Regency in 2004 was 105353192 kg / day while oxygen demand in 2019 reached 192395931 kg / day. Estimated need for green open space based on oxygen demand in Sukoharjo Regency in 2004 was 10.41 km$^2$ and in 2019 was 19 km$^2$. The availability of green open space in 2004 has been fulfilled from the available public green open space, which is 20.22 km$^2$, while in 2019 public green open space has not been able to meet the needs of green open space in 2019, which is only able to meet 18.77 km$^2$.

In this research, the interpretable type of green open space can only include public green open space. This is adjusted to the type of image used. The suggestion for further research is the use of remote sensing images with better spatial resolution and the same characteristics, so that it can simplify the process of interpreting types of public green open space in more detail and with more accurate results. In addition, data on the number of motorized vehicles in and out of Sukoharjo Regency can also be added so that the calculation of oxygen demand can be more accurate. Monitoring changes in green open space is very important to do. Future research is not only limited to monitoring changes that have occurred, but also estimating the need for green open space in relation to oxygen demand and the city's rapid development.
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