An Investigation of Oxygen Need Based on Green Open Space in Indonesia University of Education (UPI) Campus Bandung

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Abstract. Oxygen is an essence energy supporting the life for all of ecological unit. Since the ecological unit can provide O2 for its components, thus it can be apprised a balance condition and also that condition must be consider to Campus UPI. The objectives of the research are to find out Green Open Space (GOS) condition in UPI College, to estimate balance situation between consumption of the O2 and the production based on GOS. The methods which are used to calculate the balance state are comparing the both people and vehicles O2 consumption and the production of O2. Standard demand of the oxygen is utilized to calculate the person’s oxygen need per day. Furthermore, Maximum likelihood Classification are used to derive GOS and the Allometric and Nowak equation is applied to estimate both biomass and the O2 production. The result shows that total areas of GOS in UPI are about 158.774,57 m2 or only 42.59%. Likewise, based on the GOS area, it can be calculated that approximately 2.673.399,60 kg/year UPI produce the O2. In addition, balance condition show that UPI has deficit oxygen production about 994.335,41 gr/day. Moreover, optimization of the potential area for planting and developing vertical garden should be considered to gain more O2 production.

1. Introduction

Oxygen (O2) is an essence energy supporting the life for all of ecological unit. It plays a fundamental role in order to preserve their life and existence on the world. One of the essential element, oxygen together with other four components about 96% namely Carbon (C), Oxygen (O2), Hydrogen (H), and Nitrogen (N) are the constituent body of living things [1]. Likewise, in the human body, each person consist of approximately 65.0% oxygen [1]. In addition, lacking of the O2 for a human body, it could render to get serious problem either physically or unphysically. Low O2 supply to the body obtained from the metabolism process can give a problem both of human tissues and hypoxia [2–4].

Taking into account the important of oxygen, a balance condition between consumption and production need to be fulfilled. State of the balance means that amount of production and consumption are not deficit. Hence, if the amount of O2 production and consumption is not deficient then it can be assumed in a balanced condition. Human respire taking the oxygen to gain energy for their activity. Basically, in normal condition a person need O2 about 600 l/day or equal to 864 gr/day [5]. Other study shows that in a day person need approximately 0.84 kg O2/day or 840 gr/day [6]. Furthermore, in order to fulfillment their oxygen need, it can be provided by vegetation as a green open space (GOS) which can produce it. Generally, earth surface also provide oxygen from plants living in both the ocean and on
land produce annually approximately 8 mole’s oxygen per m² [7]. Within the photosynthesis process, a plant which have chlorophyll, it has capability producing O₂. Beside producing oxygen, another benefit that can be given is to maintain the local temperature and to reduce concentration of carbon dioxide (CO₂) in the atmosphere [8–10].

The amount of oxygen production can be estimated by using the total net carbon approach of living biomass for a year. Biomass is defined as the total amount of aboveground living organic matter in trees expressed as oven-dry tons per unit area [11]. The carbon deposit in the plant comes from the CO₂ residues that accumulated and then turns into carbon (C) as a results of the respiration process [12]. Thus, the O₂ production from the plants can be estimated by comparing the molecular weight between C and O₂ [7,12]. Recently, few studies have found related to estimate the oxygen production using biomass approach. Nowak et al. (2007) calculates the amount of O₂ production from urban plant by means of biomass approach in urban area. In tandem with this, another study conducted to approximate of oxygen production from dominant plants in Konnagar Municipality, India and calculating the carbon storage to get the oxygen production in Turkey [13,14].

Recently, biomass prediction can be done using conventional method (field measurement) by using allometric equation and it can be assumed by utilizing remote sensing technology. The use of LiDAR (Light Detection and Ranging) as a way to estimate biomass has been widely used to estimate total biomass [15–19]. LiDAR is capable to capture objects (plants) in detail, so that either diameter, height or canopy areas should be well identified.

Considering the importance of oxygen balance condition of a region, the estimation of O₂ balance can be done with biomass approach. So, this research aims to determine the condition of green space with semi-remote sensing method and to calculate the oxygen balance condition in campus area of Universitas Pendidikan Indonesia (UPI) which in fact, total population has continued to increase every year coupled with the reduction of green area.

2. Materials and methods

2.1. Study area

Geographically, Universitas Pendidikan Indonesia (UPI) Bandung which is commonly called UPI Bumi Siliwangi located between at 107° 35’ 11.93” – 107° 35’ 47.5” E and 06° 51’ 25.36” – 06° 51’ 54.3” (Figure 1). UPI has 5 primary campus distributed around west java province, namely UPI Bumi Siliwangi, UPI Purwakarta, UPI Sumedang, UPI Cibiru and UPI Serang. Based on administrative boundary, the research location is in Isola Village, Sukasari District, Bandung Municipality. UPI Bumi Siliwangi is one of the largest campuses located in West Java [20] which has a total area of about 372,761.08 m². Based on rainfall data over past year, this area has a high rainfall of approximately 2,355.10 mm/yr in which it is supported by the location in the tropics.
Topographically, research area has altitude range from 929 m up to 967 m. Furthermore, the type of latosol soil covers all areas [21]. Latosol soil is classified as mature soil with low fertility owing to high iron and aluminium [22]. According to Directorate of student affair (2015) data, UPI Bumi Siliwangi is classified into a dense campus with a population of 26,606 consisting of students, lecturers, other employees in 2014 – 2015 [23]. In addition, the number of the population has increased every year as a result it leads to an increased need for developed areas to equip facilities for scholars by reducing GOS (Figure 2).

2.2. Green open space classification
An identifiable green open space area and its types are required to estimate how many areas covered by plant as well as its types. Both area and the type of the green open space has identified using remote
sensing and field observation survey. Classification is commonly procedure to obtain certain information regarding the land-use (LU) type derived from multispectral imagery [24]. An imagery from Google Earth within data acquisition in January 2016 is utilized to obtain GOS information by performing supervised classification using maximum likelihood classification (MLC) algorithm. MLC is a method to define distribution class as the maximum for a specified statistics and the algorithm of the MLC builds probability density functions for every class [24]. The classification has been done by using ArcGIS 10.2 which is capable to handle it. Prior to use the google earth image, georeferencing was done to get horizontal accuracy. Several studies show that imagery from google has been widely applied to get the LU classification even the object based classification [25–28]. Moreover, type of GOS identified based on the storey (height and canopy) classification during field observation when the measurement of the plant’s diameter at breast height (DBH).

2.3. Balance state of oxygen need

2.3.1. Oxygen production (OP). Basically, oxygen is a gas type which is free in the atmosphere, it can pass everywhere when no one is limiting. So that, the study assumes that UPI is a closed environment, no $O_2$ either coming in or out as well as produced only from GOS in research area. GOS is an area in the earth surface looking at 2D which is covered by plants whether floor types or even height trees.

In fact, plants have ability to accumulate the C in their body from the respiration process, thus OP is calculated by separating the molecular weight between C and $O_2$ to get the net oxygen in a year. Furthermore, the amount of OP in UPI Bumi Siliwangi has been estimated from biomass in which it can be utilized to obtain C sequestration. In order to divide the molecular weight between C and $O_2$, Nowak (2007) equation has been applied to obtain the net oxygen production in a year (Equation 1).

$$Net \ O_2 \ release \ (kg/yr) = net \ C \ sequestration \ (kg/yr) \times 32/12$$

In which $Net \ O_2 \ release$ is the net total amount oxygen in a year per kg; $net \ C \ sequestration$ is the carbon stock estimated from biomass; and $32/12$ is both atomic weight of C and $O_2$ respectively.

In addition, biomass measurement was conducted to approximate C sequestration by using semi-remote sensing approach. An allometric equation and destructive sampling for floor plant types was used to estimate the biomass production. The application of allometric equation from Brown (1997) was used to estimate the biomass production for plants with $dbh > 5$ cm surveyed in each unit area. Dbh measurements were performed on all plants located at the study site in order to obtain an accurate total biomass. Due to the precipitation conditions in the study area of 2,355.10 mm/yr included in humid climates with rainfall classification range from 1,500 mm/yr - 4000 mm/yr, the allometric formula under moist conditions is applied to calculate the total biomass (Equation 2). Then the predicted carbon sequestration is calculated by multiplying the total biomass with 0.5 because 50% of the total biomass is C [29] (Equation 3).

$$Y = 42.69 - 12.8 \ \left( D \right) + 1.242 \ \left( D^2 \right)$$

$$C \ sequestration = Y \times 0.5$$

In which $Y$ is the total tree’s biomass (kg/yr); $D$ is the diameter at breast height (DBH); 42.69, 12.8, 1.242 is the Constanta; and 0.5 is Constanta due to half of the biomass is the $C \ sequestration$.

Remote sensing approach was utilized to calculate total area of crops within $dbh < 5$ cm which is categorized to Storey E to estimate the total biomass. Destructive sampling is applied by taking samples of $1 \ m \times 1 \ m \ (1m^2)$ on each plant’s type belonging to the storey E class. Drying is done on all parts of the plant from roots, stems, leaves, flowers, and fruit to obtain their dry weight. Thus, the average of dry weight value is used as the biomass number.
2.3.2. Oxygen consumption (OC). Aforementioned, in normal condition a person consume O$_2$ about 864 gr/day or 840 gr/day [5,6]. Hence, oxygen consumption for population living in UPI is calculated by multiplying total population with the normal oxygen need. In addition, based on the schedule activity time, in a day for effectively activity in the college was assumed only 8 hours in a day. Thus, the oxygen consumption for the people in UPI need about 288 gr/8hours or 280 gr/8hours. Furthermore, the total amount of oxygen consumption is obtained by multiplying the amount of oxygen consumption in 8 hours per day with the total population in the UPI.

$$O_{in\ 8\ hours\ (gr/8hours)} = t_e \times 864\ or\ 840\ gr/day$$

$$t_e = 8/24$$

In which $t_e$ is effective time in the campus; 864 and 840 gr/day are the normal oxygen consumption in a day per each person.

Moreover, beside the estimation of the oxygen consumption for humans, the amount of oxygen consumption for vehicle are considered because the Oxygen is required by motor vehicles at the time of the combustion process [30]. Based on field observation, recorded two types of vehicles which are mostly located in the study location is motorcycle and passenger car type III in which each of the vehicle type need about 1.5 m$^2$ and 15 m$^2$ for the parking allocation areas [31]. The power and type of fuel used by the vehicle affects the amount of oxygen consumption [30]. Wisesa (1988) report that for the motorcycle needs approximately 0.58 kg/hour O$_2$, beside for the passenger type III requires 11.63 kg/hour O$_2$.

The delineation of the parking lot and its distance are done by using ArcGIS software which is supported by clear and detail visualization imagery from Google Earth to support the delineation process. Furthermore, the total number of vehicles accommodated by UPI is estimated by the standard allocation parking size of each type (Equation 6). Filed observation was used to determine the allotment of parking area’s unit whether for motorcycle or other vehicles. In tandem with this, owing to the importance of vehicle travel time, it is calculated by means on velocity equation (Equation 7 and 8). Since the maximum speed allowable in UPI about 20km/hour, the travel time for each parking area was calculated by multiplying the maximum speed with the distance. The distance measurement has been done by simulating the line from starting entrance point to each parking area.

$$Nve = \frac{Pa}{veD}$$

$$v = \frac{s}{t}$$

$$t = v \times s$$

$Nve$ is the total vehicle per size of the parking area; $Pa$ is the size of parking area (m$^2$); $veD$ is standard parking dimension per vehicle’s type (m$^2$); $v$ is the velocity (km/hour); $s$ is the distance from starting point (km); and $t$ is the travel time (hour).

2.3.3. State of balance oxygen need. Since the ecological unit can provide oxygen for its components, thus it can be apprised a balance condition. The condition is said to be balance when result of the comparison between consumption (out) and the production (in) is same or even surplus. Thus, the oxygen balance condition is calculated based on the total oxygen production minus its consumption (Equation 9).

$$Oxygen\ Balance\ (gr/day) = OPin – OCout$$
In which \( OPin \) is the \( O_2 \) production based on the GOS (gr/day) while \( OCout \) is oxygen consumption from UPI's population and vehicle (gr/day).

\[ \text{Figure 3. Research flow work.} \]

2.4. Fulfilment of oxygen need
Fulfilling the need for oxygen as an effort to increase the oxygen production of an environment for its own ecological component without taking the right of other ecological components. As a result, the burden on the environment (oxygen demand load) should be reduced. Both creating vertical garden simulation and planting a plant with measured rod diameter was simulated to the number of biomass which will affect to yield more oxygen.

Simulating the vertical garden is done by converting every building roof into a green space with the floor plant type. On the contrary, based on the results of biomass measurement showed that a plant with a dbh as high as 21 cm, it can produce oxygen as much as 994,314.11 gr/day, this indicates that one person's oxygen demand per day can be fulfilled by one tree with dbh 21 cm. So, the simulation of planting is done by adding the number of plants with the diameter.

3. Results and discussion
3.1. Green open space classification
Based on the classification result shows that the total areas of the green field are smaller than developed land. It is about 158,774.57 m\(^2\) or merely 42% compared with the others (Figure 4). Moreover, three types of the GOS was classified which are differed based on plant storey, namely tall tree, medium height tree, and grass type (E-Storey) (Figure 5). The majority of the tall trees are more than other types covering the research location which is approximately 43%. In addition, census surveys were applied to
measure all of the tree’s dbh which have dbh >5 cm. Based on the field measurement, the GOS is classified based on plant height (Storey). The results show that total number of trees in UPI is about 4870 within dbh >5 cm which divided into 4 classes. The Storey C recorded as the largest number amounted to 3,724 trees with a height class ranging from 4m – 20m (Table 1). Furthermore, especially for the storey E is define by the remote sensing classification which is classified as grass type.

![Figure 4](image1.png)

**Figure 4.** Image A depicts land proportion between GOS and developed areas in UPI; whereas Image B shows the classification types of GOS based on the classification.

![Figure 5](image2.png)

**Figure 5.** Green open space classification results based on the supervised classification within MLC algorithm.
Table 1. Storey classification of GOS in UPI.

| Storey | Height | Total | %  |
|--------|--------|-------|----|
| B – Storey | 20 m – 30 m | 13 | 0.27 |
| C – Storey | 4 m – 20 m | 3724 | 76.47 |
| D – Storey | 1 m – 4 m | 1133 | 23.26 |
| E – Storey | Floor types | | |
| Trees dbh >5 cm | | 4870 | 34.67% |

3.2. Balance oxygen need

3.2.1. Oxygen production. The results of dry weight measurements on several plant species samples belonging to the class of ease-plants (E – Storey) with a size of 1 m x 1 m (1 m²) show that the mean in each m² can yield 0.115 kg dry weight as biomass. Thus, the average dry weight is used to determine the total biomass per area (m²) for grass type. Furthermore, total biomass calculated by combining between biomass for grass type and trees within dbh >5 cm. The total biomass that can be produced by UPI in a year is about 2,005,049,70 kg. So that, when compared to the amount of biomass with the total green areas, in every m² UPI can produce 12.6 kg biomass. In addition, the quantity of the C sequestration can be assumed to be half the number of biomass [29]. Hence, multiplying the total biomass with 0.5 yields C sequestration total about 1,002,534.85 kg. After getting the C total, approximation of oxygen production from the GOS in a year can be estimated with Nowak (2007) equation in which quantity of oxygen production in UPI is ± 2,673,399,60 kg/yr or equals to 7,324.38 kg/day (1yr = 365 days). So that, in a day (24hours) UPI produce 7,324,382.45 gr/day (Table 1).

3.2.2. Oxygen consumption. The number of people and vehicles contained in UPI into consideration in calculating the quantity of oxygen consumption in a day. The calculation of O2 consumption both people and machines calculated using normal daily oxygen count requirement given by White et al. (1959) and Perry et al. (2002) as well as normal oxygen demand for each vehicle’s type by Wisesa (1988). According to the total population in UPI about 26,606 the oxygen consumption within 8 hours (assumed in a day) requires about 7,662,528 gr/8hours or 7,449,680 gr/8 hours (Table 2).

Table 2. People oxygen consumption.

| Type of UPI's population | Total | Oxygen Consumption (gr/8hours) | Oxygen Consumption (gr/8hours) |
|--------------------------|-------|--------------------------------|--------------------------------|
| Scholars                 | 24,282| 6,993,216                      | 6,798,960                      |
| Lectures                 | 1,093 | 314,784                        | 306,040                        |
| Honorable employees      | 608   | 175,104                        | 170,240                        |
| Others                   | 623   | 179,424                        | 174,440                        |
| Total                    | 26,606| 7,662,528                      | 7,449,680                      |

Note: c column is based on the White et al. (1988), beside d column is according to Perry et al. (2002).
In addition, the delineation of parking area based on their types is obtained $11,991,35 \text{ m}^2$ and $24,003.35 \text{ m}^2$ for motorcycle and passenger vehicle type III respectively (Figure 6). Thus, according to the normal dimension of the parking area per types, UPI can accommodate about 7,994.23 units motorcycle and 1,600.22 units passenger vehicle type III. Likewise, the quantity of oxygen consumption for each vehicle type which is calculated based on the number of vehicles and the travel time per unit parking area shows both of motorcycle vehicle and passenger cars type III consuming about 61,796.78 gr/hour and 594,393.08 gr/hour. Thus, the total oxygen consumption for vehicles is 656,189.86 gr/hour.

Figure 6. Image A shows result of parking area measurement and image B depicts distance simulation per unit parking area.

3.2.3. Balance condition. The balance condition is calculated by comparing between the oxygen produced from GOS and the oxygen consumption both from people and vehicles. The results show that the quantity of oxygen production is less than the oxygen consumption in a day (8 hours). The calculation in 8 hours is due to the effective time of activity in the research location. Table 3 shows the oxygen balance results in which column a is the oxygen consumption for people lying on different references. The result of the equilibrium shows that UPI experienced a deficit of oxygen requirement in one day as much as -994,335.41 gr/day (Table 3).

Table 3. Comparison among oxygen production, people and vehicles oxygen consumption (A day means 8 hour).

| Comparison         | Total (gr/day) (a) | Total (gr/day) (b) |
|--------------------|--------------------|--------------------|
| Oxygen Production  | 7,324,382.45       | 7,324,382.45       |
| People’s Consumption | 7,662,528.00       | 7,449,680.00       |
| Vehicle’s Consumption | 656,189.86       | 656,189.86       |
| Deficit            | -994,335.41        | -781,487.41        |

Note: Column a is the people’s oxygen consumption based on White et al. (1988), and column b is according to Perry et al. (2002).
3.3. Fulfilment of the oxygen need

A simulation has been done by creating a vertical garden where the top roof of the building in UPI is converted into green fields with the type of E – storey class as well as planting trees with dbh criteria about 21 cm. The first simulation shows total area from developing vertical garden yield 99,462.53 m² which means it produce oxygen 15,188.89 kg/yr or equivalent to 41,613.41 gr/day (Table 4). Although converting the roof of the building into a vertical garden, UPI still unable to cover the lack of O₂ consumption, only about reduced to 952,722.00 gr/day.

Table 4. Simulation of vertical garden.

|          | Area (m²) | Biomass | C       | O₂ (kg/yr) |
|----------|-----------|---------|---------|------------|
| Vertical Garden | 99,462.53 | 11,391.67 | 5,695.84 | 15,188.89  |

The second step is to plant the trees having a dbh as wide as 21 cm. The OP calculation results show that plants with dbh about 21 be able to produce oxygen as much as 349.44 kg/yr or equal to 957,36 gr/day. So, to cover the lack of oxygen quantity of 994,335.41 gr/day, it takes about 1,039 plants. The total production of oxygen from 1,039 trees yield is about 994,697.04 gr/day. Hence, the oxygen requirement for UPI will be fulfilled and experiencing a production surplus of 361.63 gr/day.

However, if not accomplishing both vertical garden and tree planting, UPI will be able to meet the oxygen demand within the 25-year because of tree’s dbh growth about 0,38 cm/yr. If assuming dbh trees are growing and there is no reduction or planting or extending more in the number of GOS as well as the number of people (Figure 7).

4. Conclusions

The areas of GOS in the campus are less than the area of built land, only about 42% of UPI covered by both trees type and floor plants. Moreover, based on dbh and dry weight measurements for the plants yield biomass of 2,005,049.70 kg in year and It accumulate C sequestration about 1,002,534.85 kg. The computation of oxygen production by biomass approach yields oxygen approximately ± 2,673,399.60 kg/yr or equals to 7,324.38 kg/day (1 yr = 365 days). So that, if converted in time of a day, it means in a day (24hours) UPI produce 7,324,382.45 gr/day.

In addition, the total number of oxygen consumption required both people in 8 hours and vehicle is about 7,662,528.00 gr/8 hours and 656,189.86 gr/hour. Furthermore, when compared between
production and consumption of oxygen in UPI, then UPI will experience oxygen deficit around 994,335.41 gr/day. Fulfilment of oxygen deficiency can be done either by making vertical garden or planting tree with dbh around 21 cm which can produce oxygen 349,44 kg/yr or equals to 957,36 gr/day. Developing a vertical garden converting the roof of the building into a green field with the type of grass type will not cover the lack of the oxygen deficiency, however tree planting with dbh 21 as much as 1,039 trees then the lack of oxygen production will be fulfilled even surplus about 361,63 gr/day.

5. Research limitation and further study
Since determination of the GOS for the grass types resulting from remote sensing, it neglects the measurement of the floor plant type under the tree with wide canopy. Since determination of the GOS for the grass types resulting from remote sensing, it neglects for the plant as grass type under the tree with wide canopy. As it known that oxygen-producing plants not only from the height trees but also from the grass types as well as plants that exist in the waters. Hence, for the next study computing the total plant whether under or in the water it needs to be considered. Similarly, with regard to the estimation of the total biomass, different types of plants might produce different quantity of biomass in which it will have an impact on the amount of oxygen production, so a more accurate measurement of the oxygen production can be done by differentiating the tree’s types within their allometric equations.

Considering the number of oxygen demand for a person is only calculate in normal activities, consequently the total oxygen consumption only compute not for sports or other activities that will certainly affect the increase in the consumption. For this reason, to get a more accurate total oxygen consumption can be calculated by looking at the schedule of student activity, for instance exercise, with the need for oxygen at that activity. Associated with the calculation of oxygen consumption which is only considered to the maximum capacity based on the size of parking areas. So then, making a scenario in a normal and exclusive day (graduation or big exhibition) for the number of vehicle estimates at the peak time for both in normal and other situations might be need to be computed to get more precision vehicle’s oxygen consumption.

Moreover, in line with the addition of GOS or planted cultivation to increase the number of oxygen procurement lacking to consider the concept of plant selection based on its function, thus the concept of plant selection can be used in order to obtain not only increasing more Oxygen production but also the aesthetic value. To obtain accurate measurements of plant dimensions, measurements can use LiDAR technology to obtain dbh, tree-height, and canopy width data accurately and in line with biomass estimates. One person one tree for a lifetime where one tree can provide O2 for its life and can even donate to other people.

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