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Performance Analysis of Environmental Monitoring System (EMS) towards POLMEDs Green Campus

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***Abstract*—UI GreenMetric is a guide for higher education institutions to raise awareness of sustainable development, sustainable research, building a green campus, and social influence. There are six assessment categories in UI GreenMetric. One of them is energy and climate change. The assessment point in energy and climate change is the implementation of smart buildings within the campus area. There is often pollution on campus. The campus still uses groundwater for daily sanitation; workshops' waste is discharged directly into the ground without any sewage treatment process; many private vehicles are in the campus area; and 30% of campus land has been used as vehicle parking lots. It is necessary to carry out a monitoring process to determine the concentration of CO_2 in the air. For this reason, further study is needed on smart features that will be built to support UI GreenMetric concepts. It is expected to help monitor water, soil, and air environmental parameters. This smart would later be monitored remotely using the Internet of Things (IoT) method. The maximum result of air temperature is 32.3°C, the maximum level of CO_2 is 526.8 ppm, the minimum humidity level is 47.2%RH, and the maximum level of PAR is 589.3 µ*mol/m²*s. The noise maximum level is 84 dB, and pH water maximum is 7.01. The density of students also caused an increase in some parameters. POLMED must concentrate on environmental sustainability. Therefore, we should pay for internal recycling water treatment, reducing the use of private vehicles, and expanding green open space.**

***Keywords*—UI GreenMetric; energy and climate change; environmental parameters; smart features; Internet of Things (IoT).**

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I. Introduction

Universitas Indonesia (UI) initiated world university rankings in 2010, later known as the UI GreenMetric World University Rankings, to measure campus sustainability efforts. It was intended to create an online survey to portray sustainability policies and programs for universities around the world. In 2022, 1050 universities from 85 countries around the world participated. This shows that UI GreenMetric has been recognized as the first-world university ranking on sustainability.

UI GreenMetric is a guide for higher education institutions to raise awareness of sustainable development, sustainable research, building a green campus, and its social influence. This ranking aims to contribute to academic discourses on sustainability in education and the greening of campuses. Promote university-led social change about sustainability goals, be a tool for self-assessment on campus sustainability for higher education institutions (HEIs) around the world, and inform governments, international and local environmental agencies, and society about sustainability programs on campus.

In general, UI GreenMetric has three aspects: environmental, economic, and social [1]. Environmental aspects include the usage of natural resources, environmental management, and pollution control [2]. Economic aspects include profit and efficiency [3]. Social aspects include education, society, and social engagement [4]. There are six assessment categories in the UI GreenMetric, such as setting and infrastructure, energy and climate change, sewage treatment, water treatment, transportation, and research education. Each category has its assessment criteria.

We selected assessments that show deficiencies and focus on our campus. Hence, the assessment can be corrected and monitored as follows:

- The ratio of open space area to the total area in the setting and infrastructure category.
- Smart building implementation and total carbon footprint divided by total campus population in energy and climate change category.
- Water pollution control in the campus area in the water treatment category.
- The total number of vehicles (cars and motorcycles) is divided by the total campus population.
- The ratio of the ground parking area to the total campus area in the transportation category.

Smart buildings have smart features such as automation systems, safety systems, renewable energy resources, and building comfort systems [5]. A building comfort system includes three environmental elements: water, soil, and air [6]. Environmental parameters in the air are CO_2 concentration, noise, light intensity, temperature, and humidity [7]. Environmental parameters of water include water temperature, residue dissolved in water, inorganic and organic chemistry in water, and microbiological bacteria. Environmental parameters in soil are soil moisture, the potential of hydrogen (pH) in soil, the potential of groundwater, and soil mineral content [8].

There is often pollution on campus. The campus still uses groundwater for daily sanitation needs [9]. The workshop's waste is discharged directly into the ground without any sewage treatment process [10]. There are still many private vehicles in the campus area. Students still drive private vehicles onto campus, so many campus lands have been used as vehicle parking lots [11], [12].

Pollution would have a significant impact on the sustainability of the campus. Politeknik Negeri Medan (POLMED) still uses groundwater for daily sanitation. It is necessary to monitor soil moisture level, water pH level, organic and inorganic content, and many more. There are still many private vehicles in the campus area. The parking area uses 30% of the entire campus area. It is necessary to carry out a monitoring process to determine the concentration of CO_2 in the air.

For this reason, further study is needed on *Environmental Monitoring System* (EMS) that would be built to support UI GreenMetric concepts. EMS is expected to help monitor environmental parameters in water, soil, and air on the POLMED campus. EMS would later be monitored remotely using the Internet of Things (IoT) method. It consists of a monitoring system for parameters of the environment such as air temperature and humidity, CO_2 levels in the air, solar radiation levels, noise levels, pH liquid, and soil moisture. The data logger collects measurement data and sends it to the cloud server. The communication network from the data logger to the cloud uses a GSM network. Android and website programming develop user applications. Meanwhile, we would survey to calculate the ratio of open space area to the total area and the total number of vehicles (cars and motorcycles) divided by the total campus population as well as the ratio of the ground parking area to the total campus area as supporting data for EMS.

II. Material and Method

This study uses hardware and software to detect environmental parameters on campus. A fishbone diagram was used to make it easier to understand the steps and parts involved in the research. Four aspects must be carried out in this research: determining the environmental parameters, system implementation, determining the required device specifications, and determining the research location. This is illustrated in Fig. 1.

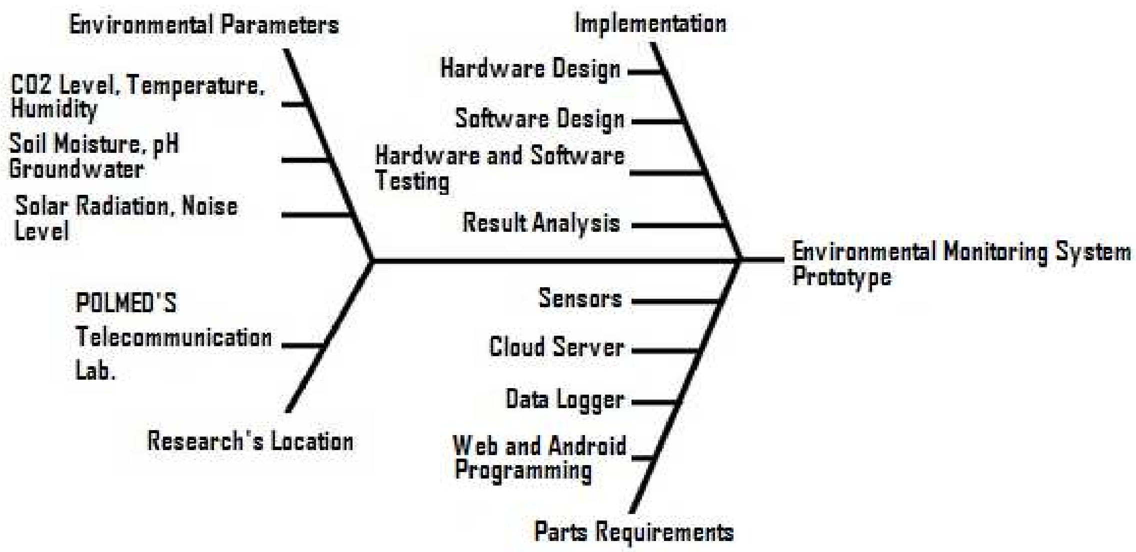

Fig. 1 Research fishbone diagram

This study uses materials that support detection methods using block diagrams, which can be seen in Fig. 2. It was used to explain the relationship between hardware and software in building an EMS prototype. Building an EMS prototype has four main blocks: the sensor block, the data logger block, the GSM network block, and the cloud server block.

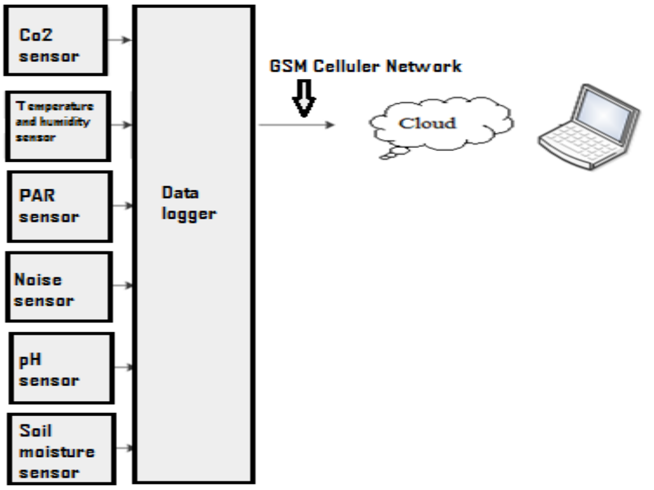

Fig. 2 Block diagram

The measurement data for each sensor would be sent to the data logger via a Wi-Fi network. In the data logger, all data is collected and then sent to the cloud server via the GSM network to be stored and accessed by users.

A. Hardware

This study uses six sensors with the following specifications:

- RK300-03 CO2 sensor with a range concentration of 0–10000 ppm
- RK330-02 ambient temperature and humidity sensor with a range concentration of -30°C–70°C and 0–100%RH
- RK200-02 photosynthetic active radiation (PAR) sensors with a range concentration of 0-2500 µ*mol/m2*s
- RK300-06B mushroom noise sensors with a range concentration of 30-120 dB
- RK500-02 pH sensor with a range concentration of 0-14 pH
- RK510-01 soil moisture sensor with a range concentration of 0–100%RH
- RK600-07 data loggers with measurement parameters of 32 max.

B. Software

This study uses Microthings Platform software to operate web-based and Android/iOS programs. Based on Fig.3, the sensors are placed according to their designation. Sensors are used for soil, water, and air. A soil sensor is a soil moisture sensor. The sensor's position is set to 10 cm deep at a radius of 5 cm from the emitter. This position is the most optimal for soil moisture [13]. A water sensor is a liquid pH sensor. The sensor's position is at least 15° above the horizontal plane to eliminate air bubbles in the pH glass bulb. This is the best result for the sensor, which should be mounted with the process flow coming towards the sensor [14]. The air sensors are a PAR sensor, a noise sensor, a temperature and humidity sensor, and a CO_2 sensor. The air sensor's position is at least 6 feet above ground level, a rooftop, or other object, and away from obstructions, vegetation, or emission sources [15], [16]. That would not interfere with the measurement.

The measurement data for each sensor would be sent to the data logger via a Wi-Fi network. The output of sensor detections is retrieved, stored, sent, and managed by the data logger to the cloud via the GSM network. It covers almost all regions in Indonesia so that environmental information can be accessed online and viewed in real time.

C. Fuel Activities

According to the Intergovernmental Panel on Climate Change (IPCC), every vehicle movement can produce gas emissions, such as carbon dioxide (CO_2), methane (CH_4), and nitrogen oxides (N_2O), from the combustion of fuel, as well as several other pollutants [17], [18]. The Mobile Combustion Formula is a mathematical model used to predict carbon dioxide (CO_2) emissions from vehicle exhaust dust. The emission (E) was calculated using Equation 1 [19].

Fuel activities a, b, c use fuel consumption from fuels such as Pertalite, Pertamax, and Pertamax Turbo. The emission factors are 2.408 ppm (Pertalite), 2.604 ppm (Pertamax), and 2.949 ppm (Pertamax Turbo).

$$CO_2\ Emission = Fuel\ Activities_{a,b,c} x Emission\ Factor_{a,b,c} \quad (1)$$

D. Variables Correlation

Correlation analysis was used to determine the strength of the relationship between variables. This study used Pearson's correlation analysis to produce a correlation coefficient [20], [21]. This value was used to determine the strength of the linear relationship between the two variables. The value of the correlation coefficient can be calculated using Equation 2. The correlation coefficient is calculated with a range of 0.0 to 1.0.

$$r_{xy} = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \quad (2)$$

Description:
r_{xy} : Correlation coefficient
x : first variable,
y : second variable
n : number of observations

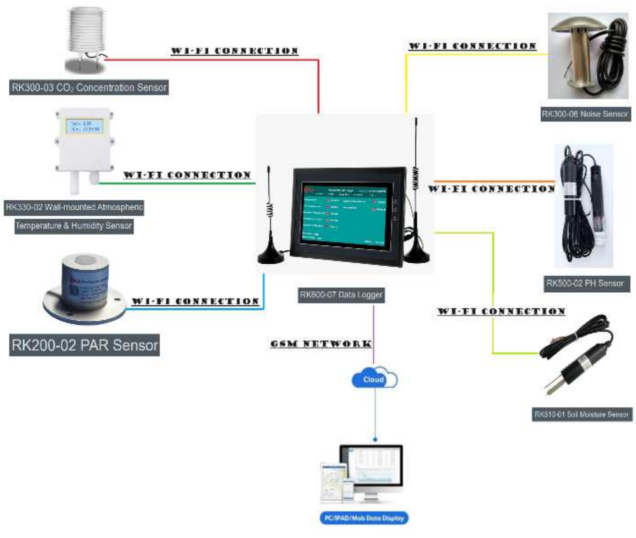

Fig. 3 Schematic diagram

III. Result and Discussion

We measured the data for the environmental parameters at four locations within the POLMED campus. These data measurement locations were parking lots, gardens, assembly points, and public roads, as shown in Fig. 4.

Fig. 4 Research locations

These data are presented in graphical form, as shown in Fig. 5 until Fig.11. According to Fig. 5, CO2 levels increase maximally from 12.00 to 12.59 during the transition time. At this time, morning class students and afternoon class students meet. Along with it, students also drive their vehicles onto campus. Morning students would drive home in their vehicles, and afternoon students would come to campus in their vehicles. So traffic would be very heavy, and there would be congestion in the campus parking lots.

CO_2 emissions would be directly proportional to the number of vehicles passing through the campus. Each vehicle would produce exhaust emissions in the form of one fuel activity and one emission factor from the fuel used in the vehicle. Based on Equation 1, the more vehicles there are, the greater the impact of CO_2 emissions. For instance, the current number of POLMED students is 6,597, and 3.32% of them drive private vehicles to campus, approximately 219 vehicles. Their vehicles use Pertalite as fuel.

$$CO_2\ Emission = Vehicles\ use\ Pertalite\ x\ Emission\ factor\ of\ Pertalite$$

$$CO_2\ Emission = 219\ x\ 2.408$$

$$CO_2\ Emission = 527.4\ \text{ppm}$$

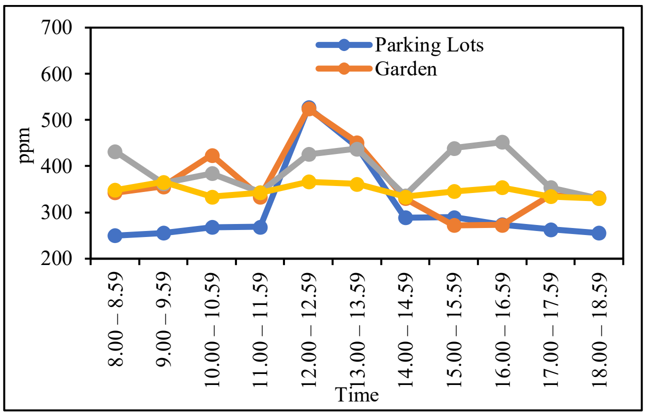

Fig. 5 Graphic of CO_2 concentration

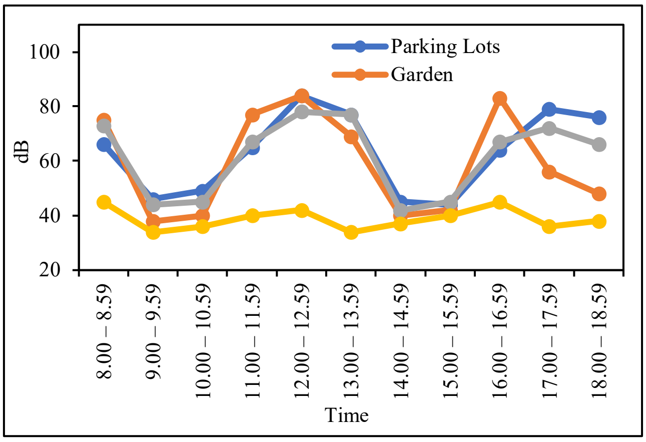

Fig. 6 Graphic of noise

According to Fig. 6, the conditions are almost the same as Fig. 5, because with many students gathering and bringing vehicles to campus, the noise would be directly proportional to the number of private vehicles passing on campus. Of course, this would increase the intensity of noise in the form of vehicle sounds on campus. Many students ride motorcycles to campus. A point-to-point calculation model is applied to obtain the sound levels when the vehicle moves. Many factors influence the sound levels, which would vary over time. It depends on driving conditions, the type of pavement the vehicle is traveling on, its speed, etc [22], [23].

As the vehicle changes its position over time, the attenuation between the sound source and the respective receiver also changes, and consequently, for each receiving position, the instantaneous noise level would vary. The emission model would determine the sound power level by taking the vehicle's driving conditions as inputs, which change over time [24]. In addition, a propagation model would be applied to determine the sound attenuation between the vehicle's location at each instant and the location of a given receiver [25], [26].

According to Fig. 7, Fig. 8, and Fig. 9 show that the three variables are interrelated, where humidity, PAR, and temperature are closely related and inversely proportional [27], [28]. If the temperature and PAR increase, the humidity would decrease. For instance, from 12.00 to 12.59 WIB, the maximum temperature value is 31.6°C, and the maximum PAR is 589.3 μ*mol/m^2*s. At the same time, the humidity value is the lowest at 47.2% RH.

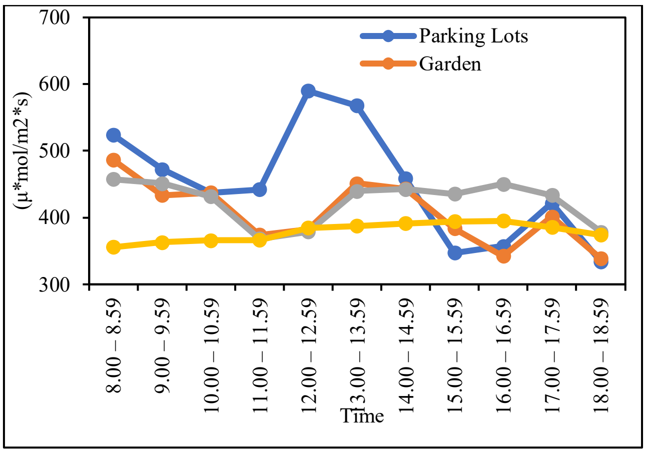

Fig. 7 Graphic of PAR

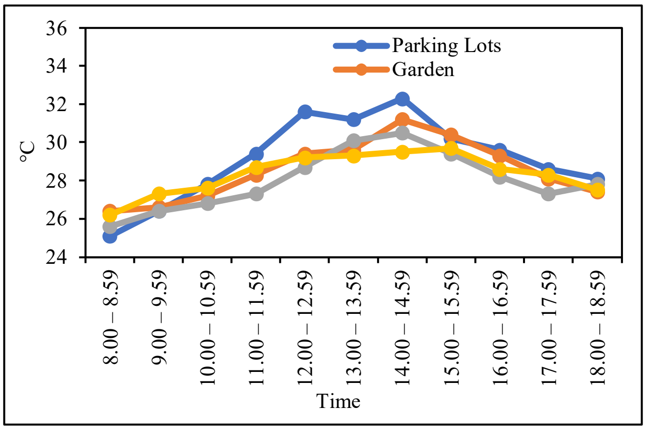

Fig. 8 Graphic of temperature

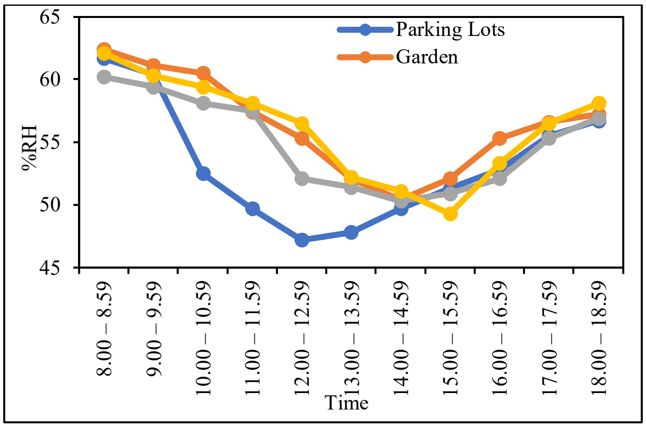

Fig. 9 Graphic of humidity

Correlation analysis was used to determine the strength of the relationship between variables. This study used Pearson's correlation analysis to produce a correlation coefficient. This value was used to determine the strength of the linear relationship between the two variables. The value of the correlation coefficient can be calculated using Equation 2. We would take data samples based on Table 5 at 12.00-12.59 WIB. The temperature value is 31.6°C, and the humidity value is 47.2% RH. We made observations 10 times (n=10)

$$r_{xy} = \frac{10\sum(31.6\ x\ 47.2) - (\sum 31{,}6)(\sum 47.2)}{\sqrt{[10\sum 31.6^2 - (\sum 31.6)^2][10\sum 47.2^2 - (\sum 47.2)^2]}}$$

$$r_{xy} = \frac{10\sum(1491.52) - (1491.52)}{\sqrt{[10\sum(998.56)\ - (998.56)][10\sum(2227.84) - (2227.84)]}}$$

$$r_{xy} = \frac{13423.68}{\sqrt{[8987.04][20050.56]}}$$

$$r_{xy} = \frac{13423.68}{13423.68}$$

$$r_{xy} = 1.0$$

Description:

r_{xy} : Correlation coefficient
x : Temperature variable,
y : Humidity variable
n : number of observations

The calculations above show that the correlation coefficient between temperature and humidity is very strong, with a value of 1.0. This shows that the two variables are interrelated, where humidity and temperature are very closely related and inversely proportional because if the humidity changes, the temperature will also change, and if the temperature increases, the humidity will decrease.

This also happened to PAR and humidity. PAR and humidity were inversely proportional. When PAR decreases, humidity increases because the photosynthesis takes place from morning to evening, but humidity would be high in the morning and even on days when warm air comes into contact with cold surfaces.

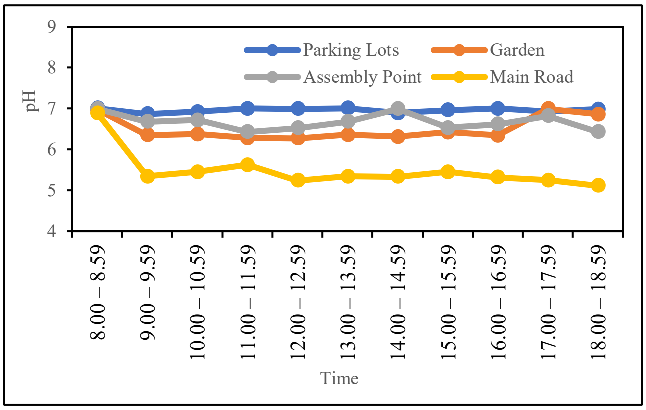

Fig. 10 Graphic of water pH

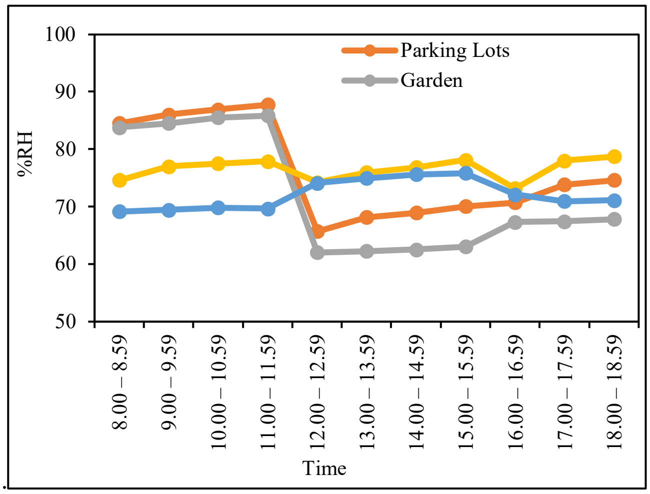

Fig. 11 Graphic of soil moisture

According to Fig. 10, from 12.00 to 12.59, students use a lot of water for toilet and worship purposes. When students gather in the morning and afternoon classes, they would do a lot of activities, such as eating, drinking, going to the toilet, and going to the mosque for worship. All of these still use groundwater for all these purposes. The large volume of water used would impact the water's pH [29]. The volume of water is directly proportional to the degree of acidity of the groundwater [30], [31]. It is also affects to soil moisture that shown in Fig.11 [32].

IV. Conclusion

All measurement data would be high during the transition between morning and afternoon classes meeting at 12.00 to 12.45 WIB, especially for CO_2, noise, temperature and humidity, PAR, and soil moisture. This is related to the many students gathering private vehicles passing through campuses. This is very worrying because the campus area is only approximately eight hectares. Thirty percent of the land has been used as parking lots (not green open land). Increasing the CO_2 concentration affects the temperature and humidity. POLMED must concentrate on environmental sustainability. Therefore, we should pay for internal recycling water treatment, reducing the use of private vehicles, and expanding green open space. The spread of vegetation is a solution to reduce CO_2 levels in the air. This process must be maintained and controlled by the smart system.

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