Conference Paper

Air Quality Study at Different Elevation Levels Using Drone Payload Air Quality Measurement Device (D-PAQ)

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Abstract.
Construction sites can be found in both urban and rural areas, often in close proximity to residences. They can thus cause home pollution due to the distance and the materials used. This study aims to visualize PM2.5, PM10, temperature and humidity by producing air quality mapping and correlating parameters at the stadium and construction site. An Arduino-based air quality measurement payload device was developed to measure the air quality by different levels. The drone was used to collect air quality data by mounting the device to the drone. Measurements were taken at three different elevations for each study area, and the application software generates the air quality map based on the location coordinates. The correlation evaluation of the concentration of PM2.5 and PM10 with temperature and humidity was then determined. The results showed that the concentrations of PM2.5 and PM10 at the construction site are much higher compared to the stadium due to the construction activities nearby.

Keywords: air quality, unmanned aerial vehicle, mapping

1. Introduction

The introduction of Satellites to the air quality measurement system offered some benefits but also raised so many unanswered questions. There are so many systems available for use, and not all of them are known for their quality and suitability. There is insufficient data available due to the limited expertise of environmental (air quality monitoring) agencies despite the lack of reliable design and implementation manuals that adds to the difficulty. Consequently, the use of drone-mounted with measurement devices of modern device technologies in this area is still not well received by the public. Further research is needed in Malaysia to incorporate the technologies. According to Malaysia Ambient Air Quality Standard (MAAQS), the Malaysian air pollution index (API) is obtained six air pollutants: particulate matter with the size of less than 10 micron

(PM10), Sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ground-level ozone (O_3) and particulate matter with the size of less than 2.5 micron (PM2.5)[1]. The rapid development of high infrastructures and transportation systems seems to be the major factor of high air pollution due to high traffic usage. The main causes of air pollution currently are coming from the ground and might also come from specific elevations [2].

Thus, it becomes considerable important to conduct experimental research that measuring air quality parameters at an elevation to provide air quality information simultaneously allows an analysis of the possible risks. The use of a drone-mounted attached air quality measurement device as the substitute device of the satellite will preserve its quality, consistency and suitability that will be selected as the most acceptable result. This portable and lightweight measurement device will result in more convenient and accessible ways to measure air quality index levels.

2. Previous Study

The immediate connection of the measurement device with the environment shows that a lot of attention should be given to the data accuracy and reliability of the measurement device. Measurement devices are classified under Assisted Living (AAL) devices. It can be divided into two main groups: measurement devices used in the intelligent environment and measurement devices that are wearable mobile [3].

According to the research that has been conducted recently, researchers are currently taking advantage of the advancement of this technology and the low budget of measurement devices for air quality measurement that has been the focus on presenting specific locations of studies [4][5]. Low-cost PM measurement devices with low ambient PM and high ambient PM are applied in research taken place at Atlanta, Georgia and Hyberabad, India, respectively[4]. A low-cost gas measurement device is also being used to implement Citizen Observatory tools for air quality studies in Belgrade, Serbia[5].

On the other hand, the advantage of the UAV application has been used by several researchers to assist the collection of the measurement device data by attaching the measurement device to the UAVs. In 2016, research took place using the idea of affixing various measurement devices on UAVs for air quality measurement in Sri Lanka[6]. In 2012, research took place by mounting a high precision Low Power Greenhouse Gas laser sensor onto UAVs[7]. Several researchers have also taken advantage of the measurement device data by producing spatial representations [8][9].

The air quality conditions are described to provide a precise benchmark for risk assessment. PM is one of the sources of air pollutions that might come from high-build buildings where it is vital to monitor the air quality conditions at that level. Research that has been conducted in previous years testify that UAVs[6], [7], balloons [10], and even eagles [11] have been employed for air quality monitoring. Still, the target has not been on the assessment taken at an elevation. In this project, a modern formulation system will be provided to incorporate an Arduino-based air quality measurement device into a DJI Phantom 4 Pro to monitor air quality parameters at different specific heights.

Malaysia Ambient Air Quality Guideline (MAAQG) was used since 1989 and recently replaced with the New Ambient Air Quality Standard (NAAQS). Six air pollutants criteria take into consideration with five existing air pollutants which are particulate matter with the size of less than 10 micron (PM10), sulfur dioxide (SO2), carbon monoxide (CO), nitrogen dioxide (NO2), and ground-level ozone (O3) as well as one additional parameter since 2017, which is particulate matter with the size of less than 2.5 micron (PM2.5)[1]. NAAQS has set the air pollutants concentration limit that stages will enhance until 2020. It involves three interim targets set, which consists of interim target 1 (IT-1) in 2015, interim target 2 (IT-2) in 2018 and the complete enforcement of the standard in 2020[12], as shown in Figure 1. In this research, the result will be compared to PM2.5 and PM10 for an averaging time of 24 hours according to the 2020 standard.

Pollutants	Averaging Time	Ambient Air Quality Standard		
		IT-1 (2015) $\mu g/m^3$	IT-2 (2018) $\mu g/m^3$	Standard (2020) $\mu g/m^3$
Particulate Matter with the size of less than 10 micron (PM_{10})	1 Year	50	45	40
	24 Hour	150	120	100
Particulate Matter with the size of less than 2.5 micron ($PM_{2.5}$)	1 Year	35	25	15
	24 Hour	75	50	35
Sulfur Dioxide (SO_2)	1 Hour	350	300	250
	24 Hour	105	90	80
Nitrogen Dioxide (NO_2)	1 Hour	320	300	280
	24 Hour	75	75	70
Ground Level Ozone (O_3)	1 Hour	200	200	180
	8 Hour	120	120	100
*Carbon Monoxide (CO)	1 Hour	35	35	30
	8 Hour	10	10	10

Figure 1: New Malaysia Ambient Air Quality Standard. (Source: Department of Environment, Malaysia).

3. Research Methodology

The main device to be used in this research study is a drone DJI Phantom 4 Pro model. There are three primary purposes and objectives to be achieved accordingly. The first part is to develop an Arduino-based air quality measurement device payload for DJI

Phantom 4 Pro. In the collection of parameters data, the air quality measurement device will be developed using electronic components that reflect the variables of PM2.5, PM10, Temperature and Humidity and GPS for location (Latitude, Longitude) mapping purposes. In the second part, a casing for the measurement device, which consists of the measurement device box and the mount, will be developed and mounted to the drone's legs, followed by the analysis of the product. In this part, the drone-mounted with the casing will be modelled using CAD Solid Work Software followed by simulation of Finite Element Analysis (FEA) method to carry out the structural properties, which included stress, strain and displacement strength that will be obtained before the actual model or prototype is fabricate [13]. In the third part, the air quality parameters mapping will be developed using a graphic representation of the air quality level based on PM2.5 and PM10 that will be correlated with meteorological factors of temperature and humidity at three different elevations for each study area for a certain period. A flowchart of the overall methodology of the project study is shown in Figure 2.

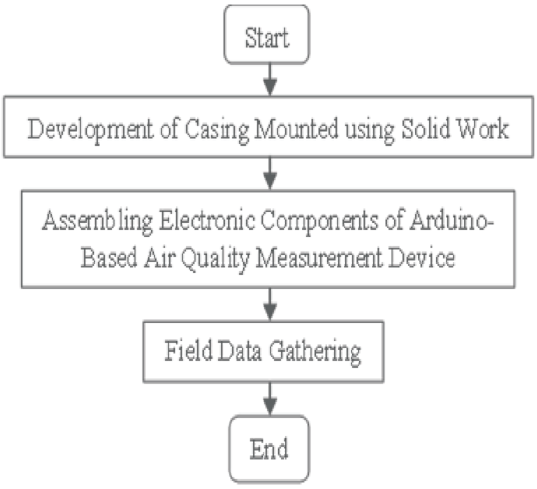

Figure 2: Summary Methodology Flowchart.

3.1. Sampling Method

The data collected for the parameters were between 12:00 pm and 1:00 pm with an average of 3-minutes for each elevation using the DJI Phantom 4 Pro mounted with air quality the measurement device as shown in Figure 3. The aerial view of the study areas, as shown in Figure 4, were analyzed using GPS and Google Earth Pro.

4. Results and Discussion

Figure 3: DJI Phantom 4 Pro mounted with air quality measurement device.

(a) Open Stadium (b) Costruction site

Figure 4: Aerial view of study areas.

4.1. Parameters Result

The results of air quality parameters during deployment is shown in Table 1. From the summary of the table, the relation and correlation between temperature and humidity for PM2.5 and PM10 perimeters is analyzed based on the location considering three different elevations of the study areas.

4.2. Discussion

Table 1: Results of Air Quality Paramenters During Deployment.

Location	Elevation (m)	3-min Average PM2.5 (µg/m^3)	3-min Average PM10 (µg/m^3)	Temperature Average (°C)	Humidity Average (%)
Open Stadium	30	7.9	11.6	33.2	61.9
	50	7.7	12.0	33.5	60.5
	70	8.2	13.2	32.9	59.5
Construction Site	50	10.4	13.6	34.2	58.8
	70	10.8	14.2	33.5	60.8
	90	11.1	14.6	33.2	61.2

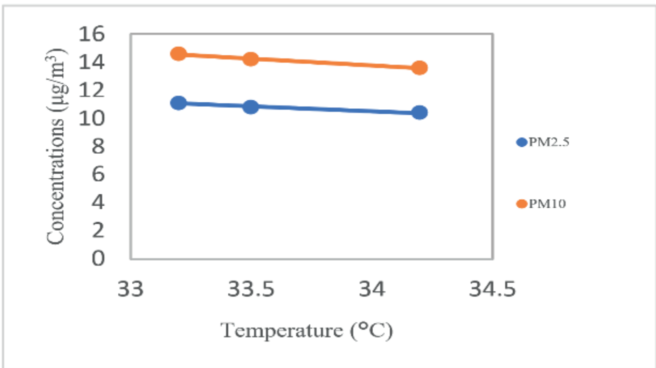

Figure 5: Relation between Temperature and concentration of PM2.5 and PM10 at Construction Site.

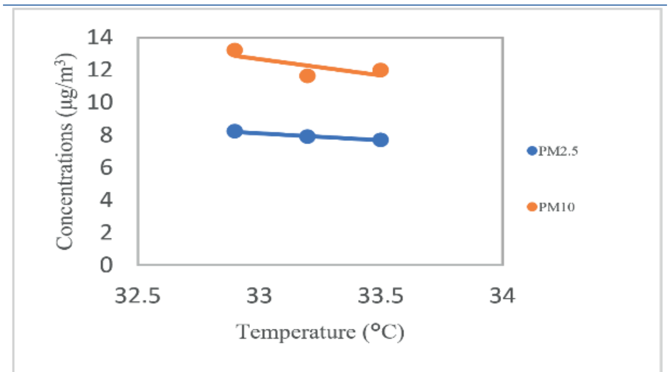

Figure 6: Relation between Temperature and concentration of PM2.5 and PM10 at Open Stadium.

4.3. Comparison between Temperature for PM2.5 and PM10 at two different study areas

Figure 5 shows the relation between temperature and PM2.5 and PM10 concentrations at Construction Site. The temperatures at the site ranged from 32.2°C to 34.2°C on average. At the lowest temperature (32.2°C), the recorded value for PM10 is at the highest (14.6µg/m^3) meanwhile at the highest temperature (34.2°C), the recorded value for PM10 is at the lowest (13.6μg/m^3). In this case, PM2.5 shows the same behaviour as PM10, at the lowest temperature (32.2°C), the recorded value for PM2.5 is at the highest (11.1μg/m^3) meanwhile at the highest temperature (34.2°C), the recorded value for PM2.5 is at the lowest (10.4μg/m^3). As the result was analyzed, PM2.5 and PM10 possess a weak negative correlation with temperature, which indicates that high temperatures will increase vertical mixing of air particles, which cause air pollutants to be higher and causing the concentration of air pollutants on the earth's surface to be lowered [14][15].

Meanwhile, Figure 6 shows the relation between temperature and PM2.5 and PM10 concentrations at Open Stadium. The temperatures at the site ranged from 32.9°C to 33.5°C on average. At the lowest temperature (32.9°C), the recorded value for PM10 is at the highest (13.2μg/m^3) meanwhile at the highest temperature (33.5°C), the recorded value for PM10 is lower (12μg/m^3), even though it is not the lowest recorded concentration of PM10 which is (11.6μg/m^3) but it is close to the value. In this case, PM2.5 shows the same behaviour as PM10, at the lowest temperature (32.9°C), the recorded value for PM2.5 is at the highest (8.2μg/m^3) meanwhile at the highest temperature (33.5°C), the recorded value for PM2.5 is at the lowest (7.7μg/m^3). As the result was analyzed, PM2.5 and PM10 possess a weak negative correlation with temperature. When the temperature rises, air pollutants are pushed upwards to maintain atmospheric pressure, causing cleaner air to fall to the surface, lowering the concentration of air pollutants.

The findings are consistent with studies by Nam et al., who found that the concentration of contaminants rises as the temperature drops [16]. However, the findings were in direct opposition to Cuhadaroglu and Demirci's study, where they discovered that particle concentration rises as temperature rises due to the presence of an inversion layer, where the temperature at the surface is lower than the ambient temperature on days, preventing the air from vertical dispersion[17].

4.4. Comparison between Humidity for PM2.5 and PM10 at two different study areas

Figure 7 shows the relation between humidity and concentration of PM2.5 and PM10 at the Construction Site. The humidity at the site ranged from 58.8% to 61.2% on average. As the humidity value increases, the concentration of PM10 also increases. At the lowest humidity (58.8%), the recorded value for PM10 is at the lowest (13.6μg/m^3) while, at the highest humidity (61.2%), the recorded value for PM10 is at the highest (14.6μg/m^3). In this case, PM2.5 shows the same behaviour as PM10, at the lowest humidity (58.8%),

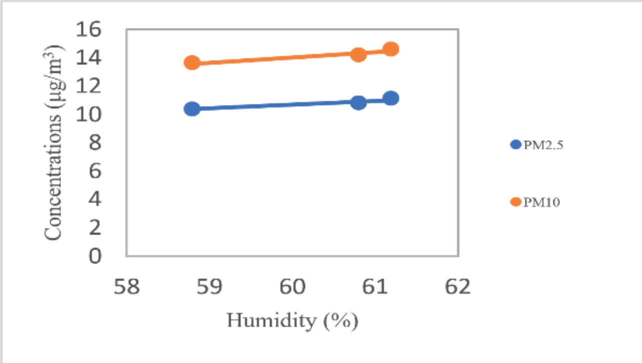

Figure 7: Relation between Humidity and concentration of PM2.5 and PM10 at Construction Site.

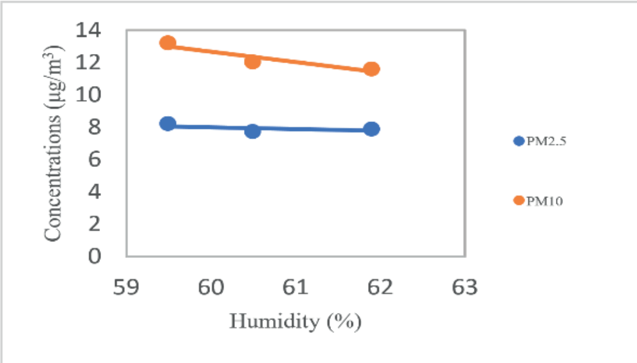

Figure 8: Relation between Humidity and concentration of PM2.5 and PM10 at Open Stadium.

the recorded value for PM2.5 is at the lowest (10.4μg/m^3) meanwhile at the highest humidity (61.2%), the recorded value for PM2.5 is at the highest (11.1μg/m^3).

As the result was analysed, PM2.5 and PM10 show a high positive correlation with humidity. The rationale would be similar to correlation with PM10 at the Construction Site, where moisture in the atmosphere aids in the coagulation of tiny particles into bigger particles, resulting in a cleaning effect and a reduction in pollutant concentrations. A positive correlation indicates that many finer particles are generated nearby, and moisture in the air aids in the coagulation of smaller particles into bigger particulates, resulting in a more polluted environment and a rise in PM2.5 and PM10 concentrations.

Meanwhile, Figure 8 shows the relation between humidity and concentration of PM2.5 and PM10 at Open Stadium. The humidity at the site ranged from 59.5% to 61.9% on average. As the humidity value increases, the concentration of PM10 decreases. At the lowest humidity (59.5%), the recorded value for PM10 is at the highest (13.2μg/m^3), while at the highest humidity (61.9%), the recorded value for PM10 is at the lowest (11.6μg/m^3). In this case, PM2.5 shows the same behaviour as PM10, at the lowest humidity (59.5%), the recorded value for PM2.5 is at the highest (8.2μg/m^3), meanwhile, at the highest humidity (61.9%) the recorded value for PM2.5 is lower (7.9μg/m^3) even though the lowest recorded concentration of PM2.5 is (7.7μg/m^3).

As a result was analyzed, PM2.5 and PM10 show weak negative correlation with humidity. The rationale would be similar to correlation with PM10 at the Construction Site, where moisture in the atmosphere aids in the coagulation of tiny particles into bigger particles, resulting in a cleaning effect and a reduction in pollutant concentrations. As the humidity rises, the particle concentration falls [17]. A similar tendency was seen in research by Fadl et al., high humidity was shown to be negatively connected with PM10, indicating that tiny particles may settle owing to the effects of humidity on coalescence [18]. Research by Siti Rahmah et al. [19] found that PM10 had a low negative association with relative humidity, comparable to our findings.

4.5. Comparison between NAAQS, DOE with PM2.5 and PM10 at two different study areas

The data collected at Open Stadium shows that the lowest recorded value of PM2.5 are 7μg/m^3, 7μg/m^3 and 6.2μg/m^3 at 30-meter, 50-meter, and 70-meter, respectively, whereas the highest recorded value of PM2.5 is 12.4μg/m^3, 15μg/m^3 and 13.1μg/m^3 at 30-meter, 50-meter, and 70-meter, respectively. Meanwhile, the data collected at the Construction Site shows that the lowest recorded value of PM2.5 are 8μg/m^3, 9.3μg/m^3 and 9.2μg/m^3 at 50-meter, 70-meter, and 90-meter, respectively. The highest recorded value of PM2.5 is 13μg/m^3, 13.2μg/m^3 and 11.9μg/m^3 at 50-meter, 70-meter, and 90-meter, respectively.

As for PM10, the data collected at Open Stadium, the lowest recorded value are 8.7μg/m^3, 10.4μg/m^3 and 11.2μg/m^3 at 30-meter, 50-meter, and 70-meter, respectively. The highest recorded value are 14.2μg/m^3, 17.7μg/m^3 and 17μg/m^3 at 30-meter, 50-meter, and 70-meter, respectively. Meanwhile, the data collected for PM10 at Construction Site, the lowest recorded value are 11.3μg/m^3, 10.9μg/m^3 and 15.5μg/m^{3}at 50-meter, 70-meter, and 90-meter, respectively. The highest recorded value are 17.6μg/m^3, 18.3μg/m^3 and 15.5μg/m^3 at 50-meter, 70-meter, and 90-meter, respectively.

Compared to the NAAQS, the air quality standard reading as of 2020 for averaging 24 hours are 35μg/m^3 and 100μg/m^3 for PM2.5 and PM10, respectively. The data collected for both study areas revealed that for PM2.5 and PM10 values are below the standard, and it can be concluded that the air quality is considered reasonable since the particulate matter with the size of less than 2.5 micron is lesser than 10 micron that will result in a lower concentration of PM2.5 value[15]. It has also been proven that the surrounding area of the Open Stadium and Construction Site is clear from any possible sources of polluted air. Even though construction activities are happening near the site, the contractor's air quality level is well-monitored and still below the standard reading.

5. Conclusion

This research has become the significant benefits in evaluating and analyzing the functionality and suitability of DJI Phantom 4 Drone in helping air quality distribution study at different elevations using Arduino-based air quality measurement device. Based on the result, the air quality mapping can be beneficial in various perspectives as the result show that:

1. DJI Phantom 4 Pro drone has become a practical tool in assisting the data collection for the air quality mapping parameters at high elevation by implementing a system that can attach the air quality measurement device to the drone, making it more convenient and easier controlled to its user-friendly approach.
2. Through the analysis and designing, it was plausible and reasonable to have a small, mounted measurement device box containing the Arduino-based air quality measurement device attached to a specially designed mount to a DJI Phantom 4 Pro drone.

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References

[1] Department of Environment. New Malaysia ambient air quality standard. [cited 2021 May 31]. http://www.doe.gov.my/portalv1/wp-content/uploads/2013/01/Air-Quality-Standard-BI.pdf (

[2] MK Fadzly, MF Rosli, T Amarul, and MSM Effendi. Smart air quality monitoring system using Arduino Mega. IOP Conference Series: Materials Science and Engineering. 2020. https://doi.org/10.1088/1757-899X/864/1/012215

[3] Ivan G, Nuno MG, Ciprian D, Constandinos XM, Rossitza G. Enhanced living environments state-of-the-art algorithms, architectures, platforms, and systems.

Lecture Notes in Computer Science. 2019;11369. https://doi.org/10.1007/978-3-030-10752-9

[4] Jamal HH, Pillay MS, Zalina H, Shamsul BS, Sinha K, Zaman Huri Z, Khew SL, Mazrura S, Ambu S, Rahimah A. A study of health impact and risk assessment of urban air pollution in the Klang Valley, Malaysia. Western Pacific Regional Office Manila. January 2015.

[5] Afroz R, Hassan MN, Ibrahim NA. Review of air pollution and health impacts in Malaysia. Environmental Research. 2003 Jun;92(2):71–7.

[6] Josepha W, Lanka U, Ali A, Ebrahim A, Ahmed A, Saeed A. Air quality monitoring for sustainable systems via drone based technology. IEEE. 2016. https://doi.org/10.1109/ICIAFS.2016.7946542

[7] Khan A, Schaefer D, Tao L, Miller DJ, Sun K, Zondlo MA, et al. Low power greenhouse gas sensors for unmanned aerial vehicles. Remote Sens (Basel). 2012 May;4(5):1355–68.

[8] Aberer K, et al. OpenSense: Open community driven sensing of environment. Proceedings of the ACM SIGSPATIAL International Workshop on GeoStreaming, IWGS 2010. 2010:39–42.

[9] Piero Z, Elizabeth B, JingHong P, William GG. The CitiSense air quality monitoring mobile sensor node. Proceedings of the IPSN'12 Workshop on Mobile Sensing. 2012.

[10] Doerenbecher A, Basdevant C, Drobinski P, Durand P, Fesquet C, Bernard F, et al. Low-atmosphere drifting balloons: Platforms for environment monitoring and forecast improvement. Bulletin of the American Meteorological Society . 2016 Sep;97(9):1583–99.

[11] Rick MT et al. Avian sensor packages for meteorological measurements. Bulletin of the American Meteorological Society. Mar 2018;99(3):499-511. https://doi.org/10.1175/BAMS-D-16-0181.1

[12] Department of Environment. Air quality standards. [cited 2021 May 24]. https://www.doe.gov.my/portalv1/en/info-umum/english-air-quality-trend/108

[13] Glodová I, Lipták T, Bocko J. Usage of finite element method for motion and thermal analysis of a specific object in SolidWorks environment. Procedia Engineering. 2014 Jan;96:131–135.

[14] Khasawneh OF, Halim H, Abdullah SN, Razali SA, Algburi HR, Salleh AH. Characterization of environmental noise pollution based on noise measurement and mapping at USM engineering campus. IOP Conference Series: Materials Science and Engineering. 2020;920(1). https://doi.org/10.1088/1757-899X/920/1/012004

[15] Chooi YH, Yong EL. The influence of PM 2.5 and PM10 on Air Pollution Index (API). Faculty of Civil Engineering Universiti Teknology Malaysia. 2016:132-143.

[16] Nam E, Kishan S, Baldauf RW, Fulper CR, Sabisch M, Warila J. Temperature effects on particulate matter emissions from light-duty, gasoline-powered motor vehicles. Environmental Science & Technology. 2010 Jun;44(12):4672–7.

[17] Cuhadaroglu B, Demirci E. Influence of some meteorological factors on air pollution in Trabzon city. Energy Build. 1997;25(3):179–84.

[18] Fadi A, Al Katheeri, Muthanna AO. Concentrations of particulate matter and their relationships with meteorological variables. Sustainable Environment Research. 2013; 23(3):191-198. https://www.researchgate.net/publication/286384763_Concentrations_of_particulate_matter_and_their_relationships_with_meteoro

[19] Latif MT, Abidin EZ, Praveena SM. The assessment of ambient air pollution trend in Klang Valley. World Environment. 2015;5(1):1–11.