Utilisation of Airborne LiDAR Data in Perspective of Department of Survey and Mapping Malaysia

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ABSTRACT: Geospatial Mapping trend in Malaysia focus more on Light Detection and Ranging (LiDAR) for various precise application. As we knew, there are several forms of LiDAR data capturing techniques ranging from fixed terrestrial LiDAR scanning to mobile and airborne (fixed-wing, helicopter, UAVs). LiDAR data are highly accurate point cloud and commonly used to visualize topographic surface and features in three-dimensional (3D). This type of accuracy will open up a wide dimension of application towards amazing discoveries. Future generation in geospatial data revolution to cater to the abundance of rich dynamic information by manipulating any geospatial input such as LiDAR data. Department of Survey and Mapping Malaysia (JUPEM) as the authoritative government agency for any survey and mapping activities in Malaysia. The Ministry of Energy and Natural Resources has recognized JUPEM's expertise and has appointed JUPEM to lead and be a consultant to any agency in implementing activities or projects related to LiDAR. Therefore, this paper shall highlight related LiDAR technology in JUPEM inclusive standard terrain LiDAR output created such as Digital Surface Model (DSM), Digital Elevation Model (DEM), Digital Terrain Model (DTM). Last but not least, fusion and manipulate of terrain data with other geospatial data for various applications from the perspective of JUPEM.

1. INTRODUCTION

The development of Light Detection and Ranging (LiDAR) technology shows various positive outputs in line with the rapidity of the world. The application multi-measurement platform of LiDAR technology such as terrestrial laser scanning (TLS), airborne laser scanning (ALS), and mobile laser scanner (MLS) opens a new dimension of digital data utilization for public benefit (Abdullah et al., 2018). Various efforts are made to upgrade the agency's capabilities both in terms of system and human capacity. This upgrade not only supports key sectors but also encourages the country's potential to open up more space for various geospatial information technologically supported new developments in society (Abdul Rahman et al., 2020a). Geospatial information has proven crucial for planning, monitoring, management, analysis, decision-making, and improving overall productivity and efficiency (Paris et al., 2017). In today's digital development, it has impacted various transactions where geospatial technology has evolved and has become one of the norms in the routine of our daily lives. Technological developments such as Artificial Intelligent (AI), the Internet of Things (IoT), and Big Data have changed our economy, organization, industry, society, and way of life (Ganendra et al., 2018).

The role of the data providers seems to create a positive impact on society and economies. Department of Survey and Mapping Malaysia (JUPEM) as the main geospatial data provider in Malaysia for more than 20 years has to consistently adapt to the evolution of technologies for the worldwide benefits (Isa et al., 2015). With the development of such technology in the Industrial Revolution 4.0 (IR 4.0), it is a challenge for us in the delivery of geospatial services today to improve the quality of service delivery provided. This revolution will also cause some sectors to move forward such as the robotics sector, blockchain, 3D printing, autonomous vehicles, and so on with the availability of 5G technology (Abdul Rahman et al., 2020b). Therefore, JUPEM as a LiDAR subject-matter expert (SME) for government agencies finding that the Strategic Partnership and Smart Collaboration approach is the best step in providing services in the delivery of geospatial data. In order to discuss in detail regarding utilisation of airborne LiDAR data in perspective of JUPEM, this manuscript is divided into two (2) main sections namely the advancement of LiDAR in JUPEM and LiDAR utilization in the perspective of JUPEM.

2. ADVANCEMENT OF LiDAR IN JUPEM

2.1 LiDAR data acquisition activities

The use of LiDAR in JUPEM started in 2002 using OPTECH ALTM 30/70 (ALS) and CYRAX 2500 (TLS) devices. The year 2013 and 2014, LiDAR data acquisition activities were conducted only in the Federal Territory area Kuala Lumpur and Putrajaya inclusive of the SmartKADASTER project in JUPEM (Isa et al., 2015). LiDAR activities are accelerating and widely used in Malaysia where a lot of data processing has been done with some companies started investing in the purchase of LiDAR sensors. From the year 2016 to 2019, JUPEM put a lot of effort into tendering out LiDAR data acquisition. In addition to JUPEM, there are also government and non-government agencies that are also involved in LiDAR data acquisition. A chronological summary of LiDAR activities at the JUPEM level can be seen in Figure 1.

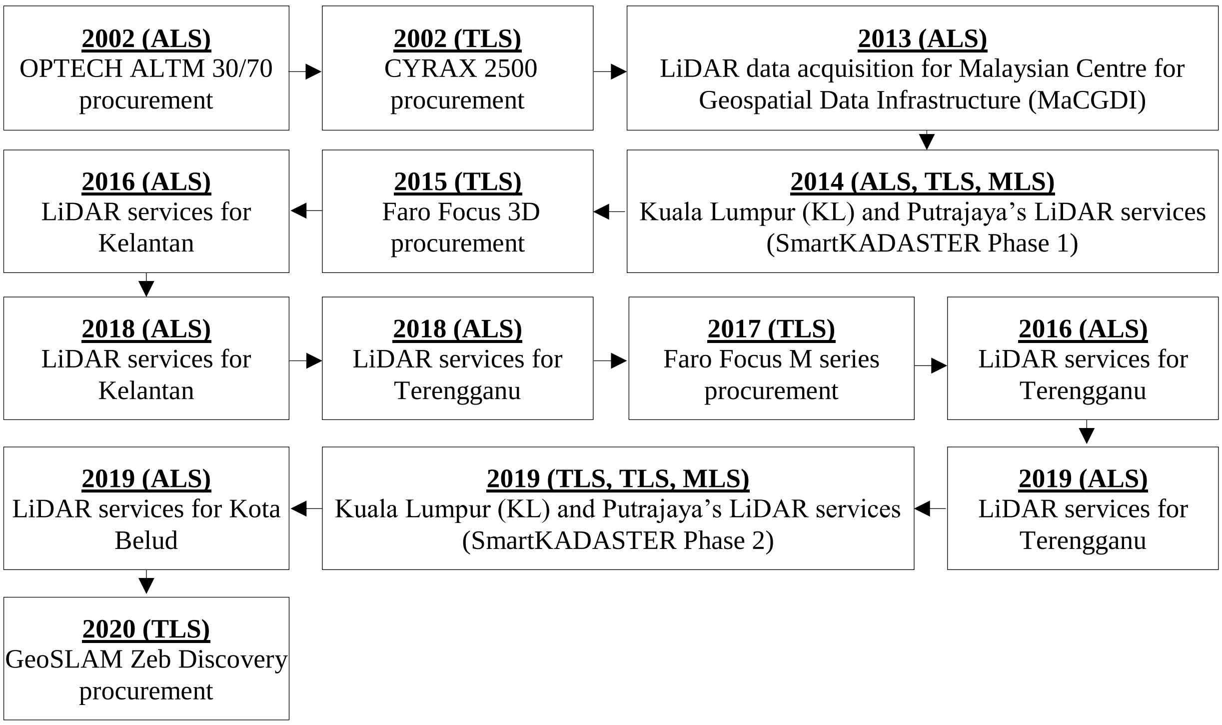

Figure 1. Chronological summary of LiDAR activities

JUPEM is also a subject-matter expert (SME) of LiDAR for government agencies involved with any project related to LiDAR data acquisition. National Institute of Lands and Surveys

(INSTUN), also contribute to the development of LiDAR activities by conducting LiDAR related courses for interested individuals or groups. Other government agencies such as the Department of Minerals and Minerals (JMG) and the Department Irrigation and Drainage (DID) are also not left behind in LiDAR activities, where JUPEM officers participated in providing mapping advisory services. On top of that, the implementation of LiDAR activities was monitored by the National Audit Department as an entity that conducts checks and balances implementation of this activity with the assistance of JUPEM as a LiDAR data auditor.

2.2 Data processing and final output

There is a standard procedure for data processing to fulfill JUPEM's data requirements. Framework for the JUPEM practices in the production of DTM as in Figure 2. Firstly, the classification process of converted LiDAR data in *.LAS* format is conducted based on the classification code that has been established by the International Society for Photogrammetry and Remote Sensing (ISPRS) (Saylam et al., 2018). The classification process that using classification principles such as Artificial Neural Network and Random Forest is seen as very helpful in the process of classification (Raczko & Zagajewski, 2017). This is because the principle implemented in LiDAR data processing software help to reduce the processing time and stretches high-quality outcomes. The classification output is classified in detail and enhances the quality of the Digital Surface Model (DSM) and Digital Terrain Model (DTM) produced (Saraf et al., 2020).

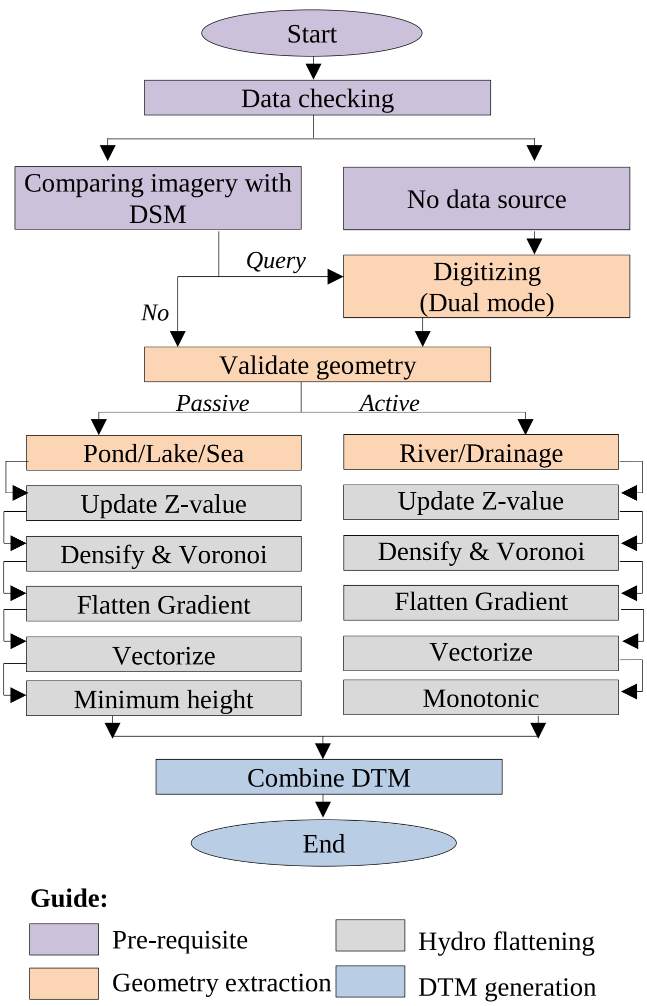

Figure 2. JUPEM's framework practice in the generation of DTM

The quality checking process is mandatory to reduce as many data errors such as void area and spikes to ensure the data quality is maximized (Saylam et al., 2018). After removing all possible errors, the data correction is applied. This rigid process to important because the generated DTM is a benchmark to high-quality data. For example, the generation of good contours is fully reliant on the quality of DTM produced (Saraf et al., 2020). The main objective of the final output is to ensure that the final output is precise and as close as possible to the condition of terrain surface in the real world. Some final output examples of the LiDAR data are shown in Figure 3.

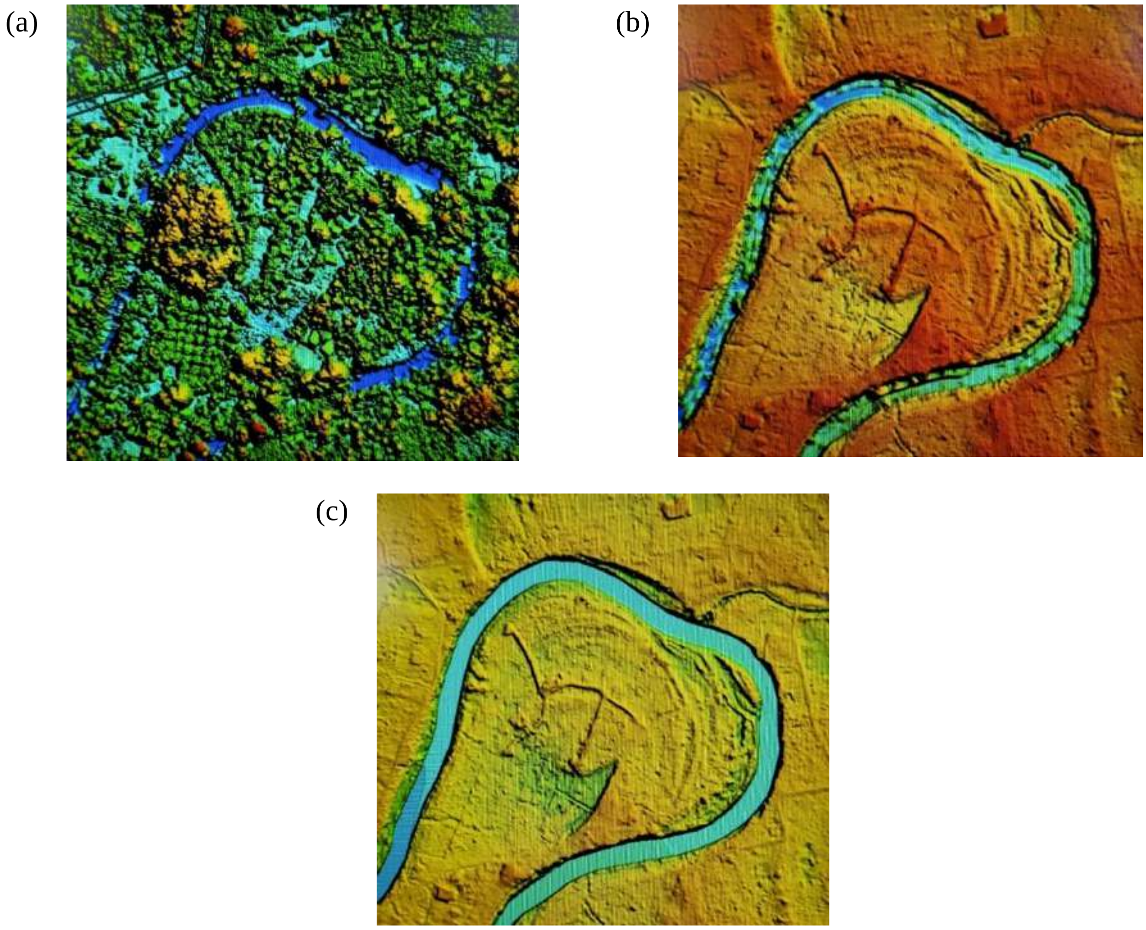

Figure 3. Generated digital model (a) DSM, (b) DEM, and (c) DTM

3. LiDAR UTILIZATION IN PERSPECTIVE OF JUPEM

Data utilization in the government sector moved in tandem with current developments in IR 4.0 (Isa et al., 2015). Data is a major source of various sectors especially geospatial data. The importance of geospatial data in Big Data Analytics and Smart City is critical to support important decisions that cannot be implemented by non-spatial data (Sameen & Pradhan, 2019). The advantages of LiDAR technology slowly became a pioneer in geospatial applications due to the richness of information and easy to manipulate for multipurpose (Wang et al., 2018). There is two (2) method to utilize the LiDAR data which are profile and semantic utilization.

3.1 Profile utilization

Profile utilization is a method that manipulates the spatial information that is mostly used to visualize specific results of the analysis. Most profile utilization that was conducted is not limited to ALS LiDAR data but also involved with TLS and MLS LiDAR data. This method is usually used in Smart City applications where the profile information of point cloud and imagery were manipulated to represent the earth's surface information in digital form. The generation of DSM, DTM, and 3D modeling was later used to formed analysis based on the combination of profile information. Currently, most agencies are looking for Smart City applications not only for planning purposes but also for visualization purposes.

JUPEM also involve with the Smart City concept by implementing SmartKADASTER Interactive Portal (SKiP) based on a web-based application (Isa et al., 2015). SKiP was developed as a pilot project in 2014 that limited to Kuala Lumpur and Putrajaya regions. The main purpose of SKiP is to utilize multi-purpose cadastral information with mapping elements that developed based on LiDAR technologies. There are plenty of geospatial data combined to become a geo-enabled Smart City application in a single platform such as DSM, DTM, National Digital Cadastral Survey Database (NDCDB) lots, Building Information Modelling (BIM) building model with various Level of Details (LOD) stages (LOD 1 to LOD 4) and so on. Most data were utilized using LiDAR technologies such as ALS data that formed DSM and DTM, TLS data that generate 3D BIM model, and MLS data that provide dense point cloud from terrain that utilize as 3D mesh-model. The combination of multiple-scale LiDAR data can be seen in Figure 4.

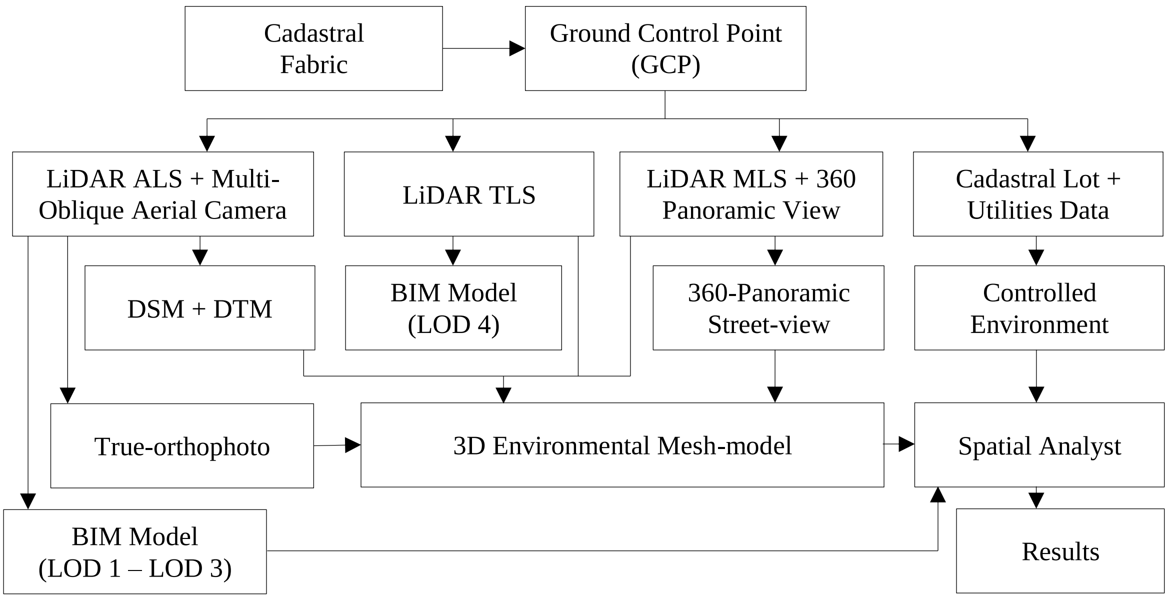

Figure 5. Combination of multi-scale LiDAR data within SKiP

This profile utilization is not limited to visualization activities but also can be part of spatial analysis components. The advantage of the LiDAR data source is the elevation information provided can support the 3D spatial analysis. For example, the flood simulation analysis (Figure 6) that part of SKiP is capable in predict and animated the flood progression based on the DSM data that merge with imageries for the 3D mesh-model. Besides that, the viewshed analysis also provides a result that is based on LiDAR data source which helps users in planning or visualizing the concept of Smart City. It shows that LiDAR profile data utilization can give benefit to the public not limited to visualization but also on spatial environmental analysis.

Figure 6. Flood simulation analysis in SKiP

3.2 Semantic utilization

Semantic utilization is a method that manipulates the semantic information that is actively used in analytics activities. Compared to profile utilization, sematic utilization focus on the information that lay within that data itself. The advantage of semantic utilization is the manipulation of data can be conducted with multiple different data sources such as geospatial data, statistical data, and so on. The application of Big Data Analytics helps in catalyzing the sematic utilization, especially when involved with LiDAR data. JUPEM was not left behind by conducting Big Data Analytics (BDA) project. The BDA project was held in 2019, on Geospatial Data Management in environmental control. The focus was river pollution in the Sungai Tebrau area of Johor. BDA approach such as machine learning analytics and smart visualization helps JUPEM to manage geospatial data and decision making.

The semantic utilization within BDA helps JUPEM to improve and enhance the information technology environment by leveraging geospatial data assets from all divisions in JUPEM besides enhancing surveying and mapping work products and services based on analytical results from various data sources that are available. One of the main utilization of LiDAR semantic data to BDA is through the effected population calculation for the Sungai Tebrau river pollution case. The population calculation framework of BDA as shown in Figure 7. There are three main phases involved which are 3D data utilization, 2D data relationship, and population database development.

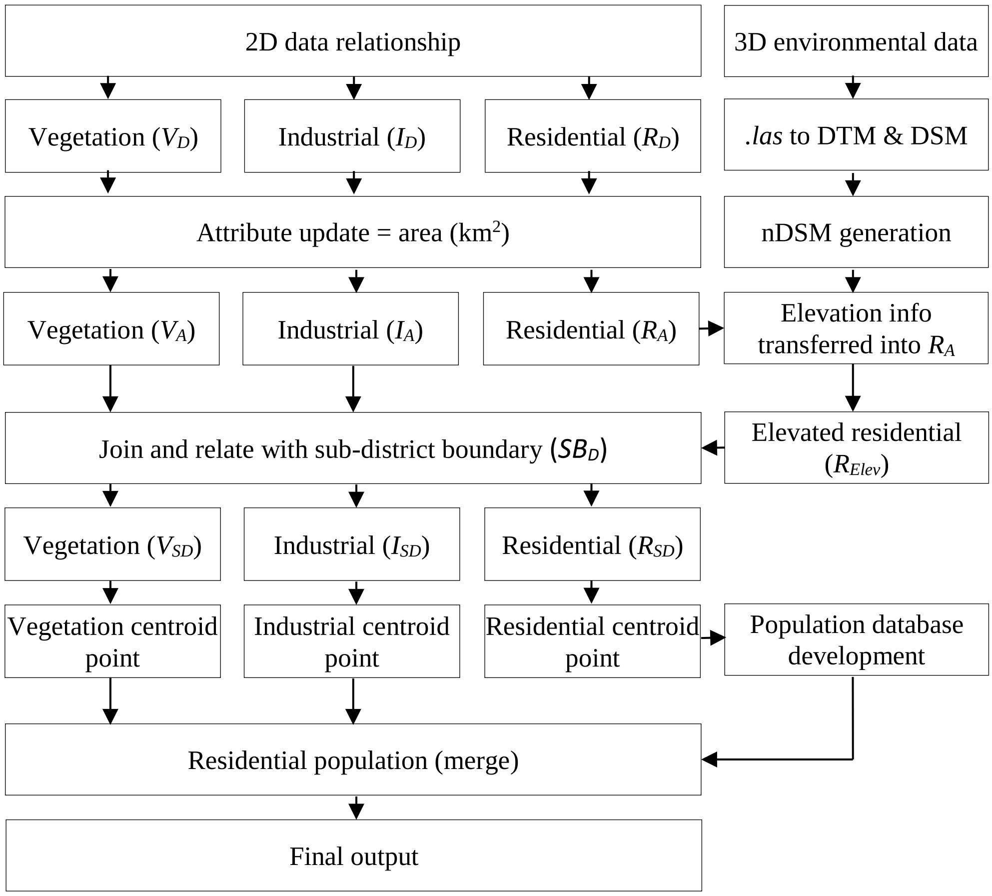

Figure 7. Population calculation framework of BDA

3D environmental data

The main purpose of 3D environmental data is to utilize the elevation value for specific buildings for geospatial population distribution. Geospatial distribution of population at a scale of individual buildings is needed for analysis of people's interaction with their local socio-economic and physical environments. Using the Digital Surface Model (DSM) and Digital Terrain Model (DTM) to obtain the Normalized Digital Surface Model (nDSM) and be able to extract building height. nDSM is the model that represents the height above the ground surface of man-made structures, natural features, and vegetation. It is derived by subtracting every grid cell in DTM from the corresponding grid cell in DSM as in Equation 1. All of the pixel values depicted in the DSM represents the height of the object from the terrain. The derived nDSM of the model area is shown in Figure 8. Data from nDSM was overlaid with residential features (R_A) and the elevation value are transfer to residential attribute data (R_{Elev}) through adding surface information as in Equation 2.

$$nDSM(i,j) = DSM(i,j) - DTM(i,j) \tag{1}$$

$$R_{Elev} = nDSM + R_D \tag{2}$$

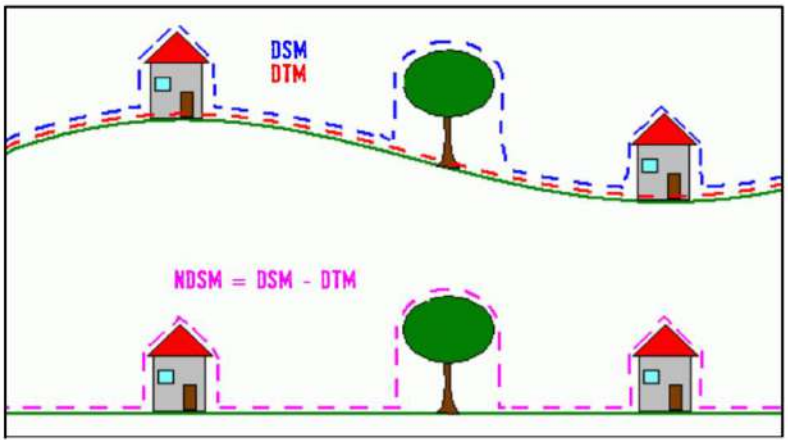

Figure 8. Derivation of nDSM model area

2D data relationship

The main purpose of the 2D data relationship is to find and rank factors that contribute to pollutants and land usage according to spatial sub-district data. The relationship between data is used by investigating the relationships between different attribute data pairs and always works on the currently filtered data. There are five (5) main data models used to make the 2D data relationship happens which are Linear Regression, Spearman R, Anova, Kruskal-Wallis, and Chi-square model. The Linear regression and the Spearman R options allow to compare numerical columns, the Anova option helps in determining how well a category column categorizes values in a (numerical) value column, the Kruskal-Wallis option is used to compare sortable columns to categorical columns, and the Chi-square option helps to compare categorical columns.

There are three (3) features of 2D data used which are vegetation (V_D), residential (R_D), and industrial (I_D). Each data attribute was calculated with a geometry calculator to utilize the area information as numeral columns (V_A, R_A, I_A) based on geometry features. To create a relationship for the data, all the data enhance with sub-district boundary (SB_D) information through join and relates tools based on the feature's spatial location to become multi-relationship features of enhancing vegetation (V_{SD}), residential (R_{SD}), and industrial (I_{SD}) features. The 2D data relationship is used in this proses as in Equation 3.

$$\begin{aligned} V_{SD} &= V_D + SB_D \\ R_{SD} &= R_{Elev} + SB_D \\ I_{SD} &= I_D + SB_D \end{aligned} \quad (3)$$

Population database development

After that, the utilization of geospatial population distribution is calculated based on the enhanced features of residential information. An additional attribute field created for the population categorizes value in the analysis based on Anova and Kruskal-Wallis data model. From the surface information of residential building height that obtained, derivation of population estimation can be conducted for single structure building (SS_B) such as terrace house using Equation 4 and multi-story buildings (MS_B) such as apartment using Equation 5. Lastly, the centroid point for each feature was generated for the final output analysis process.

$$SS_B = \left(\frac{nDSM}{3}\right) * 4 \tag{4}$$

3 = 3 meters vertical height for each floor
4 = 4 occupants per unit based on average household statistic by DOSM (DOSM, 2019)

$$MS_B = \left(\left(\frac{nDSM}{3}\right) * 4\right) * 8 \tag{5}$$

3 = 3 meters vertical height for each floor
4 = 4 occupants per unit based on average household statistic by DOSM (DOSM, 2019)
8 = average of 8 unit per floor for a multi-storey building

4. CONCLUSION

The capabilities of LiDAR in capturing terrain information is already well known and proven in various data acquisition activities. With the advance of current technologies, the manipulation of LiDAR data can be easily done but need to follow a strict procedure in order to maintain the output precision. This is because the output product such as DSM and DTM becomes fundamental to various mapping applications around the world. These data are not only beneficial due to their profile information, but also on semantic information. The utilization can be applied to both information as implemented by JUPEM through SmartKADASTER and Big Data Analytics platform. Therefore, the application and utilization of LiDAR data should be constantly improved from time to time to fully enhance the development of information that meets the requirement of IR 4.0.

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