

SUSPECTED UNREGULATED DUMPING SITE DETECTION AND VERIFICATION USING HIGH RESOLUTION SATELLITE IMAGES AND DRONE FULL MOTION VIDEO (FMV) DATA

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ABSTRACT: By the year 2020, more than 30,000 tons/day of solid waste are estimated to be generated by Malaysians. Under the Malaysia Solid Waste and Public Cleansing Management Act 2007 (Act 672), solid waste are categories into public waste, import waste, household waste, institution waste, special waste, commercial waste, industrial waste and construction waste. Like other countries, unregulated dumping site has become serious matter to be taken up by the government because it able to causes risk to human health and the environment. The location of suspected unregulated dumping site are usually in hidden area and difficult to detect by the local authorities. However with the recent advances in remote sensing satellite technology, the location of suspected unregulated dumping site landfills can be identified. In order to provide an accurate information and location to local authorities for the enforcement purposes, drone system with FMV capability was used to verify the waste category, area estimation of dumping sites and nearest sensitive area effected such as: residential, school and waterbody. Through FMV data, others required information such as identity of the suspects, vehicle registration number and potential threat to the local authority to enter the area can be immediately identified in real-time. Even dynamic information like ongoing activities at suspected unregulated disposal area can be seen clearly and recorded. Through capabilities of remote sensing satellite and drone FMV technologies, detection and enforcement works can be done more effectively in future by the local authorities.

1. INTRODUCTION

It is estimated that by 2020, Malaysia will produce more than 30,000 tons/day of solid waste (Jereme et. al, 2015) (Rahim et. al, 2016) (Sreenivasan et. al, 2012) (KPKT, 2015) that generated from household, commercial, institutional and industrial. Like other countries, unregulated/ illegal dumping has become serious matter to be taken up by the government where there are many cases of unregulated/ illegal dumps are reported and some of the unregulated/ illegal dumped wastes that linked to industries wastes are found at remote areas. In the state of Selangor alone there are 500 illegal plastic waste facilities conducted without approved permit (AP) from the National Solid Waste Management Department where most of the plastic waste are not processed correctly but dumped or burned in open air (Greenpeace Malaysia, 2018). Such activities can cause adverse effects on health and the environment such as air, water and soil pollution. The illegal waste burning has contributed significantly to the increase in environmental pollution, particularly of dioxins. Environmental pollution of waste dumping affects health through both short and long-

term effects (Mattiello, A. et al, 2013) (Porta, D. et. al, 2009). General symptoms such as stress, anxiety, headache, dizziness, nausea, eye and respiratory irritation have been also described (Kah, M. et. al, 2012).

In addition, construction and demolition (C&D) solid waste also one of the materials that unregulated/ illegally dispose. The projection of C&D solid waste generated in 2020 is about 36,473 tons/days. According to statistic as show in Figure 1, 60% of C&D waste are possibly dumped illegally at private land (KPKT, 2015). The illegal dump of C&D waste can causing threat to human life where it contribute to mosquito breeding ground in which leads to dengue.

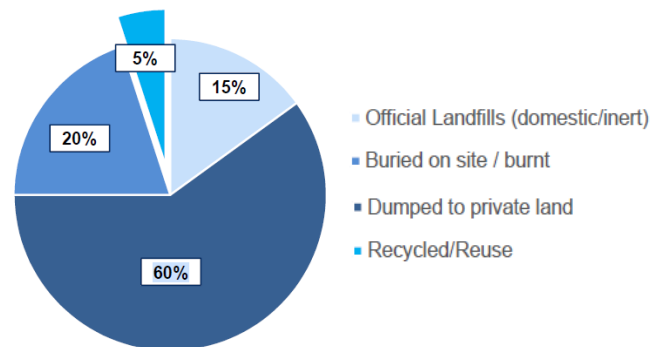


Figure 1: Disposal of C&D Waste (KPKT, 2015)

Remote sensing technologies are seen as one of the alternatives in detecting suspected unregulated waste disposal activities. Several research has been done over the past 15 years in developing methods on monitoring and mapping hotspot waste disposal area using remote sensing technologies which includes satellite images, airborne data and most recently the use of unmanned aircraft system (UAS) or also known as drone. For detection of suspected unregulated waste disposal area, high-resolution satellite imagery are required especially to detect small area of disposal area such as illegal domestic waste disposal sites. Visual identification is used in several existing methods to be appears relatively effective it require significant time and human expertise (Glanville, 2015). The stress of vegetation shows in spectral signature of satellite imagery indicate presence of illegal waste.

The used of drone also being applied in waste management. Drone are used to monitoring landfilled in real-time where it safer and cheaper compared to monitoring using manned aircraft. In Australia, drone are used to tackle and deter unregulated dumping site especially in remote area. The recorded video will be used as evidence to prosecute offenders. Furthermore, the effectiveness in use drone to collect and record the video evidence had been successfully showed by Environment Protection Authority Victoria EPA VIC which issued 98 remedial notices to stop or clean up illegally dumped waste across the state (Waste Management Review, 2016).

Sometimes dangerous situation, potential threat or restriction by irresponsible individual when monitoring and inspection the hotspots want to be implemented (Greenpeace Malaysia, 2018). Thus, through combination of remote sensing satellite and drone data especially those areas beyond/ difficult-to-reach/ dangerous, these information can be quickly identify.

In this paper, FMV technologies are add up for identification and verification in real-time. By using the FMV data, waste category verification and estimated area of waste disposal site able to be done in real-time. In Section 2, explanation on the usage of high resolution satellite imagery for detecting potential suspected unregulated dumping site. After the hotspots are detected using high resolution satellite images, drone technology are used to gather real-time information through

FMV data where are explain in Section 3. The pilot test and results are explain in Section 4 and in Section 5 is about the conclusion of this paper.

The term of suspected unregulated used in this paper, where at the site illegal operations seem to be conducted, but it couldn't be established without doubt, whether the establishment had any permit or not. The term of unregulated also used, where despite having permits, the establishments appear to be poorly regulated and/or in violation of permit requirements, e.g., where the verification identified signs of open burning or seemingly harmful dumping.

2. POTENTIAL SUSPECTED UNREGULATED DUMPING SITE DETECTION USING HIGH RESOLUTION SATELLITE IMAGERY

In this paper, the pilot test area are in the west of Peninsular Malaysia. The Pleiades and SPOT-7 satellite imagery data with resolution range 0.5 to 1.5 meter used in this study. The observation dates were 14 February 2019 for SPOT-7, whereas 22 February 2019 and 26 March 2019 for Pleiades data. Pan-sharpened images of the target area generated from the data, and then targets in the obtained images identified accordingly. There are many methods had been developed for identification of dumping site using satellite images based on resolution and type of sensor as Table 1 below:

Table 1: The identification methods of suspected unregulated dumping site areas using several categories of satellite images

Sensor Used	Resolution (meter pixel size)	Methods of Analysis
Moderate Resolution Satellite Data	12–50	Combination of principal component transformation and unsupervised classification
Medium Resolution Satellite Data	4–12	Spectral signatures and pure spectral pixels
High to Very-High Resolution Satellite Data	high (1–4) and very-high (0.5–1)	Visual identification techniques

For this study, since high-resolution data is available in this study area, the visual identification techniques was used for analysis. Pan-sharpened high-resolution imagery is very helpful to extracting surface changes by visual interpretation depends on how radiance differs which is affected by transmittance and solar zenith angle. From these images, any scrap or junk easily identified since plastic, concrete and bare soils generally appeared as high reflectance and inhomogeneous structure. The use of Pleiades and SPOT-7 which provide high resolution images possible to detect dumping site which is surrounded by build-up and vegetation area by assuming the presence of garbage and the parameter such as area and distance from residential area. For visual interpretation technique, the target detected and evaluated for risk level using criteria as follow:

- i. Un-Occupied Area;
- ii. Sick/ Dead Vegetation;
- iii. Route In/ Out;
- iv. Soil/ Water Texture/ Colour;
- v. Away from Residential Area;
- vi. Near to Drainage System; and
- vii. Waste Deposit.

Un-occupied area and waste deposit means an open area with brownish white colour as well as had uneven texture, this texture usually looks smooth. Typically, a healthy normal vegetation will appear green in satellite image, nevertheless a sick or dead vegetation will be brownish in colour. Route in and out can be seen clearly in a high-resolution image with some features like road network constructed of stone and tar or red soil forming a line. Water appear dark blue in colour with uniform and flat surface texture. Some of the potential dumping site area might be far away from residential area where the routes are distant from any main road. Other than that, by using vector data that we have criteria such as nearby to drainage system is one of the favourite potential dumping sites that has been detected. From this technique, 10 suspected unregulated dumping sites randomly selected for further verification process using FMV drone system in order to gather accurate information at the hotspot areas.

3. SUSPECTED UNREGULATED DUMPING SITE DETAIL AND REAL-TIME INFORMATION USING DRONE FMV DATA

Based on the potential dumping site hotspot identified through high resolution satellite imagery, MYSA together with related agencies have operated drone to acquire dynamic information for verification and examination of the disposal areas. This information is an essential input for enforcement works effectively and to increase the authority's ability to detect suspected unregulated dumping site in remote and difficult locations, as well as providing evidence to prosecute offenders.

Quadrotor drone system equipped with the FMV optical sensor system was tasked to collect and gather the information in designated hotspot areas by streamed directly from drone for real-time/on site FMV data analysis activities. The real-times FMV data analysis activities was carried out by the analysis drone data operator using TacitView FMV analysis software. The connection between aircraft and base station was used radio frequency and between base station and mobile workstation including TacitView software was through RJ45 wired cable to maintain reliability of data streamed and avoid any transmission delay or connectivity interruption. The real-time FMV drone data also was streamed directly from drone operation site (On Site) to MYSA Air Command Center in Kuala Lumpur using Dejero devices. Dejero devices transmit high-quality live video with low latency by using integrated smart blending technology intelligently combines multiple network connections in real-time for enhanced reliability, expanded coverage, and greater bandwidth capacity.

High resolution optical satellite images and extracted hotspot were uploaded and displayed into TacitView software to enable the verification tasking can be done at the right location. Figure 2 below showed the interface of TacitView Software which use by the analysis drone data operator to analyse the hotspot areas.

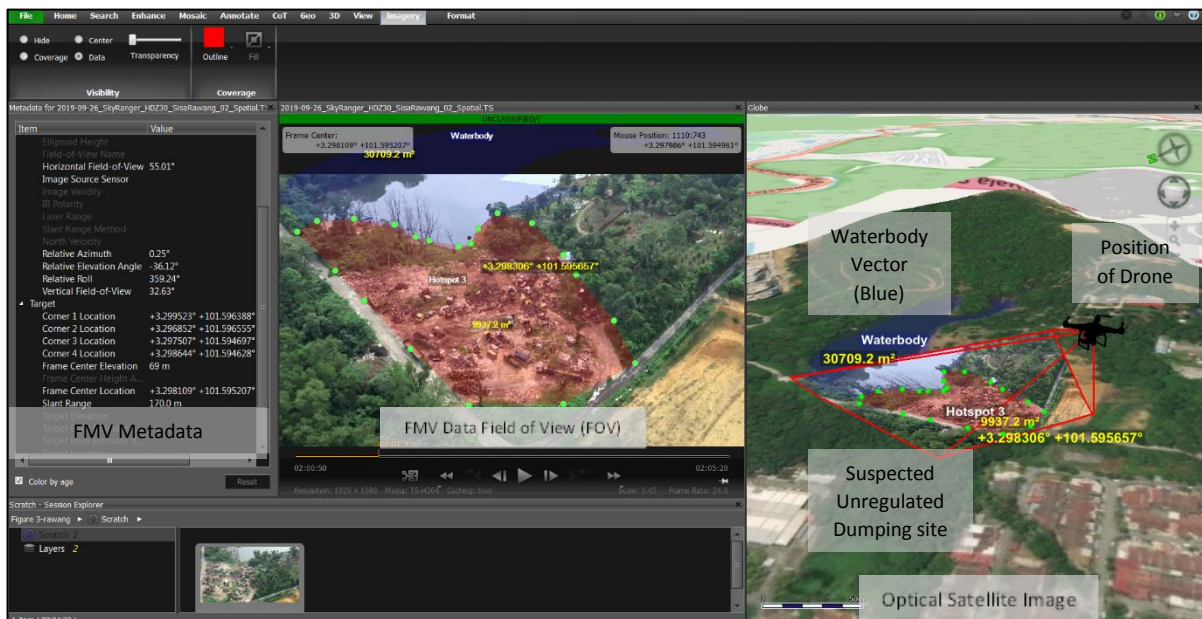


Figure 2: TacitView Software Interface

The use of high performance drone is important input to enforcement agencies in compliance and enforcement toolkit. The land with minimum visibility/ private land/ difficult-to-reach and dangerous area tends to be an attractive place for unregulated/ illegal dumping site. FMV drone data have the potential to get the information during drone verification task are as follows:

- i. The waste category;
- ii. The estimation area of dumping sites;
- iii. The sensitive area (e.g.: Residential, School and Waterbody); and
- iv. To record evidence picture/ video of irresponsible individual/ activities such as identify the suspects, vehicle registration number and potential threat to the local authority to enter the area.

Figure 3 and Figure 4 showed examples of the output from Call Out method analysis made during in-flight in potential hotspot area. This method easily measure the area of suspected unregulated dumping sites in real-time and this information able to disseminate through live streaming to MYSA air command center, Kuala Lumpur.

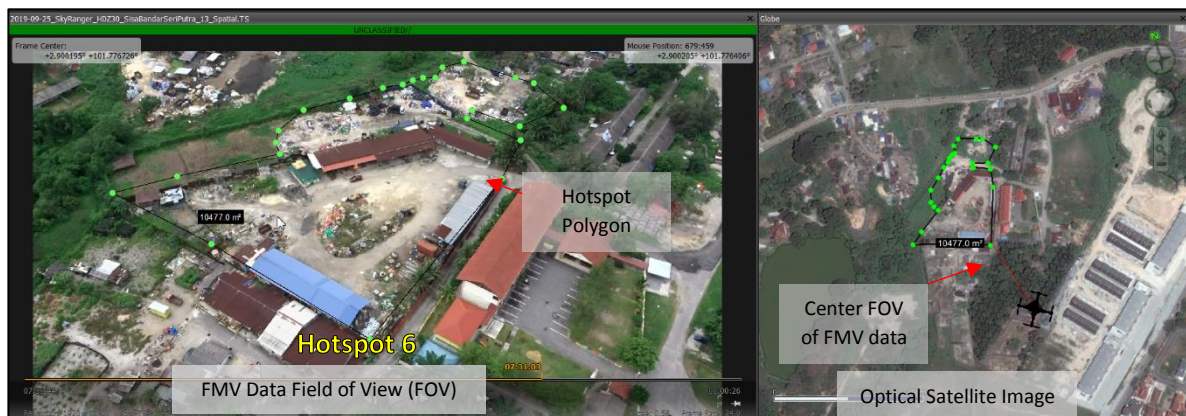


Figure 3: In-flight Call Out method to estimate the area of hotspot

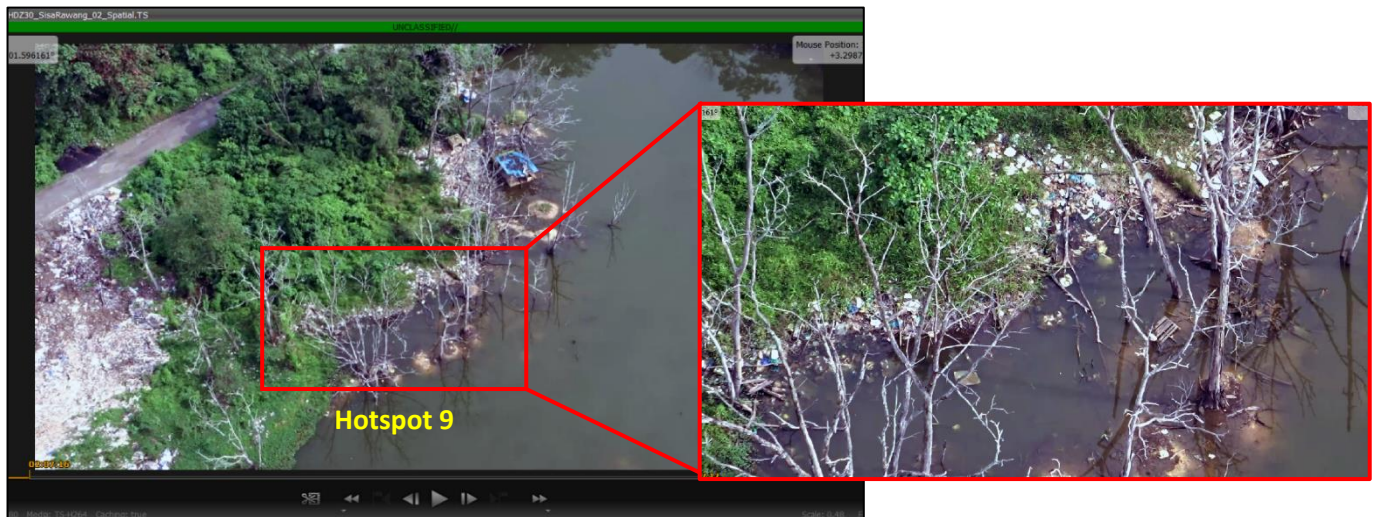


Figure 4: The seepage of polluted water from suspected unregulated dumpsite into nearby waterbody

The drone FMV data exploitation by using Super-Resolve method has a capability to increase the resolution Area of Interest (AOI) for the identification waste category, irresponsible individual/suspects and vehicle/ machine registration number in the suspected unregulated dumping site area. The Super-resolve method extract single frame image from AOI FMV by using high quality spatial (in-frame) upscaling and motion compensation for finding corresponding areas in neighbour frames algorithms. The video motion detection and tracking are then employed using sub-pixel accurate motion compensation, the similar areas in neighbour frames and intelligently merge frames to combine information for enhance the identification capability. The Figure 5 and Figure 6 shown examples of super-resolve image extract from drone FMV data to enhance the identification capability.

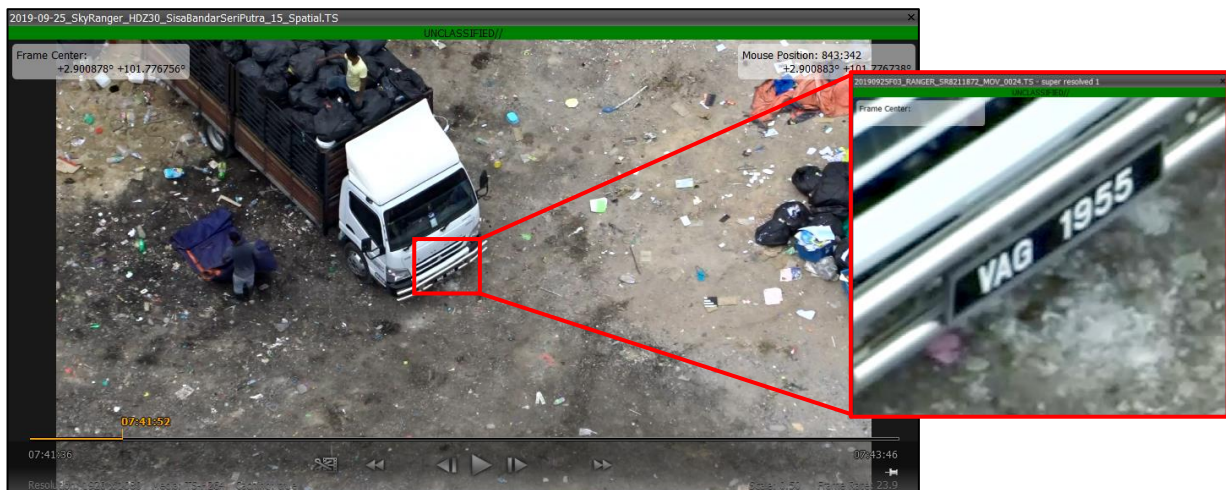


Figure 5: The identification process of vehicle registration number operated in the hotspot area



Figure 6: Several waste categories in the unregulated dumping site area

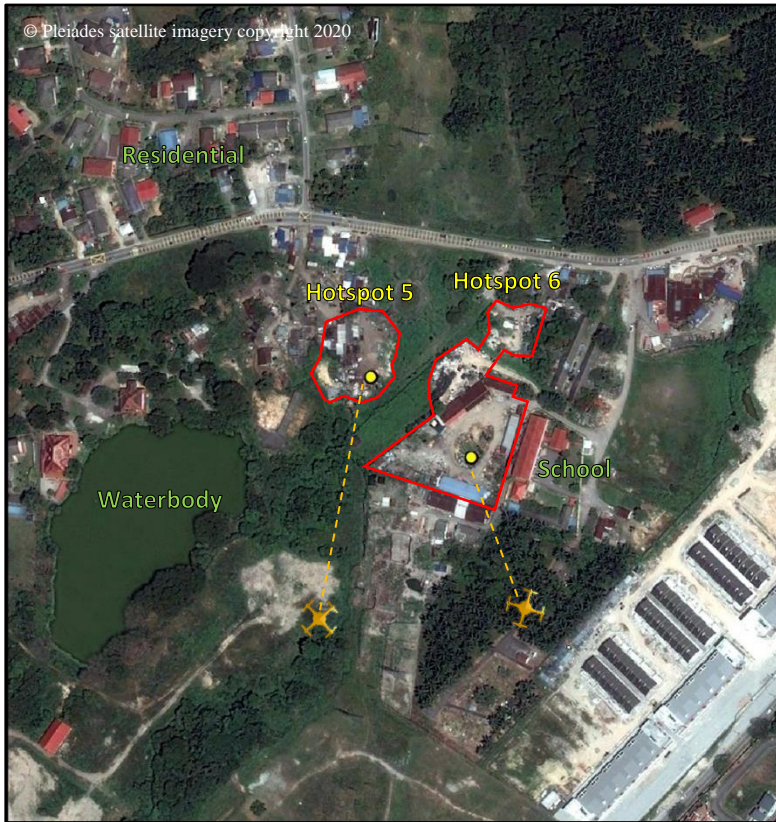
4. PILOT TEST AND RESULT

Above method as mentioned in section 2 are implemented and from the hotspot of suspected unregulated dumping site areas, 10 hotspots randomly selected as a sample for the pilot test. All the identified potential hotspots show criteria such as Unoccupied Area, Sick/ Dead Vegetation, Route In/ Out and Soil/ Water Texture/ Colour clearly be seen using the high-resolution satellite imagery. Therefore the verification through drone system deployment as in section 3 was executed after the extraction of hotspots location were identified. The FMV drone footage and information of the potential hotspots are as follows:

i. Hotspot 1-4



ii. Hotspot 5-6



Public solid waste
(Plastics, papers)
(12,544 m²)



Construction solid waste
(Metals, pipes, woods, electrical wastes)
(12,544 m²)

iii. Hotspot 7



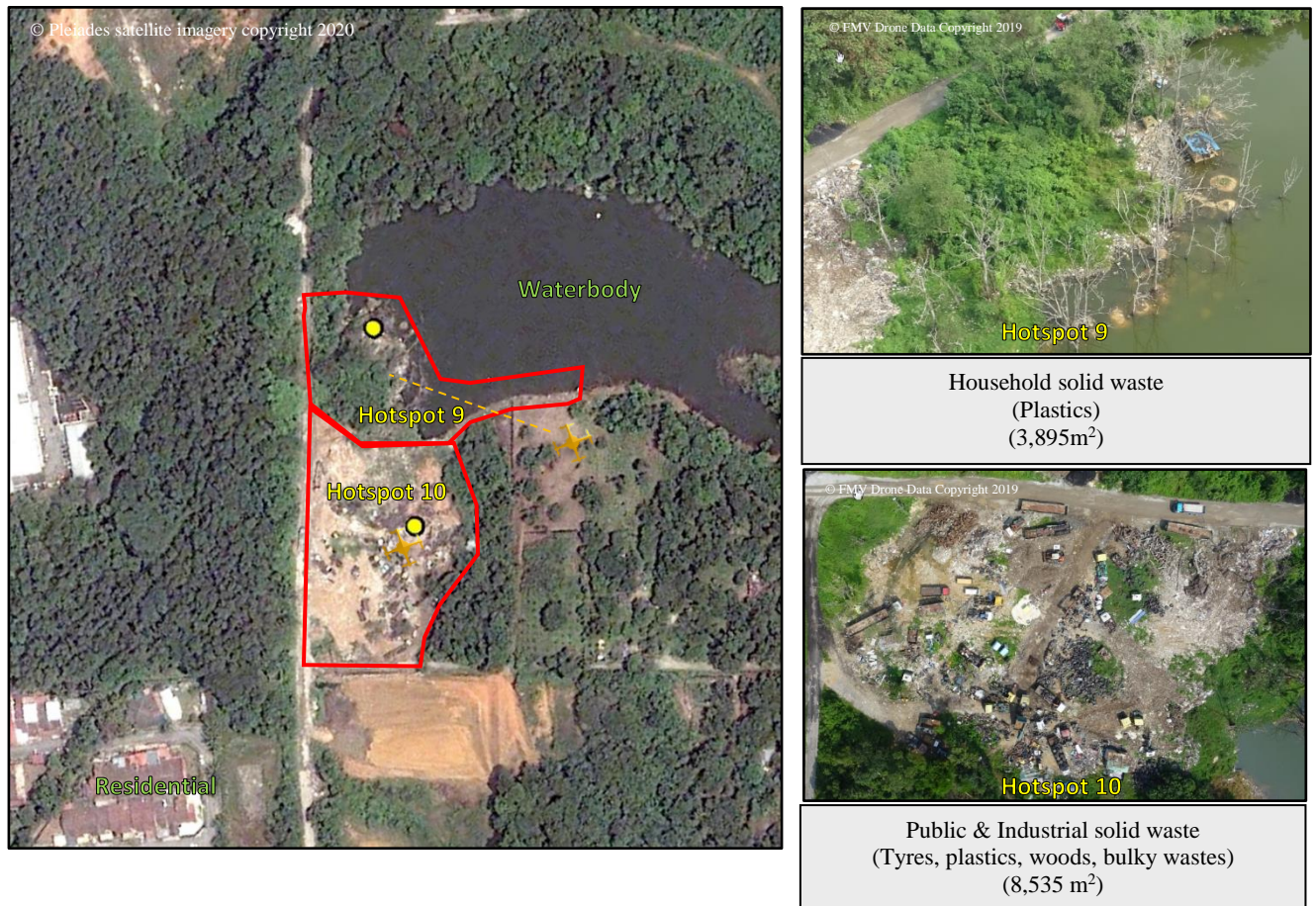
Household solid waste
(Plastics, organic wastes)
(12,544 m²)

iii. Hotspot 8



Industrial solid waste
(Metals)
(14,180 m²)

iv. Hotspot 9-10



The result of drone verification process, 9 out of 10 hotspot areas are suspected as the unregulated dumping site. Electricity pylon and waterbody reserve have a higher potential to be an urban dumping site hotspot. The suspected unregulated dumping site in this study easy to distinguish between legal/ register and illegal/register dumping site when several facilities such as site office, leachate treatment plant and security control are not provided while the characteristic of non-register dumping site are scattered waste, no has daily soil cover and away from main road. The close distance between landfill and sensitive areas such as school, residential and waterbody pose the environmental threats that directly contributed to health effects on students and nearby communities.

5. CONCLUSION

The usage of high resolution satellite imagery provide the opportunity to detect the suspected unregulated dumping site and the combination FMV drone data technology as a complementary input able to provide accurate information to related agencies as a new mechanism to enhance the capabilities of enforcement works.

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