APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEM IN LIVESTOCK INDUSTRY IN MALAYSIA FROM YEAR 2010 TO 2020

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ABSTRACT. The Geographical Information System (GIS) evolves and transforms each decade along with the GIS technology and its capabilities. It would continue to evolve and transform to keep up with the new technology. This study is aimed to provide an overview of the application of GIS on environment, diseases monitoring, farm management and environment in the Malaysian livestock industry, specifically for the Department of Veterinary Services (DVS) from 2010 to 2020. GIS is used to help with management and decision making at the farm management level, particularly in accurately determining the areas for the farms in informative map. The management can easily identify and utilize all areas in the farm using these maps based on the geographical condition and nearby features. In the monitoring and control of animal diseases, notably zoonotic diseases such as Asian highly pathogenic avian influenza (HPAI) in 2017, rabies in 2019, and others, an Online Animal Disease Information System was developed for reporting and managing animal diseases in order to control and eradicate the diseases. This disease data sharing is important for disease control collaboration during the stages of preparation, response, and recovery. The mapping approach provides a clear visual description of the disease incidence distribution in specific areas. Because of its ability to provide a baseline pattern of distribution and identifying possible disease clusters in the monitoring process carried out by the department, it could also be used for animal disease surveillance in the future.

Keywords: GIS, livestock, Web-GIS, disease mapping, precision farming

INTRODUCTION

Geographic Information Systems (GIS) is often used to access, manipulate, and analyse spatial data (Malaysia National Geospatial Centre, 2021). The GIS was previously used to fulfil the government's need in the focus area of land and farm management, urban planning, population census, surveying, and mapping. The change of software from silo stand alone to sharing capability and crowd sourcing allows the data information to grow faster and spread wider.

Global Positioning Systems, or GPS, is used to determine the location of objects by utilizing satellite signals. Geospatial data, also known as geographic information, are data or information that identify the geographic location of features and boundaries on earth, such as natural or man-made features, oceans, and more (Neethu & Subu, 2013). Spatial data are typically stored in the form of coordinates and topology and visualized by mapping. This means that the records in a dataset have locational information attached to them in the form of coordinates, address, city, or ZIP code. GIS is a software programme that represents geospatial data. It has emerged as a tool with a multidisciplinary field with practical potential to be applied for any discipline handling data related to geographical locations (Norstrøm, 2001). GIS has been used in a range of fields that require geo-location to fulfil tasks in the field, as seen in Figure 1. Other sources of geographical data include GPS data, satellite imaging, and geotagging. GIS is used to record information on maps. GIS technology allows users to compare the locations of various objects to see how they connect to one another. Using this facility, the same map might identify places that pollutes the environment, such as an animal farm, as well as areas that are vulnerable to pollution, such as wetlands or water resources. The output from this technology enables the researchers to determine which wetlands are the most vulnerable (Zhou & Li, 2021).

The advancement of hardware and software, as well as changes in user perspective and activities, are all contributing to the advancement of GIS. The GIS is currently undergoing a number of processes in terms of development, maturation, and transformation. Some development and transformation were previously restricted, but there are now or will be in the future. This paper briefly discusses the use of GIS software and technology among the researchers and users in the livestock industry from 2010 to 2020. Despite the size of the livestock business, this study focuses on the use of GIS in Department of Veterinary Services (DVS) in Malaysia, which is the primary authority for the Malaysian livestock industry. Figure 2 illustrates the research field in which GIS applications are used to improve the quality of service delivery to farmers and general public by DVS.

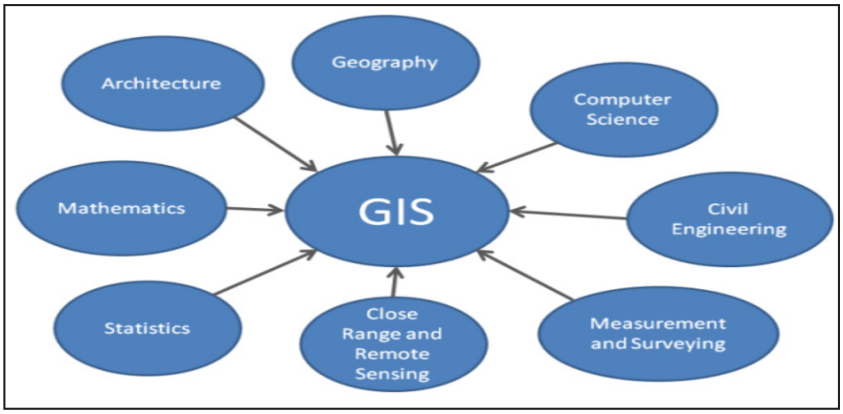

Figure 1. The use of GIS in various industries that use geo location in work activities.

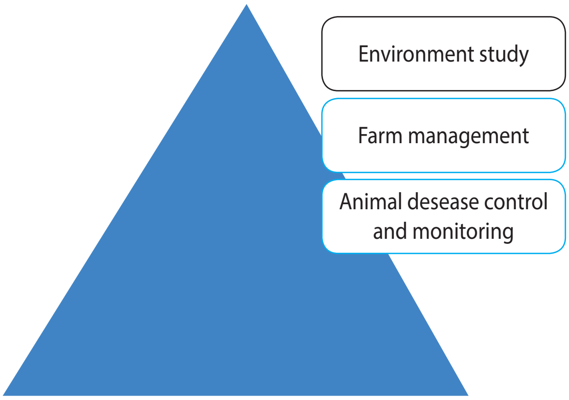

Figure 2. GIS Application by DVS

Animal Disease Control and Monitoring

GIS is being used to visualize disease foci, monitor newly infected or re-infected villages, and identify populations at risk, target cost-effective interventions, and monitor eradication efforts. It has been effective and prudent tool for researchers to monitor disease outbreak by collecting, compiling, and analyzing the samples (Inbaraj *et al*., 2020). DVS Malaysia is the main organization that is responsible for animal disease monitoring and control, animal production, food safety and security as well as animal welfare in livestock industry. The department's key functions and operations are disease monitoring and control. DVS Malaysia conducts surveillance through GIS screens for the disease clusters in space and associates the disease along with the territory. Despite extensive research, it is necessary to monitor and collect the spatial data relevant to the phenomenon (Krieger *et al*., 2005).

Currently, GIS has become a crucial tool in animal disease control and have been widely used for visual assessment and to provide data for advanced spatial analyses. Control of animal diseases requires epidemiological data about that particular disease. These data can be gathered using different systems such as by using surveillance system. There is in fact evidence to suggest that animal health surveillance is an essential tool to detect disease or infection, monitor disease trends, support claims for freedom from disease or infection, provide data for use in risk analysis, and substantiate the rationale for sanitary measures (Tadesse & Amare, 2021). Besides, there is also another study done by Inbaraj *et al*. (2020) which employed the GIS active and passive surveillance for the livestock disease in South India. Apart from that, other previous studies conducted using similar method include animal Foot Mouth Disease (Lee *et al*., 2013), and dengue fever (Alzahrani *et al*., 2013) also demonstrate the benefits of GIS to plan eradication of diseases based on habitats of vectors or wild animal population.

The mapping approach provides a clear visual description of the distribution of animal disease incidence in specific areas as shown in Figure 4 and Figure 5. It could also be used to provide a baseline pattern of distribution and identify possible disease clusters in the DVS monitoring program. The pattern and the presentation of spatial disease distribution can be divided into dot, diagram, choropleth, and flow maps (Kistemann *et al*., 2002). Dot maps are able to show each health event with the resolution of a pair of coordinates, *x* (longitude) and *y* (latitude). The representation of disease incidence data can vary from simple point maps for cases and pictorial representation of counts (Mollalo *et al*., 2020). The findings of this study could be useful to improve future epidemiology research and serve as a springboard for the development of more effective control strategies in Malaysia. It is also being used to portray the occurrence of animal diseases over time as shown in Figure 3.

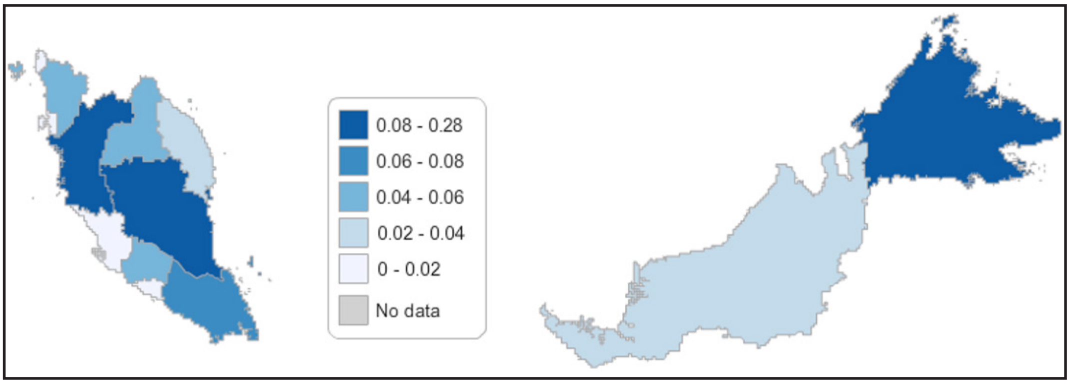

Figure 3. Seropositive cases for melioidosis in Malaysia for year 2012 (Masrin *et al.*, 2018).

GIS perspective has evolved from data description to simulation and modelling. Nowadays, the data created to store and manage a niche project can be analysed in variety of ways and modelled to have a greater impact on all. In addition, GIS also shifts the focus of the work from data conversion to spatial analysis. Huge amounts of data from various sources are analysed to provide valuable information and forecast trends and predictions. All users will benefit greatly from GIS cloud sourcing and sharing technology. This technology helps the users to utilize the collected data and share them among the users anywhere and at any time. This technology or technique uses the 'one to many' concept, which means that data collected by one person can be used by all. For example, data premise location collected during industry registration can help in disease outbreak control (Salina & Azmie, 2013). Many studies done by DVS staffs that use GIS technology to generate visualization of disease cases or outbreak as shown by Figure 4 and Figure 5.

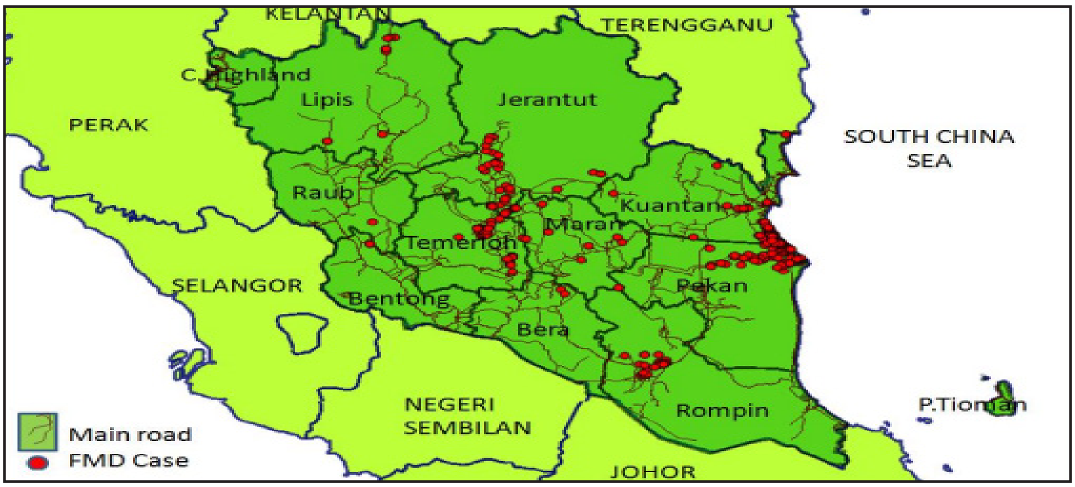

Figure 4. Positive cases of FMD in southern peninsular (Senawi, 2012).

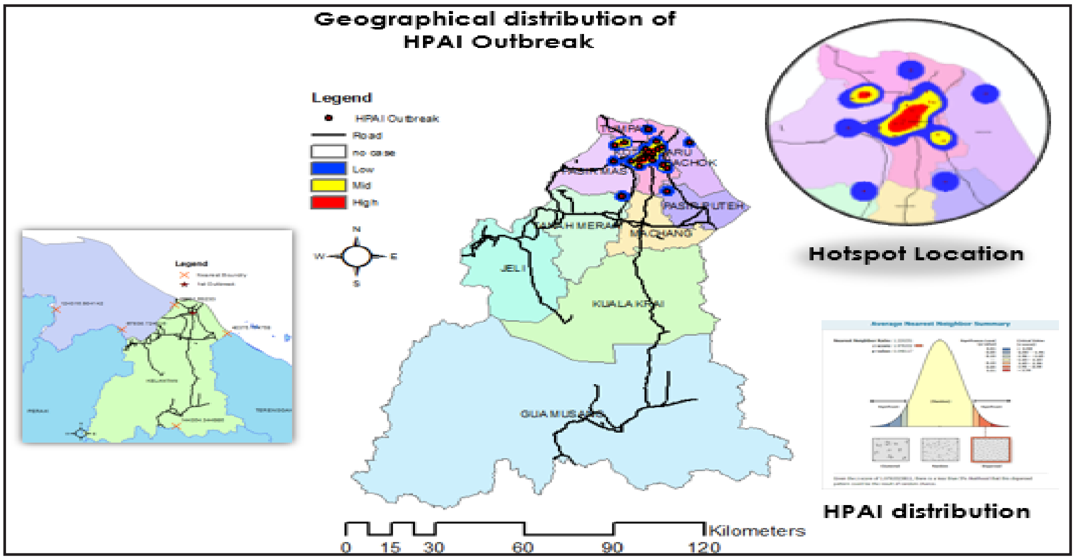

Figure 5. HPAI outbreak, distribution and hotspot location in Kelantan (Shamsiah Aini *et al*., 2019)**.**

Google map/earth has given huge impact on GIS technology and changed the collective geographic expectations when it comes to exploring high and medium resolution imagery. It also adds a new dimension to GIS data representation, resulting in increase of market demand for data and information representation. As a result, progress in developing a web-based GIS system has increased. To meet market demand, many methods, such as Mashup technique and Google API integration, have been used to create Web GIS. ArcGIS released ArcGIS Online and Portal for ArcGIS in 2012, transforming modern web GIS (ESRI, 2008). Furthermore, it also makes data sharing much easier, faster, and effective.

In 2012, DVS developed a web-based GIS disease monitoring system based on the MapGuide platform which is named GISDVS. It provides a real-time and dynamic way to represent disease information on maps and quarantine control zoning. This reveals potential mechanisms responsible for data sharing that are important for disease control program collaboration at each stage of preparation, response, and recovery. It is hoped that this study will lead to new insights of managing the disease outbreak in a particular area.

In addition to the web-based system, this research extends the previous work by incorporating the rapid growth of mobile technology in the consumer market, which has greatly aided in GIS works and system development. Veterinary Online MAP (VENOM) was developed by DVS in 2017 using mobile environment that specifically used GIS data collection which contains livestock information as well as their location (Figure 6). By the end of 2020, Disease Monitoring System (Figure 7) has been developed and being used to get the farm location using a common database system and HTML5 geolocation tagging. It also employs the use of a bootstrap mobile view and a leaflet Mapbox map to plot the map. This study sheds light on the data collection using GIS via mobile application, and hence would be of great interest. However, there is still a great amount of work to be done in this area.

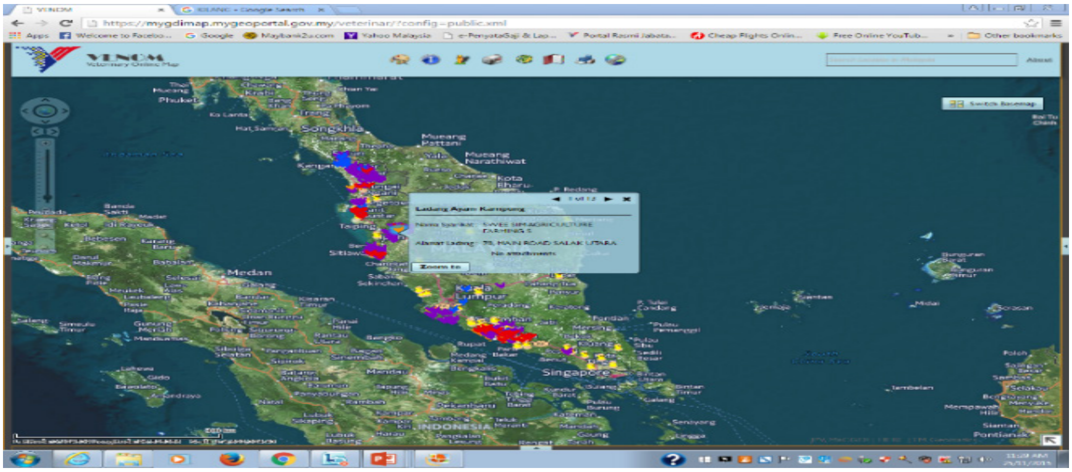

Figure 6. Veterinary Online Map (Venom) developed in 2017 using mobile environment.

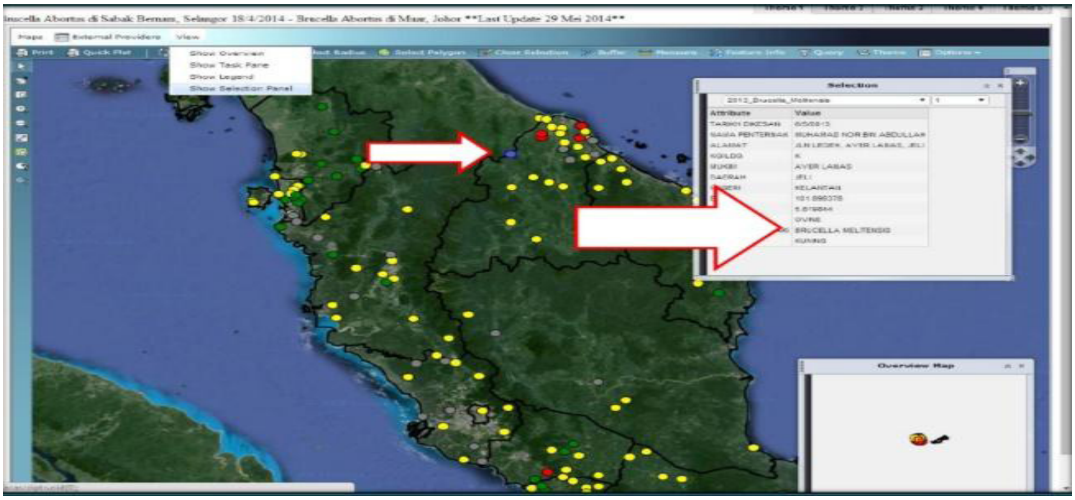

Figure 7. Disease Monitoring System (IP) developed using common database system and HTML5 geolocation tagging.

Farm Management

According to a lot of previous studies, GIS has become an indispensable participation in every aspect of the world (Cinderby, 1999). Notably, GIS and spatial analysis can be powerful tools for understanding, preventing, and organising strategic city development. For example, in terms of land management, GIS software can be used with multivariate analyses (principal component analysis (PCA), redundancy analysis (RDA) combined with forward selection of variables, and cluster analysis as a visualization aid to investigate links between land-use pattern and water quality in the KRB (Kharaa River Basin). Currently, livestock production encounters many challenges, such as increase in production costs and adverse effect on the environment. This is due to excessive use of chemicals fertilizers and pesticides. Therefore, a more accurate and rapid management practice based on these technologies is required. The integration of GIS, GPS and RS technologies using an open-source platform is deployable and viable in creating an online mapping system. The creation of this map would assist the farm level management in the decision-making process. The visualization of a wide range of area coverage in a short period of time, as well as a cost-effective method in conducting field assessment, would increase farm resource use efficiency, and productivity while lowering the overall farm production cost (Pilevar *et al.*, 2020).

The ability to share and visualize information through an online base system that is accessible from anywhere and at any time would be the unique selling point of this mapping system. As a result, the use of fertilizer has been reduced by more than 38 %. Up to 25 % of the total area was identified as inefficiently managed, and 5 paddocks were identified as unproductive due to high percentage of waterlogged areas and native weeds invasion. Overall, farm management can save as much as RM 42,745.28 by purchasing urea fertilizer at RM 1500/tonne. By using remote sensing technology such as satelite image processing as shown in Figure 8, farm manager can easily manage the farm in their zone, which include every single usable paddock, pasture type, fertilizer rate and date of application, unproductive area, actual area, and pasture maintenance schedule (DVS unpblished data).

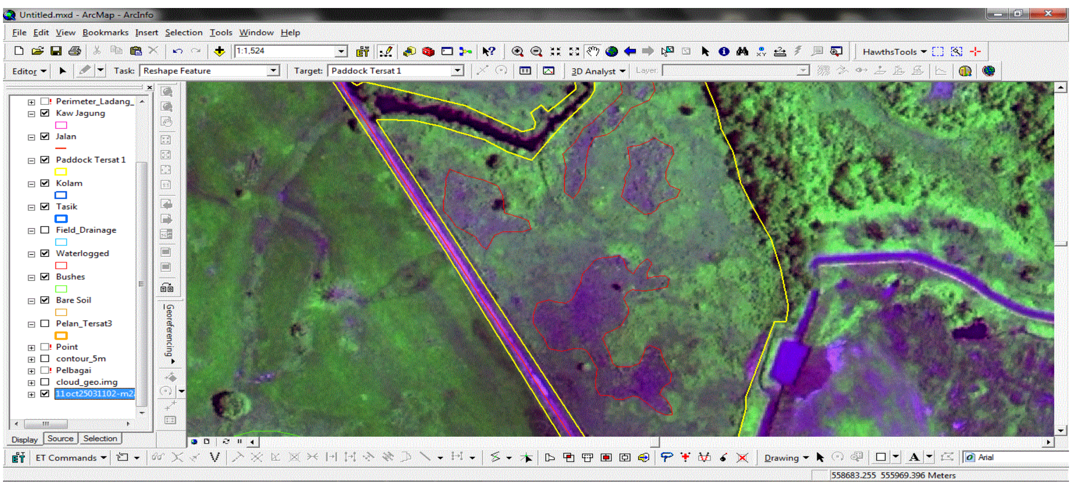

Figure 8. The color composite which were performed through different bands of color combinations (R:G:B) ranging from 3:2:1 to 1:4:3 can enhance and further identify areas such as waterlogged and bare soil areas

This precision farming is an approach of managing scarce resource of farm inputs efficiently by assisting farmers in the decision-making process using qualitative and quantitative data through information technology platforms. The incorporation of geographical GIS, remote sensing (RS) technology and GPS into today's modern agriculture has raised the standards in the management of agricultural and livestock production. One of the key challenges addressed by precision farming is spatial variability, which occurs when a measured quantity from various spatial locations exhibits different values across the monitored area, resulting in spatial complexity and heterogeneity. Management factors such as actual planting area, fertilizer rate, crop assessment, yield prediction, and various socio-economic variables can be determined by using remote sensing software and technology (Tashayo *et al*., 2020). Figure 9 shows some information that can be recorded, edited and saved using ArcGIS or other current software available in the market.

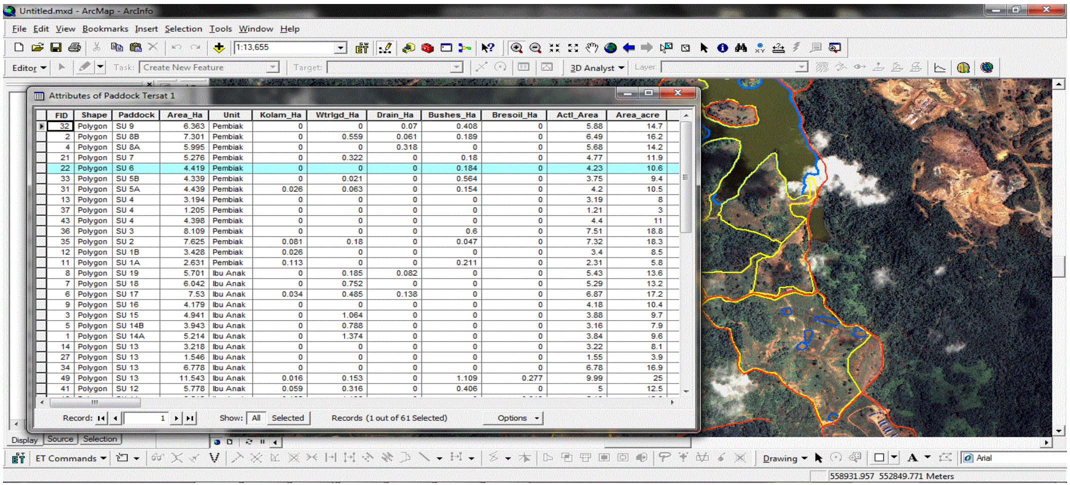

Figure 9. Attribute data and useful information layer.

GIS work has also been used in the process of redevelopment of the Kaprima Farm. In 2015, a total of 8 Kaprima Farms in Terengganu were offered to successful entrepreneurs for farm redevelopment. However, there were constraints in determining the specific area to mark the offering area, as well as to indicate current facilities, buildings and the geographical condition within the farm perimeter. This information is important for planning the management strategy and ensuring that the farm perimeter is valid and can be fully utilized when the farm is awarded to the entrepreneurs. Thus, it was decided that GIS technology would be used to generate a comprehensive map of the Kaprima Farms. Insights into these aspects are expected to contribute to a better understanding of farm development.

Each farm has two different maps, one that shows all of the locations with coordinates, the length of the roads, the perimeter and all of the farm features as shown in Figure 10, while the other map in Figure 11 provides the contour details. From the total of eight farms, a few farms were required to redo their fencing perimeter because the current fence perimeter was not within the farm perimeter. This could have occurred due to the hillside, river and thickets being overlooked. This map can also assist entrepreneurs to plan and strategize the location of pens, fertilizer store, paddock, and water tank to ensure that the perimeter is fully utilised. Furthermore, contour maps can be used to show valleys, hills, and slope steepness (Bernard *et al*., 2011) .

By using these maps, farm management can easily identify and utilize all areas of the farm based on the geographical conditions and features nearby. Other than that, these maps can be used to develop a precise and efficient method of accessing a wide range of farm areas in a systematic manner for assisting decision making at farm level. Furthemore, farmers can identify and differentiate between the productive and unproductive areas for paddock rotation strategy (Boyd & Foody, 2011).

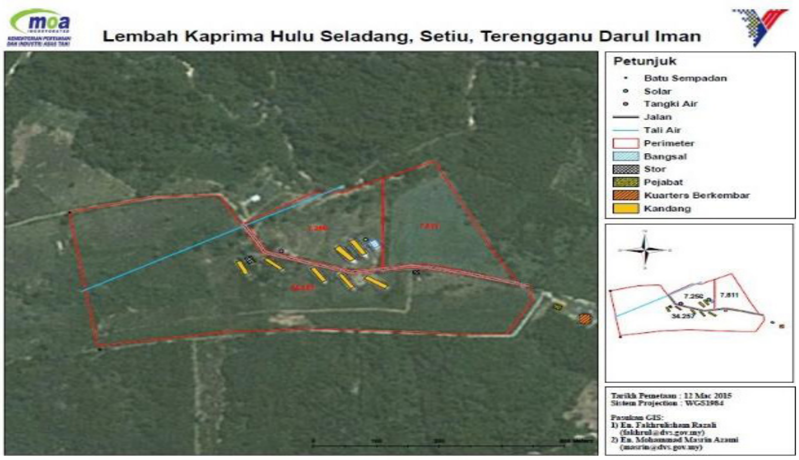

Figure 10. Lembah Kaprima Farm at Setiu Terengganu. This map provides information on coordinates, road lengths, perimeter, and farm features.

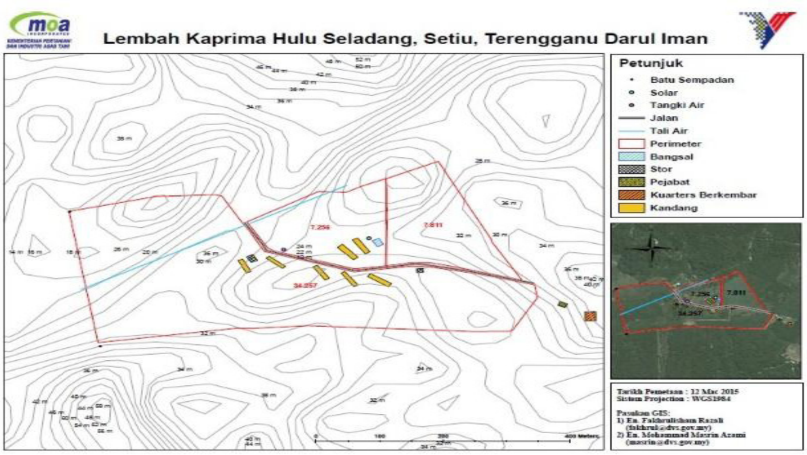

Figure 11. Lembah Kaprima Farm at Setiu Terengganu. This map provides contour information.

Farm digital mapping would provide beneficial information when multiple informative layers are overlaid to provide a better understanding of what is happening in the field. Unproductive areas in the field were determined using digital analysis, which included a color composite analysis. The information sharing and visualizing are enabled through an online base system such as MapGuide Open Source Platform. The significance of this research lies in the fact that it will further benefit the use of this technology by making it accessible from any location and at any time (Zainuddin *et al*., 2011).

Environment

GIS is a powerful tool for environmental data analysis and planning. GIS stores spatial information (data) in a digital mapping environment. A digital basemap can be overlaid with data or other layers of information onto a map in order to view spatial information and relationships.

Sakai *et al*. (2016) carried out a study using GIS to visualize catchment areas of the sampling points where source profiling was conducted to identify the pollution sources based on a correlation between a daily pollutant load of the detected contaminant and an estimated density of human or livestock population in the catchment areas as shown in Figure 12.

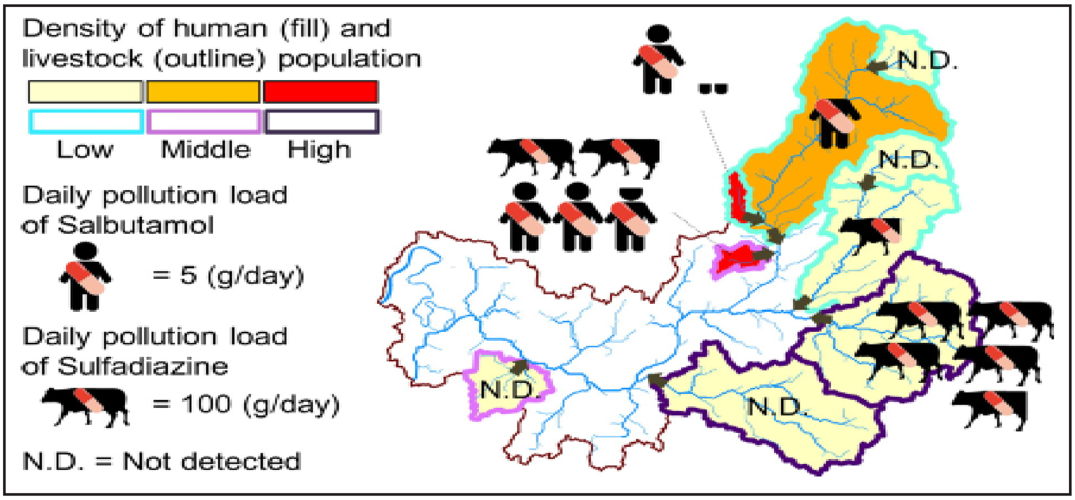

Figure 12. GIS used in the study by Sakai *et al.* (2016).

That study detected six compounds of beta-agonists and sulfonamides in surface water collected from the Langat River basin. It was suggested that sewage was the main source of salbutamol and sulfamethoxazole pollution, while sulfadiazine was discharged from cattle, goat and sheep farms effluents. The source profiling did not work for sulfadimethoxine, sulfapyridine and sulfamethazine, but the areas of the pollution sources were identified by the spatial analysis. These drugs were discharged from mid-catchment areas and distributed towards estuary. It could lead to adverse effects to vulnerable aquatic species or cause drug resistance in bacteria. Currently, Good Animal Husbandry Practice (GAHP) which is a component of Malaysian Good Agricultural Practices (MyGAP) is employed as a guideline for prudent use of veterinary drugs and waste management. However, GAHP is only mandatory for exporting farms. Therefore, effective enforcement is required to control both the sewage and effluents from livestock farms throughtout the river basin. In 2019, a study was conducted to investigate the fly problem at PLUS R&R based on public report as shown in Table 1 and Figure 13. One of the objectives was to determine the relationship between the poultry farm location and the occurence of the fly problem.

Table 1. Number of public complaints on the occurence of the fly disturbance for year 2016 to 2018.

	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Total
2016	0	1	0	0	4	0	1	0	2	1	2	0	11
2017	3	1	0	1	2	0	1	2	3	1	0	2	16
2018	0	0	0	2	2	1	2	1	1	1	0	2	12
Total	3	2	0	3	8	1	4	3	6	3	2	4	39

In this study, 20 farms near to PLUS R&R that are known to be the main factors for this flies problem were identified. However, further study is required to obtain more information on how to control these issues.

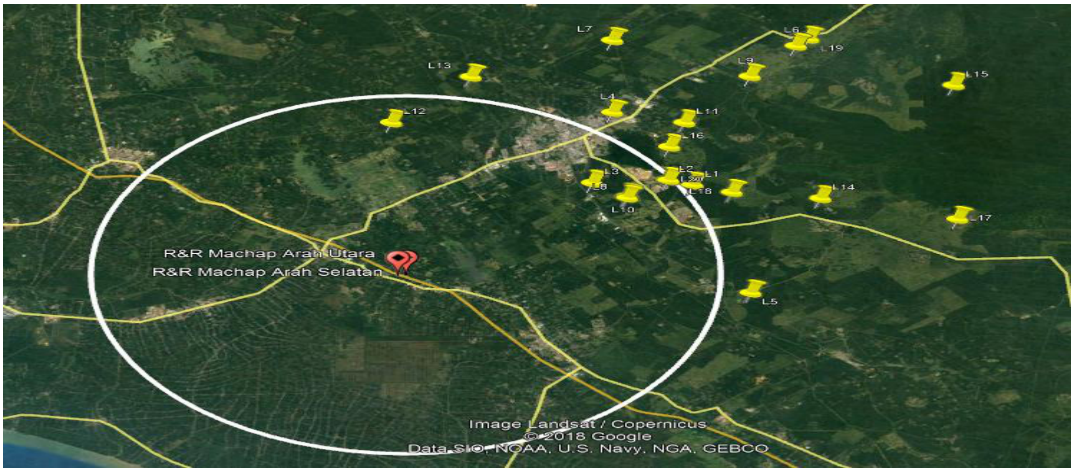

Figure 13. GIS used to mark the location of the trap and buffer tools were applied to identify the nearest livestock farm within 10 km from the R&R.

Figure 14. Fly sampling work at R&R PLUS. GIS used to mark the location of the trap and buffer.

DISCUSSION

GIS is widely accepted around the world and transformed from a research-dominated to a user-dominated. With the exponential growth of GIS technology, advancements in communication and telecommunication technologies, such as the internet, have played a significant role in turning the concept of GIS around the world. Furthermore, the rapid growth of mobile technology in the consumer market has also greatly aided in the development of GIS work and systems. The advancements in communication and mobile technologies help people to get connected without limit and boundary (Pauleen *et al*., 2015). However, Kang *et al.* (2012) discussed some obvious drawbacks with mapping populations using mobile phone data. First, the mobile phone base stations have variable effective transmitter powers, which create inconsistencies between generated Thiessen polygons and actual radio coverage. Second, Kang *et al*. (2012) also demonstrated that the low correlation between the caller volume and underlying population reveals the inadequacy of treating the distribution of mobile subscribers as a representation of the distribution of an entire population.

The idea behind the Internet of Things (IoT) is that all physical devices are embedded with electronics, software, sensors, and network. These components will connect the device to a network to collect and change data, allowing the object to sense and be controlled remotely. Drone technology is increasingly being used in DVS for mapping and monitoring. Block chain technology for Edible Bird Nest (EBN) traceability that consist of location and premise information, has also been developed and implemented at the end of 2020. Thus, there is urgent need for a better understanding of drone and blockchain technology since these are the prominent areas to increase the output from livestock industries.

Next, long-range wireless protocol (LoRa) Technology, which is a long-range, low-power wireless qualities enables the use of low-cost sensors to send data from the farm to the cloud, where it can be analyzed to improve operations. Yao *et al*. (2017) revealed that there is a strong positive correlation between remote sensing observations and GIS technology. More recent approaches of using remote sensing, such as impervious surface and nighttime light data have been found in the studies of Azar *et al*. (2010), Stevens *et al*. (2015), and Yao *et al*. (2017).

Along with the acceleration of technology, DVS will encounter bigger challenges in terms of interpretability of GIS data and data integration. To the best of the researcher's knowledge, no assessment of this issue has been published. Due to these issues, more valuable information will be unavailable and wasted. Hence, there is a strong need for a novel approach especially for management of data collected by GIS systems. With the current technology advancement, large amount of data can be processed in the shortest curve, and it has emerged as a new frontier for geospatial analysis. However, the most challenging and important need today is the requirement of real-time analysis to predict and control the disaster, disease outbreak, and occurrence. As data sharing are becoming more accessible, it is hoped that more experts will be able to work together in one team for analysis and prediction. Thus, the answer probably lies in further large studies with the collaboration between DVS and industry players.

CONCLUSION

GIS development evolves and transforms with each decade, along with the GIS technology and the capabilities. The technology will benefit to the organization, groups, and individuals who use it in many ways. The expanding and flexibility of GIS technology makes it open to create new branch of technology, such as integrating GIS with artificial intelligence technology. In the future, it is possible to see human coexisting with robots and controlling them at the tips of the finger. For veterinary and farming system in DVS, there is a shift towards smart farming system that include GIS element such as animal location via GPS device or transponder that also carries other information. However, with all data collected with multiple device and technologies, software integration or interoperability may be an issue that must be addressed to get better analysis and results. With current situation, DVS has much more space to adopt and enhance the GIS technology so it can help farm management as mentioned earlier. But the effectiveness of technology is determined by how it is implemented. Uncontrolled and unethical use of GIS could raise concern in country's security and privacy. Thus, DVS Malaysia should invest and keep up with current technology to safeguard its sovereignty in the future. It is hoped that this paper provides valuable information for further investigations. The future works would be management and analysis of data captured by GIS system to portray the real situations that occur in disease outbreak, environmental issues, farm development, and others.

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