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Remote Sensing and GIS Application for Sustainability Management of Oil Palm Plantation

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ABSTRACT

Geospatial technology has been described as systems that collect and process location-specific data about the Earth. The technologies comprise remote sensing, Geographic Information Systems (GIS) and Global Positioning Systems (GPS). Based on this, Oil Palm Resource Information System (OPRIS) was developed based on GIS specific functions to enable a complete geospatial data management workflow. It consists of several data layers such as administrative boundaries, soil types, agroclimatic conditions, topography, oil palm landcover, suitability areas, site yield potential (SYP) and others. Initially, geospatial data was digitised from scanned maps and standardised into the same coordinate and projection to allow more data to be overlayed together. Data is presented and integrated into a web map, web apps, story maps, dashboards and applications and mobile. Data can be displayed interactively. Data from OPRIS has been used to map 162 sustainable palm oil clusters (SPOC) and Malaysian Sustainable Palm Oil Certification (SPOC), block mapping for agronomic study, pest and disease monitoring among others. OPRIS will be enhanced with advanced server management and more portal application to promote and improve users accessibility.

ABSTRAK

Sistem Maklumat Sumber Sawit (OPRIS) telah dibangunkan berdasarkan fungsi khusus GIS untuk membolehkan aliran kerja pengurusan data geospatial yang lengkap. Ia telah dikembangkan untuk penyiasatan saintifik, pengurusan sumber dan perancangan pembangunan industri tanaman sawit. Geodatabase OPRIS terdiri daripada beberapa lapisan sempadan pentadbiran, jenis tanah, jenis agro-iklim, topografi, litupan tanaman sawit, kesesuaian tanah dan potensi hasil setempat. Pada mulanya, data geospatial telah didigit daripada peta yang diimbas dan diseragamkan ke dalam sistem koordinat yang sama untuk membolehkan banyak data ditindankan ke dalam unjuran yang sama. Data dibentangkan dan diintegrasikan sebagai web map, web apps, story map, *aplikasi* dashboard *dan penggunaan aplikasi mobil. Maklumat daripada peta dan lapisan data boleh ditimbulkan secara interaktif. Data dari OPRIS juga telah digunakan untuk membantu pemetaan 162 kelompok minyak sawit mampan (SPOC) dan kemajuan pensijilan MSPO, pemetaan blok tanaman untuk kajian agronomi, pemantauan serangan perosak dan penyakit dan sebagainya.*

Keywords: agronomic practices, geospatial, GIS, MSPO, oil palm, remote sensing, sustainability.

INTRODUCTION

Oil palm is Malaysia's most important plantation crop, covering 5.87 million hectares in 2020 which contributes to about 18.3% of global palm oil and 34.3% of the total palm oil trade (Parveez *et al.*, 2021). As the world's second-largest producer and exporter of palm oil and palm oil derivatives, Malaysia's palm oil industry continues to contribute significantly to the nation's economic development and foreign currency earnings. The industry is under pressure to increase yields due to the scarce fertile land and labour dependency in the majority of oil palm operations hence priority must be given for research and development (R&D) to meet the needs of Malaysian oil palm industry.

Oil palm plantations are challenged by the lack of digital and spatial data for reference impacting on the decision-making process, as well as on the interpretation of the shared information. For instance, data that are formerly kept in stand-alone databases could only be accessible within the organisation's infrastructure. Therefore, numerous research has been done in conjunction with the advancement of information technology to foster the creation of new technological discoveries such as remote sensing (RS), geospatial technology comprising Geographic Information Systems (GIS), and geolocation that are quickly gaining interest.

RS uses samples of electromagnetic (EM) radiation emitted and reflected from the Earth's terrestrial, atmospheric and aquatic ecosystems to find out and keep track of the physical features of

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an area without actually going there. Most of the time, passive or active sensors on planes or satellites are used for this method. Passive sensors respond to things happening outside of them by picking up radiation that an object or the space around it is reflecting or putting out. Most of the time, reflected sunlight is the source of radiation that is measured by passive remote sensing. Active sensors use internal signals to gather data. They send out energy to scan objects and areas, and then measure the energy that comes back from the target. Active remote sensing tools like RADAR and LiDAR measure the time between an object's emission and its return to figure out where it is, what direction it is going and how fast it is moving. The remote sensing data is then processed and analysed with remote sensing hardware and computer software which are available in both proprietary and open-source versions. Remotely sensed data can be used for assessment, planning, simulation, and visualisation. Images and other raster formats have been used to capture geographic data at ever-increasing scales and sharper resolutions using remote sensing imagery.

GIS is a computer-based information system to store, manage, analyse and retrieve geographically linked data. It links data about objects' positions to the characteristics of the objects in a combination of thematic layers or maps that carry information about a certain geographic area. Computer hardware, software, data and experts are deployed to explore the earth's data and its relationships to other aspects. Since it can integrate multiple layers of information about the same geographic area, it is significantly more complicated than a simple paper map. Using a mapping application, GIS may be utilised to organise and interpret information.

All kinds of data, including RS, GPS, census, foliar and soil samples as well as irrigation networks, weather stations and mill locations contribute to the GIS data set. Therefore, this article demonstrates the establishment of a geospatial database of natural resource inventory constructed from existing and new data, entitled Oil Palm Resource Information System (OPRIS).

DEVELOPMENT OF OIL PALM RESOURCE INFORMATION SYSTEM (OPRIS)

Malaysian Palm Oil Board (MPOB) has designed and developed a digital technology to improve the management of oil palm plantation, known as Oil Palm Resource Information System (OPRIS) (Nordiana *et al*., 2008). The OPRIS was developed based on ArcGIS software and mobile devices that record and store spatial data of the oil palm plantation in multiple formats. The OPRIS geodatabase comprises multiple layers such as administrative boundaries, base map, infrastructure layer, water bodies and river networks, soil type, agroclimatic information, topographic and agricultural land use. It was constructed from existing maps and satellite imageries while the new data was generated from the established data. OPRIS is purposely used for scientific investigation, resource management and development planning for the oil palm industry. *Figure 1* shows the structure of OPRIS. The spatial data model specifies the principles that must be followed for data to be organised properly. The spatial data model defined the following as the fundamental information:

i. Spatial data type
ii. Feature classification codes and coding standards
iii. Unique identification number
iv. Spatial location number
v. User-defined attributes
vi. Spatial relationship (topology)

Software

The OPRIS is developed using the multi-functions of ESRI software.

Cloud Infrastructure of OPRIS

Cloud computing is growing in importance for GIS professionals. Reasons for its importance include cost, scalability, flexibility, and rapid deployment. Two specific scenarios for GIS in the cloud that are particularly compelling are listed below:

1. Increasing Operational Efficiencies with On Demand GIS - Cloud infrastructure allows GIS users to systematically or temporarily increase their computing power and data storage capacity without impacting their local IT infrastructures. Users are choosing this because of the cloud's elastic scaling and load balancing features - in other words, its ability to extend an organisation's capabilities to support larger audiences and handle peak loads during the busiest times. In addition, the cloud environment involves zero up-front capital investment, complete access by any device anywhere and at any time, and low system administration cost.
2. Streamlining Application Development and Deployment - GIS application developers are finding ArcGIS in the cloud an ideal environment for building and testing application prototypes. They can carve out their own space in the cloud so that they can provision computing resources that match the destination infrastructure, pull in application templates, access hosted APIs and software development kit components,

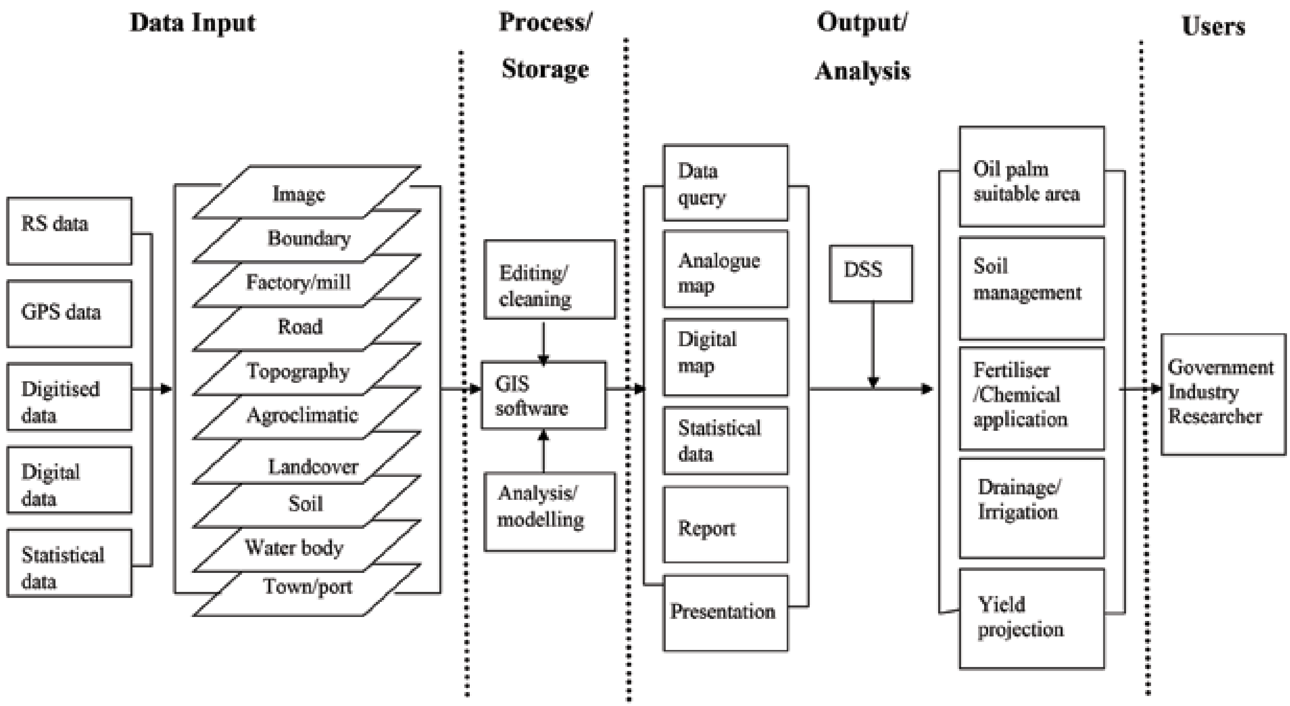

Figure 1. Structure of Oil Palm Resource Information System (OPRIS).

and connect to shared widgets and add-ins. When the applications and services are ready for beta testing, they can be shared with specific user groups or with the actual customers for gathering feedback and making refinements. When it's time for deployment, the applications can be migrated to the on-premises environment or moved to a production environment in the cloud (ESRI, 2021).

ArcGIS Online was designed to function as a complete stand-alone Software as a Service (SaaS) application for web mapping and geographic information management. It was scalable and fully integrated with ArcGIS software deployed on-premises. ArcGIS Online maps and services could be used by any client's facilities including desktop, mobile, and web applications. Users can author their maps with ArcGIS Desktop software or simply create maps by uploading their data using a browser. They can then publish these maps as map tiles or feature services in ArcGIS Online and provide access to any ArcGIS client via open REST APIs to any web or mobile client. Users can control access to the maps they wish to share while, at the same time, supporting multiple open collaboration opportunities. Once a map is created, it could be shared with a specific group or everyone. And because the information is stored in the cloud, anyone who has access to the map will be able to discover, view, add additional layers and graphics, and share it again as a new map in a cloud environment.

Organisations could leverage their investment in GIS by publishing their maps and data for others to use in ArcGIS Online. At the same time, smaller organisations and even individuals can share their data and maps as map services without having to acquire their GIS server software. ArcGIS Online provides access to powerful capabilities that can be implemented by anyone, from professional GIS analysts to casual mapmakers. With ArcGIS Online, all components run in Esri-managed cloud infrastructure in a Software as a Service (SaaS) model. In other words, the computer and data storage resources, the website, and every other aspect of the system are being hosted by Esri in a highly scalable environment. ArcGIS Online can be used to create, use, and share maps and apps with your organisation and the public.

A cloud-based geospatial platform has been applied to the OPRIS. A cloud-based and web-based applications that lets users view, save and organise numerous datasets following a spatial data model is used to do this. Users can submit their datasets to OPRIS and have them overlay with the existing data in the system. OPRIS makes use of the ArcGIS Online platform to provide cloud-based services. For web mapping, web application development, and geographic information management, ArcGIS Online was created as a comprehensive stand-alone Software as a Service (SaaS) platform that can be used by anybody. It was scalable and fully integrated with ArcGIS software that was installed on the client's facilities. Maps and services from ArcGIS Online can be accessed through any client, through desktop, mobile and web-based applications

(*Figure 2*). As shown in *Figure 3*, a geospatial homepage comprised of OPRIS data shown in online maps, as well as web apps developed on the ArcGIS Online platform. Users can input their data into web maps and web apps in the formats that are currently available for viewing and printing. Other options apart from using the ArcGIS Online platform are by setting up a GIS portal for the application service.

APPLICATION OF OPRIS

Determination of Oil Palm Suitability Area

The combination of the multiple datasets in the OPRIS creates a new dataset that offers useful information to the oil palm industry. Integration of the soil and agroclimatic layers forms an oil palm land suitability area class. Based on the characteristics of the soil that influence oil palm growth and production (*Table 1*), the soil layers are categorised into suitable, marginal and unsuitable classes. Meanwhile, the agroclimatic combination which comprises the information of rainfall data and soil water content also influences oil palm growth and production. The agroclimatic information determines the number of moist (rain + soil moisture = pan evaporation), wet (rain + soil moisture > pan evaporation) and dry months (rain + soil moisture < pan evaporation) of each area based on the amount of annual rainfall and soil type (soil water holding capability). *Tables 1, 2* and *3* shows the soil, temperature and rainfall suitability and the agroclimatic suitability classes for oil palm. This information is combined to produce oil palm land suitability maps for Peninsular Malaysia,

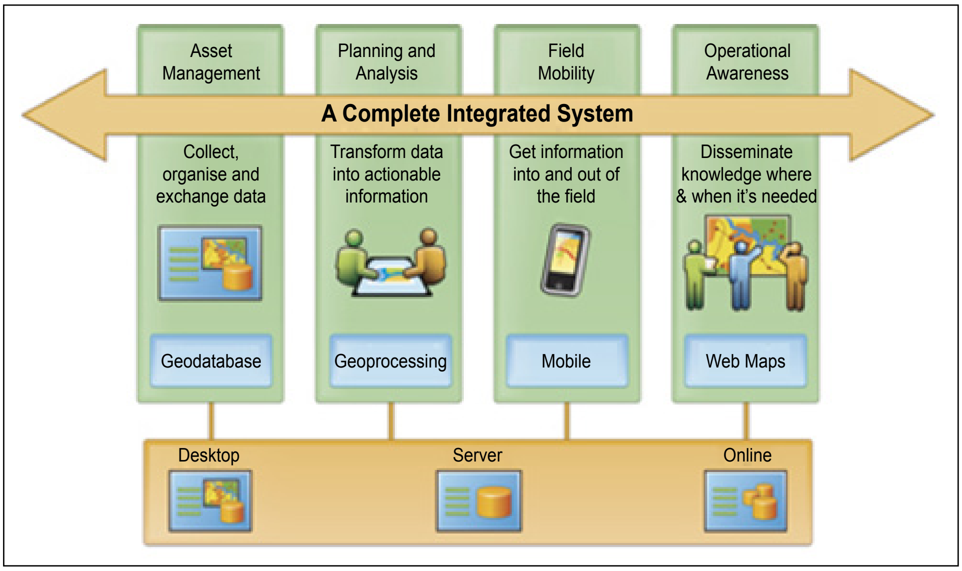

Figure 2. The integrated system of the ArcGIS platform. (http://pngrb.gov.in/pdf/orders/Knowledgesharing4_21122018.pdf)

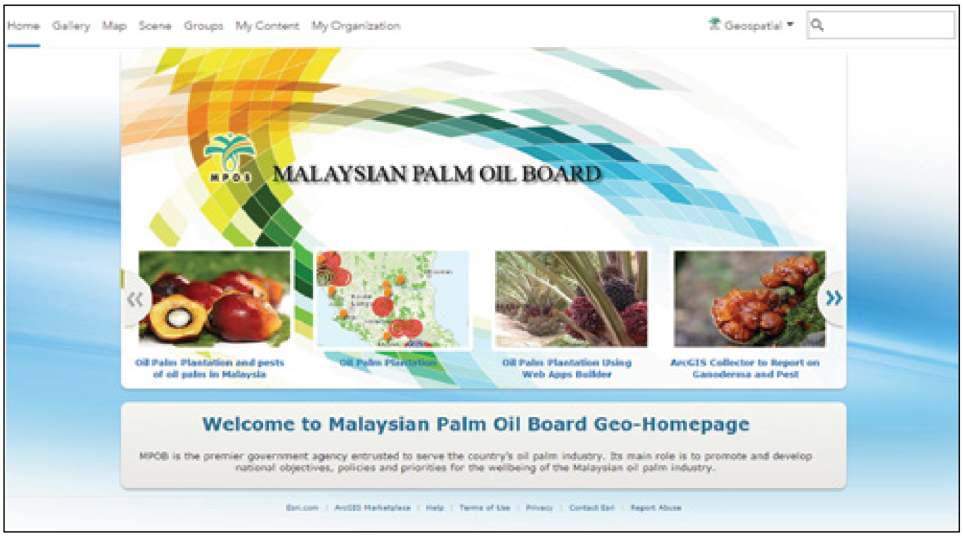

Figure 3. Oil Palm Resource Information System (OPRIS) from cloud.

TABLE 1. SOIL SUITABILITY CHARACTERISTICS FOR OIL PALM

Parameter	Suitable	Marginal	Unsuitable
Slope	0° - 12°	12° - 20°	>20°
Drainage	Imperfect to well drained	Somewhat excessive and poorly drained	Very excessive and poorly drained
Effective depth	>100 m	50-100 cm	<50 cm
Texture and structure	Exclude structureless sands and massive clays	Massive clay	Structure fewer sands
Salinity	<2 mmhos	2-4 mmhos	>4 mmhos
Depth to acid sulphate layer	>50 cm	25-50 cm	<25 cm
Organic Horizon Thickness	<75 cm	75-300 cm	>300 cm
Stoniness	<25% and uniformly distributed or present below 75cm depth	25%-75% and uniformly distributed or present below 75 cm depth	>75% between 100 cm depth
Nutrient Imbalance (CEC)	>24 cmol and without excessive micro nutrients	16-24 cmol and without excessive micro nutrients	<16 cmol or with excessive micro nutrients

Sources: I. F. T. Wong (1986) and S. Paramananthan (2000).

TABLE 2. TEMPERATURE AND RAINFALL SUITABILITY CHARACTERISTICS FOR OIL PALM

Climate factors	Suitable	Marginal	Unsuitable
Temperature (°C)	23-32	32-34 20-23	>34 <20
Rainfall (mm/yr)	1 700-3 000	3 000-4 000 1 100-1 700	>4 000 <1 100

Source: K J Goh (2000).

TABLE 3. AGROCLIMATIC SUITABILITY CLASSES FOR OIL PALM

Crop	Suitability classes			
	Highly suitable	Suitable	Marginal	Unsuitable
Oil palm	10-12 total wet/ moist months/ yr	7-9 total wet/ moist months/ yr	5-6 total wet/ moist months/ yr	<4 total wet/ moist months/ yr

Source: Malaysian Meteorological Service (1993).

Sabah and Sarawak as the final output of OPRIS. The combination of data enables analysts to do geospatial analytics to make decision-making easier and more efficient. The integration of the soil and agroclimatic layers resulted in the production of oil palm land suitability area classes and site yield potential (SYP). *Figure 4* shows the oil palm land suitability maps for Peninsular Malaysia, Sabah and Sarawak as the final output of the MPOB geospatial product. The map is very useful for identifying a suitable area for oil palm plantation management and planning (Nordiana *et al.*, 2008).

Mapping of Oil Palm Landcover

The satellite imagery has been effectively utilised for classifying land cover types and detecting land cover conditions. Various remotely sensed imageries such as *Satellite pour l'Observation de la Terre* (SPOT), Landsat, RapidEye, Worldview and Quickbird image with different spatial resolutions have been widely used to determine and map the extent and changes of the oil palm landcover over years. *Figure 5* shows one mosaic of SPOT images for oil palm landcover determination in Sabah. The crucial point for this kind of activity is to apply an optimal classification approach, which will ensure high-class recognition accuracy and classification repeatability. The traditional spectral based method and object-based classification method were used to improve the classification output (Wahid *et al*, 2010). In OPRIS, data layers and a map of the oil palm landcover are prepared and stored for reference. The layer will be used for reference data as public access to the oil palm layer will be established. It will also helps to identify the actual distribution of oil palm to ensure the effort to maintain the total oil palm areas not more than 6.5 m ha will be successful. The data is also useful for monitoring oil palm planted on peat and as the source of insights for the planters to avoid planting new oil palms on peatland. *Figure 6* shows the oil palm landcover map in 2019/2020.

Mapping of Oil Palm Block

As planters and smallholders have increased their motivation in using digital technology to help with their plantation management, precision agriculture to maximise yields by utilising data received from remote sensors directly on farm gear has become very crucial. Therefore, precise block mapping in MPOB Research Station is established. *Figure 7* shows linear and block extraction in one of the research stations for database development.

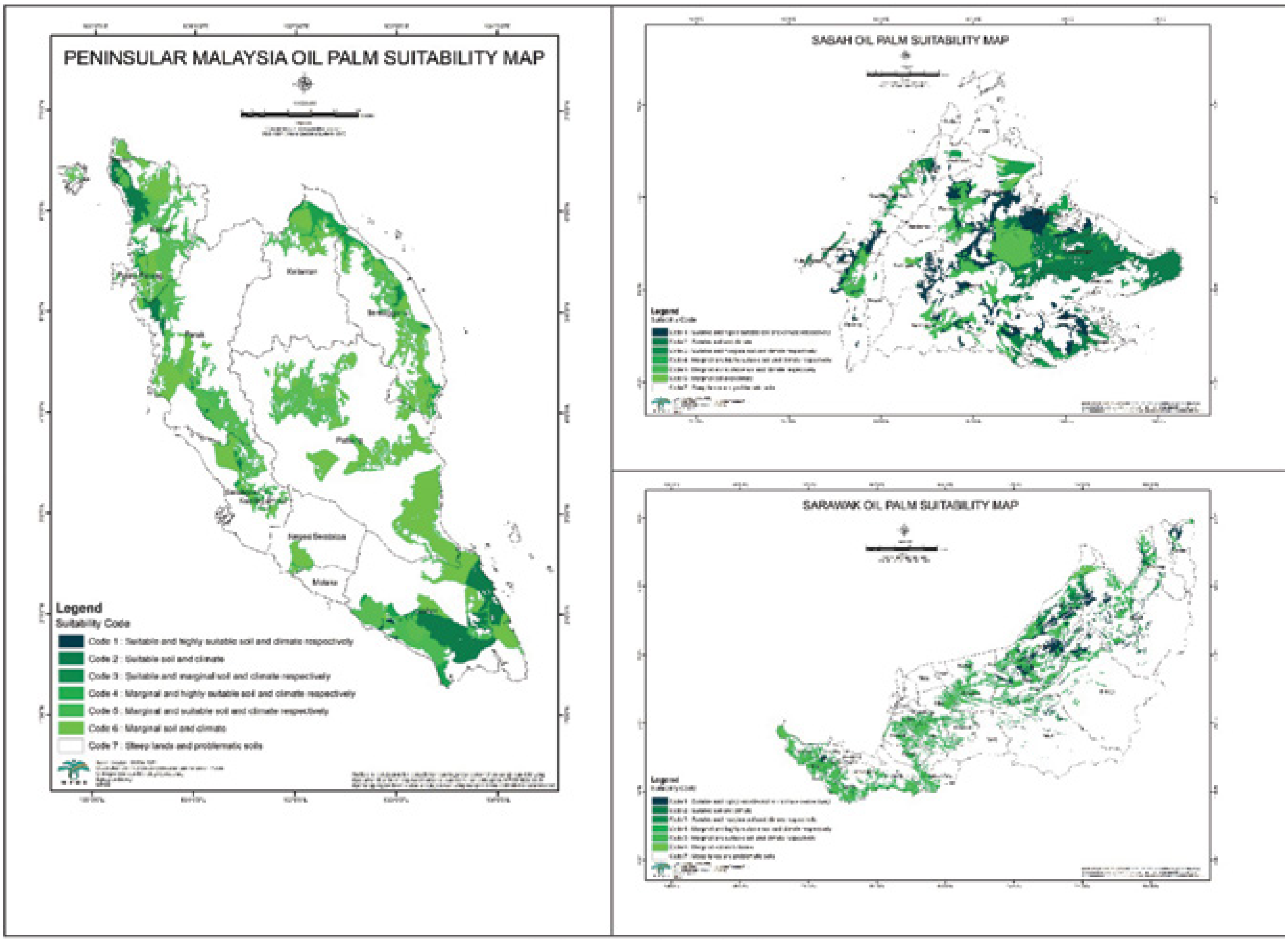

Figure 4. Suitability area for oil palm.

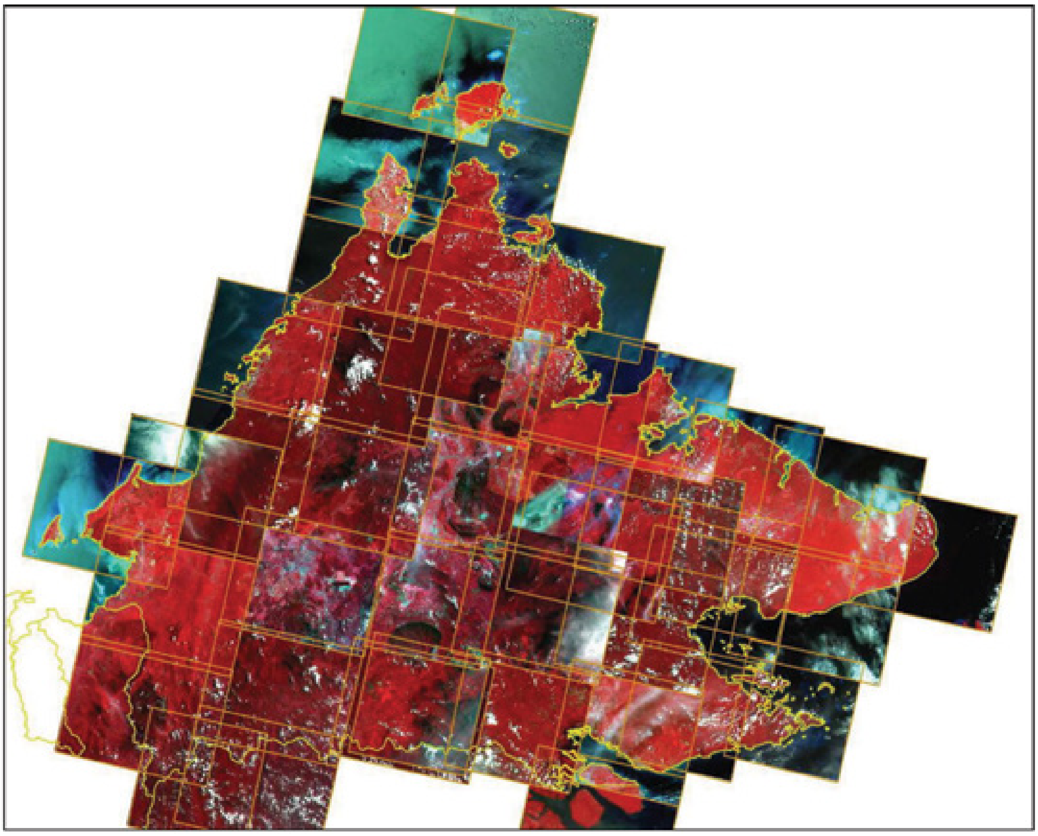

Figure 5. Scenes of multispectral imagery of Sabah.

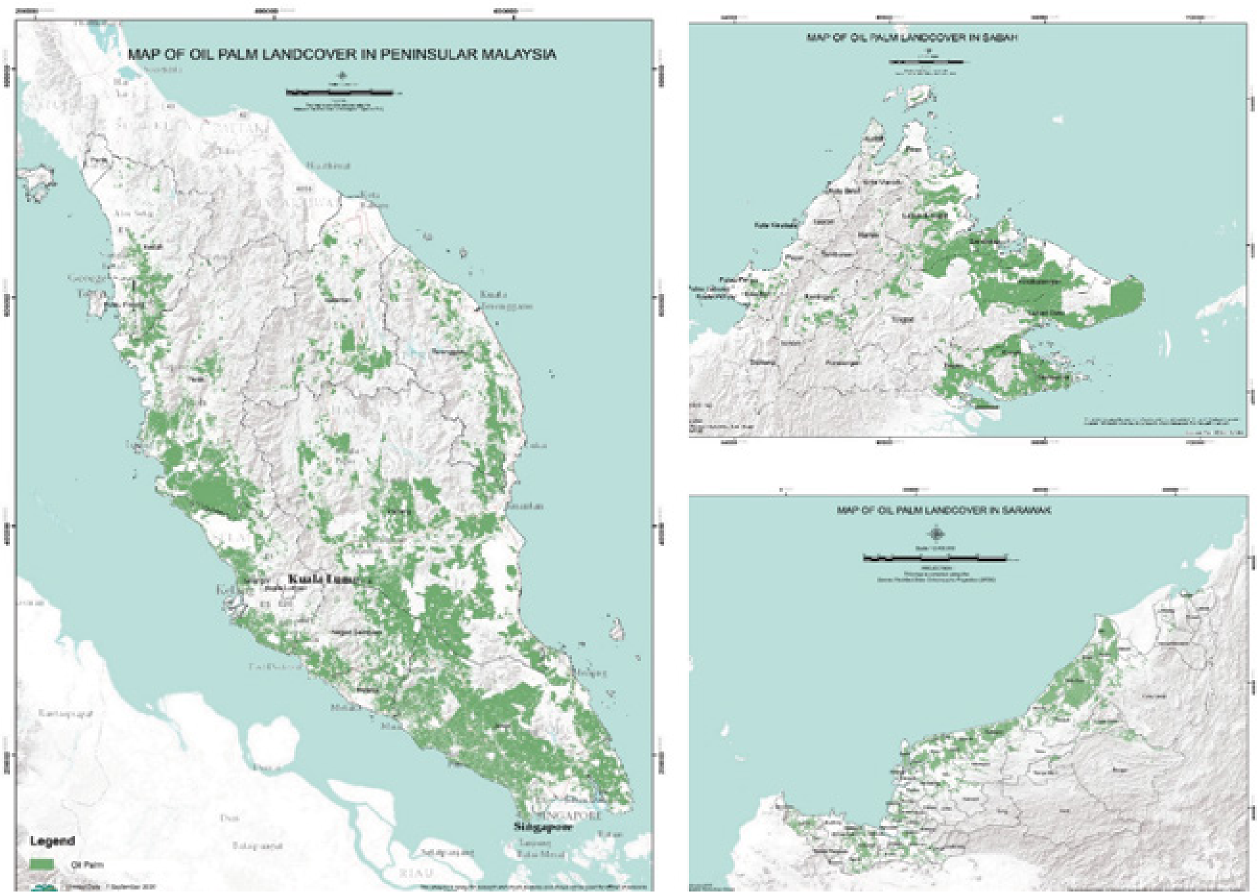

Figure 6. Oil palm landcover mapping 2019/2020.

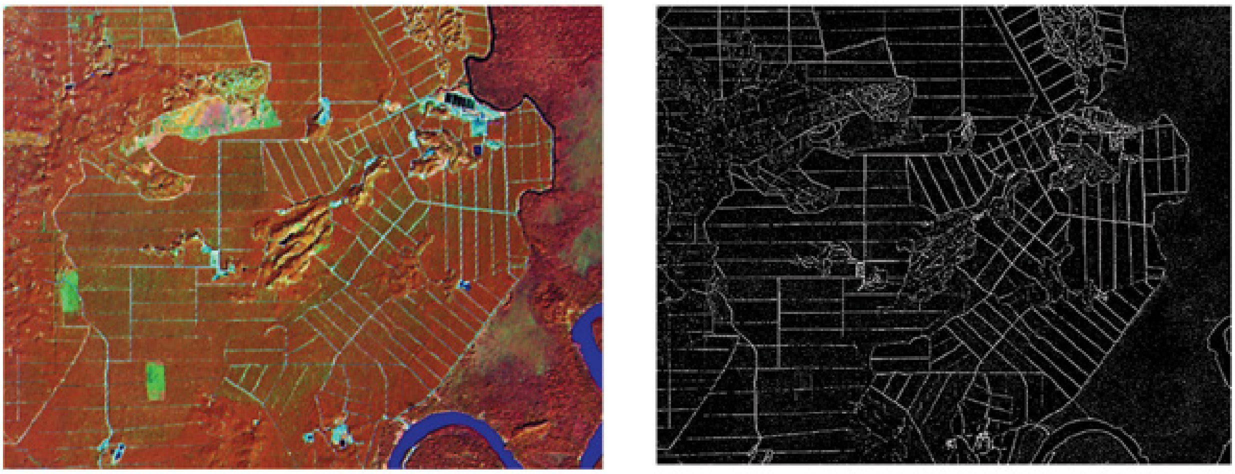

Figure 7. Linear and block extraction.

Automatic tree crown delineation from high spatial remotely sensed imagery was developed mainly for forestry applications. Extracting the information on forest inventories parameters such as tree species, crown area and tree height is required for sustainable forest management. Current field survey methods are labour intensive and costly, resulting in low sample coverage and frequency. RS provides a potentially low-cost alternative to field-based assessment. Crown delineation is the process that depends on the quality of the image, the physiognomy of the stand, the skill and experience of the interpreter. *Figure 8* shows the crown delineation to determine the actual standing palm per hectare (SPH) for plantation block management in the MPOB research station. SPH helps in determining the yield performance in each block (Nordiana, 2018).

Pest and Diseases

Oil palm pest and disease (P&D) detection at the early stages is very important to reduce the impact on crop health and yield production. Early and advanced detection is appropriate for crop care and immediate treatment. A conventional method of detecting the disease depends on human knowledge with the supporting device tested in the laboratory while an innovative method uses image processing methods. However, real-time data collection is critical during pest outbreaks and disease detection. Therefore, collected data need to be mapped and spatially monitored from time to time for early mitigation (*Figure 9*).

Data Acquisition for Agronomy Recommendation

Application dashboard for project monitoring on data acquisition for agronomy recommendation to smallholders under the establishment of the Oil Palm Agronomy Centre (OPAC) has been developed. OPAC is located in three MPOB Research Stations in Hulu Paka, Lahad Datu and Kluang. In this dashboard, field assessment on agronomy practices together with foliar and soil sampling are collected from smallholders in the SPOC region using a mobile application. The mobile application is integrated into the OPRIS and monitored thoroughly. Samples of foliar and soil will be processed and analysed in the OPAC laboratory to identify the nutrient content. Agronomy recommendations for each smallholder's plot are prepared to improve the current practice for yield increment.

Mapping the Progress of Malaysian Sustainable Palm Oil (MSPO) Based on Sustainable Oil Palm Cluster (SPOC)

In collaboration with the Sustainability Conservation and Certification Unit (SCCU), Smallholder Development Research Division (SDRD), OPRIS database was used to prepare the map of smallholders for 162 Sustainable Palm Oil Cluster (SPOC) in Peninsular Malaysia, Sabah and Sarawak. As stages of MSPO auditing are monitored based on SPOC, the progress of the auditing process was indicated using maps. Maps were prepared every month or from time to time as needed for official reporting.

RESULTS

Maps in the Cloud: Web Maps and Web Apps

Web map indicated information on the specific map function and its attributes whereas web apps compiled all spatial data layers into one application. The web apps could be integrated into a mobile application. Oil palm landcover, soil reconnaissance, agroclimatic and site yield potential for Peninsular Malaysia, Sabah and Sarawak have been published and launched in the Transfer of Technology Seminar in 2018. *Figures 12* to *16* indicated some of the web maps. Other than web maps and web apps, mobile

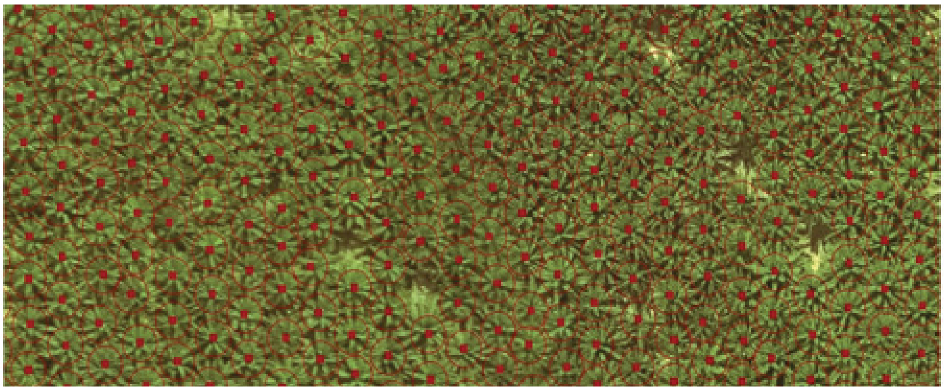

Figure 8. Tree crown delineation for standing palm per hectare (SPH) determination.

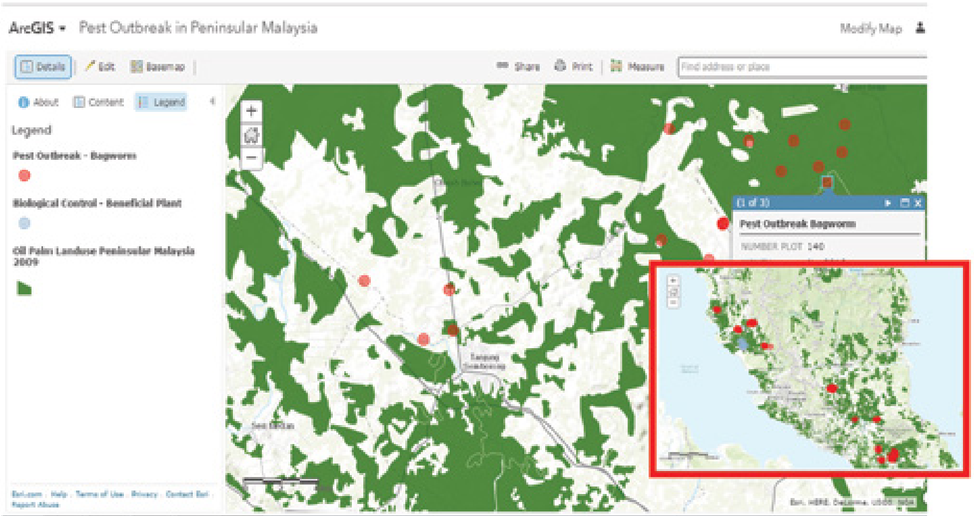

Figure 9. Pest outbreak mapping.

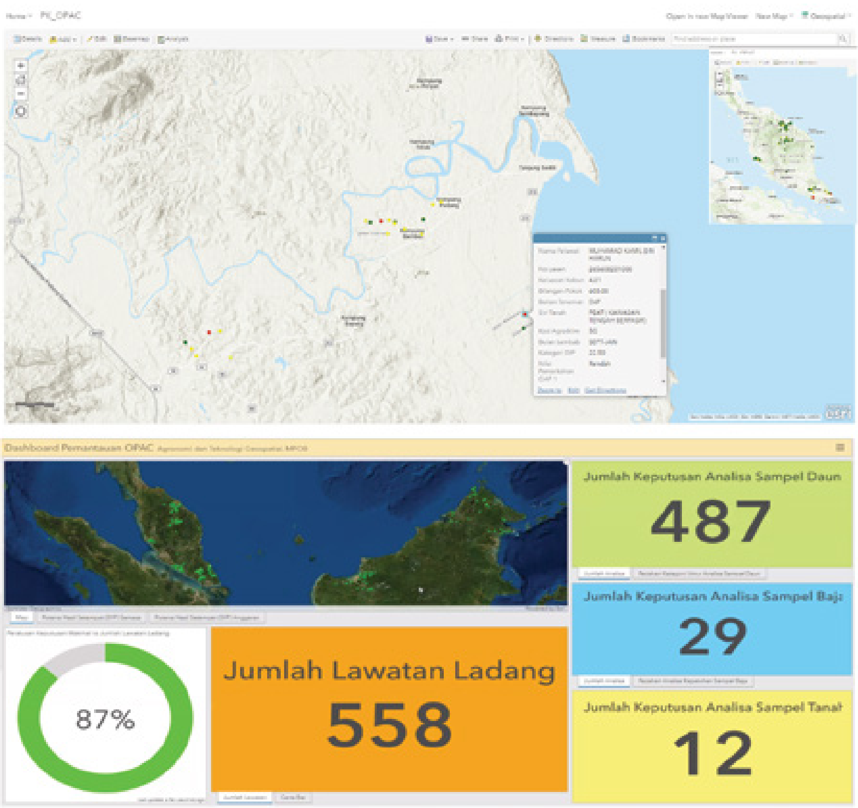

Figure 10. Dashboard application for oil palm agronomy recommendation.

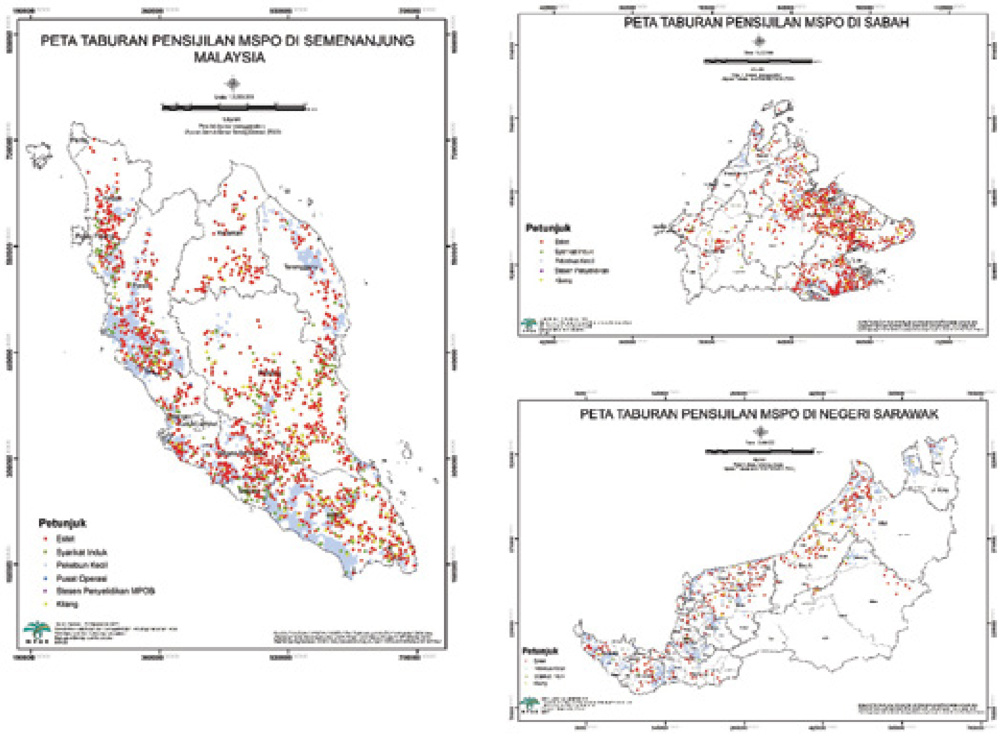

Figure 11. Distribution of Malaysian Sustainable Palm Oil (MSPO) certification.

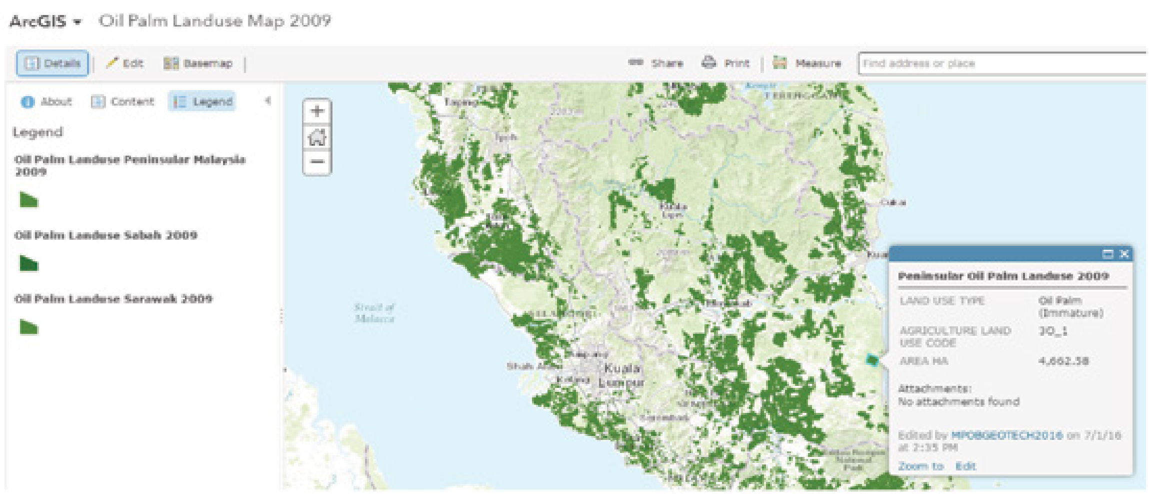

Figure 12. Web map of oil palm landcover 2009/2010.

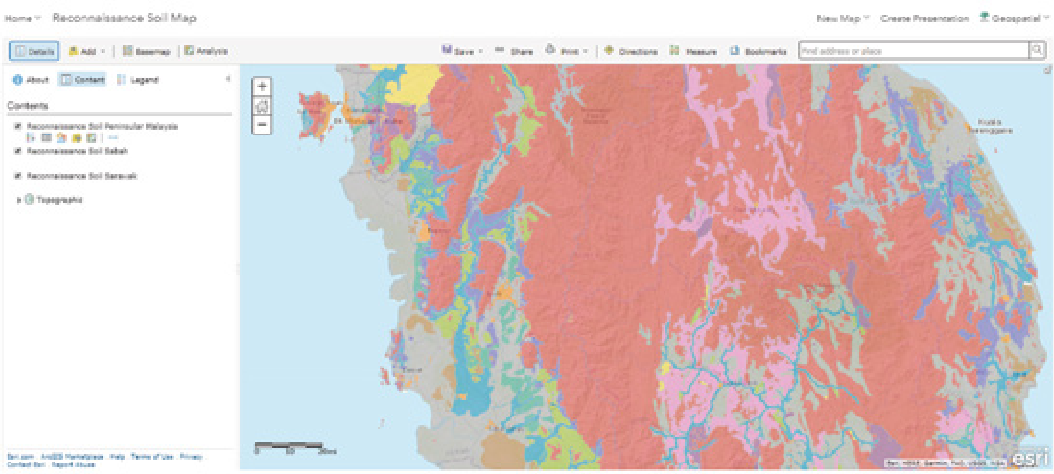

Figure 13. Web map of soil reconnaissance map of Peninsular Malaysia.

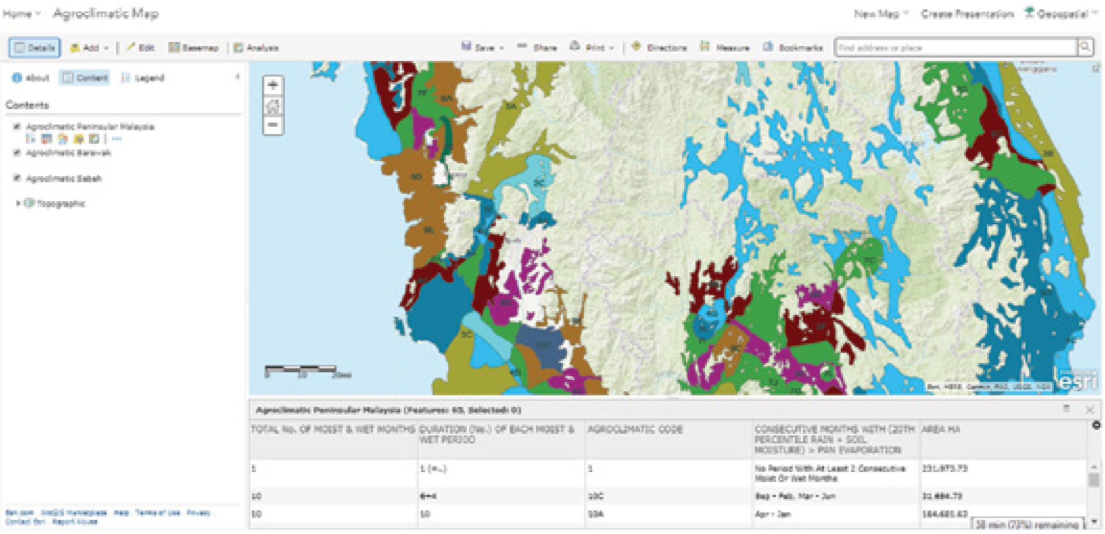

Figure 14. Web map of agroclimatic map of Peninsular Malaysia.

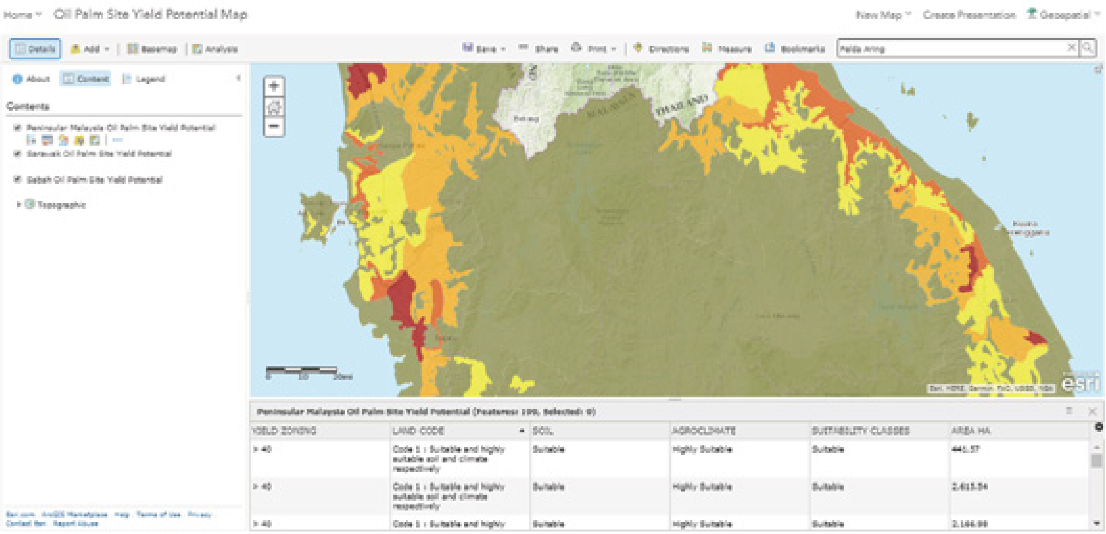

Figure 15. Web map of site yield potential map of Peninsular Malaysia.

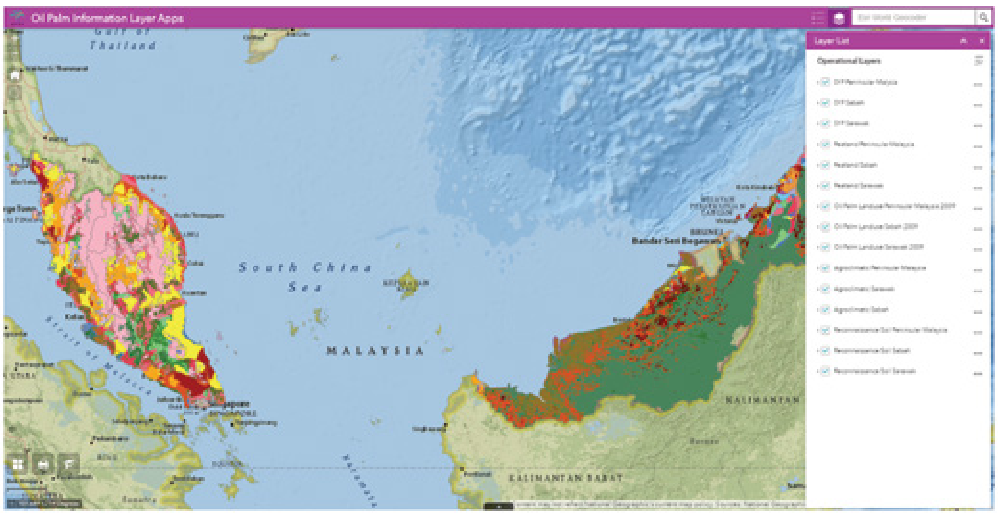

Figure 16. Web application of OPRIS.

applications could be developed and included as part of OPRIS.

Data Sharing

Some of the OPRIS data were shared with the Malaysia Geospatial Online Services (MyGOS), which allows them to make decisions quickly and correctly. Applying GIS sharing as a strategic partnership across government agencies, maximises synergies among the agencies.

CONCLUSION

The establishment of OPRIS has benefitted the industry by providing a better understanding of geospatial data organisation, improved data gathering, time management and precise analysis of spatial data interpolation. OPRIS has served as a geospatial reference platform for the oil palm industry, providing fast and reliable information. It has support better understanding and management of digital location-based data integrated with agronomic services such as census data, foliar and soil sampling along with other supporting data to enable more efficient resource allocation for GAP among smallholders and plantations. Increased use of mobile technology and applications, and handheld smartphones have democratised mapping, moving the geospatial technology experience into the hands of every individual. It is possible to prevent redundancy efforts by establishing a new geospatial platform as a reference. New data can be added periodically to enhance the capacity and applications. Enhancement of the OPRIS through server management and portal application will promote more data and application development for more users and accessibility. Therefore, to support the enhancement of OPRIS, capacity building on human development, infrastructure, policies, legal framework and institutional coordination mechanisms is crucial to accelerate the transformation and adoption of the technology. Meanwhile, training and exposure to new emerging technology segments *i.e.*, big data, data analytics, Internet of Things (IoT) and artificial intelligence (A.I) will enhance the current technology applications in oil palm management.

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REFERENCES

Parveez, A G K; Azmil Haizam, A T; Shamala, S; Loh, S K; Meilina, O A; Kosheela Devi, P P; Kamalrudin, M S; Sheilyza, M I and Zainab, I (2021). Oil palm economic performance in Malaysia and R&D progress in 2020. *J. Oil Palm Res., 33(2)*: 181-214. DOI: 10.21894/jopr.2021.0026.

ESRI (2018). https://www.esri.com/news/arcnews/summer11articles/why-use-cloud-infrastructure-for-arcgis.html., accessed on 8 October 2020.

Nordiana, A A; Wahid, O and Tarmizi, A M (2008). MPOB Geospatial products and mapping services for oil palm plantation management. *MPOB Information Series, 448.*

Nordiana, A A (2018). Oil palm resource information system (OPRIS Project BD-CIT01 (98), 868/ 2018(13).

Nordiana, A A; Wahid, O; Zulkifli, H; Hasnol, O; Rohani, K; Faizurol, H J; Noor Haliza, J and Khadijah, A (2018). Web mapping and web application of Oil Palm Resource Information System (OPRIS). *MPOB Information Series, 801.*

Wahid, O; Nordiana, A A; Tarmizi, A M; Haniff, M H and Kushairi, A (2010). Mapping of oil palm cultivation on peatland in Malaysia. *MPOB Information Series, 473*.