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RESEARCH

An Approach for Common Web GIS Platform for Agriculture Sector Modernization in Sri Lanka

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ABSTRACT

The status of innovative technology adoption in the Sri Lankan agriculture sector is significantly low. A detailed study conducted by the Department of Agriculture, Sri Lanka and TRCSL, with the assistance of FAO – UN, clearly identified the need for a common platform to manage all stakeholders in an integrated single platform. There have been some attempts by the private and government sectors to overcome the identified gap, but these have yet to produce results. This research identified the technology and services gaps and introduced a Cloud-based Microservice Architecture-based Geographical Information Management Platform, "AgriMIS", to manage the country's entire agricultural sector in a single platform. The AgriMIS platform was developed so that preloaded spatial layers such as administration boundaries, census data, land use data, disaster data, and many more are preloaded and available to the public. Privately owned data such as farmer, farm, land use, fertilizer usage, crops and other relevant details are hosted privately on the same cloud with multitenant access where only that particular data owner can access the data, and this allows the users to access public data hosted on the cloud and conduct a significant number of spatial and nonspatial analyses with the given user interfaces. Also, the platform allows users to connect their existing decision support systems through APIs to the AgriMIS platform. The platform has been assessed and proved to be successful.

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INTRODUCTION

Sri Lanka's agriculture sector is vital to the country's economic development, with an over 8.3% GDP contribution by 2020 (CBSL, 2024). Sri Lankan agricultural produce comprises rice, fruit, vegetables, and livestock primarily for domestic consumption and export-focused products such as tea, rubber, spices, and coconut. While Sri Lanka is moving towards an urbanized manufacturing and services economy, the rural agriculture industries are the sources of income for more than 5,4 million Sri Lankans (CBSL, 2024).

The current status of new technology adoption in the Sri Lankan agriculture sector is limited, not only among the farmers but also among the agribusinesses (CBSL, 2024). Supporting, Information Communication Technology (ICT) for productivity improvements in the agriculture sector, several e-agriculture programs such as interactive ICT and mobile platforms and software applications have already been developed to disseminate agriculture information (CBSL, 2024). A few e-agriculture services such as the Govimithuru by Dialog, “AgroBizz” by Celata Tech, “Helawiru” by Epic Lanka and “Geogoviya” by Agrarian Services Department are some of the mobile-based services platforms for farmers and stakeholders providing services such as market linkages, adversary services, improving price awareness and matching supply and demand to give easy access to markets are currently in operation in Sri Lanka (ICTA Sri Lanka, 2021). The proposed Agriculture Information Management System, an initiative by the Ministry of Agriculture to implement a standard Agriculture Information System for the country, is still in the implementation stage and collecting data (Ministry of Agriculture , 2024).

Effective and efficient exchange of knowledge and statistics in agriculture is crucial for intelligent farming. Farmers and related stakeholders require the latest information on the most effective planting practices, best market prices, available credit supply, soil conditions, nutrients, and plant protection (Lee & Choudhary, 2017). Most countries depend on earth observation and space technologies. However, those technologies have significant limitations, such as licensing cost, development cost, technical know-how, computer processing speed, and updating and processing data. Stakeholders like farmers, distributors, equipment and fertilizer suppliers, government authorities, retailers, exporters and large-scale supermarket chains are in search of information for more accurate and efficient ways to monitor what is happening on the ground (Granell C. , et al., 2017).

During the last few decades, GIS (Geographical Information Systems) has played a significant role in agriculture sector development in developed countries, especially in land suitability analysis, crop monitoring, reducing post-harvest damages, managing irrigation and water sources, location-based supply chain management, soil management (Yousefi & Razdari, 2014); (Prasad R. , 2019). GIS has taken precision agriculture to a new level with its unlimited capabilities (Sharma, Kamble, & Gunasekaran, 2018). Today, accessing spatial data has become an essential part of intelligent agriculture. Government agencies such as the U.S. Department of Agriculture (USDA), the Government of India, and the European Union host Websites that deliver valuable information to help farmers better understand their land and make more informed decisions. Most government agencies and private sector stakeholders could make intelligent decisions by using updated maps and relevant attributes (Pani, Chakrabarty, & Bhadury, 2014). In the rapidly evolving landscape of Sri Lanka, administrators, decision makers, and resource managers face significant challenges in accessing timely, updated information on citizens, households, land, and utilities. This information, crucial for informed decision-making, is scattered across various formats and spatial scales, demanding considerable effort to analyse and visualise. The reliance on outdated topographic maps, financial constraints, and limited access to recent satellite imagery further exacerbate the situation, hindering the efficient planning and implementation of development of the country. Despite some efforts by the government and international non-governmental organizations (INGOs) to harness new technologies for data collection, the absence of a unified platform for spatial and non-spatial data, including up-to-date citizen, agriculture and land information, poses a substantial obstacle. The implications of these challenges on Sri Lanka's development and explores potential solutions, emphasizing the need for a national platform that integrates Geographic Information Systems with conventional technologies to streamline data analysis and enhance decision-making processes (De Silva, De Silva, & Dayawansa, 2019). A Geo-Citizen Information System, working alongside the National Spatial Data Infrastructure (NSDI), would provide a robust framework for this integration. By overcoming the limitations of current systems through a centralized, accessible, and continuously updated data platform, Sri Lanka could greatly enhance its ability to address various societal and environmental challenges along with productivity enhancement in the Agriculture sector.

Mobile technology and Internet-based deployments are increasingly being introduced into precision agriculture to gather accurate data with high spatiotemporal complexity (Ye, Chen, Liu, & Fang, 2013); (Liopa-Tsakalidi, et al., 2013); (Acharya, Pawar, & Wable, 2018). Recently, geospatial technology with the integration of cloud computing, advanced mobile technologies, and IoT devices such as GPS and GSM enable measuring and monitoring sensors (temperature, PH, moisture) and has produced a new breed of spatial applications featuring real-time processing of large and varied data sources, integrated workflows, and highly interactive map-based interfaces (Knörchen, Ketzler, & Schneider, 2015). Hosting and managing Geospatial data are limited based on the system architecture, management of spatial data, hosting infrastructure and frequent updating of development languages and technologies. The introduction of Microservices architecture in software development and data management has proven that introducing microservice architecture as the software architecture will allow users to update, manage, host and maintain software systems or platforms without frequent updates on the primary source codes and main database. It allows the developers to update and upgrade the system without disrupting the main functions and operations. It has significantly impacted the Geospatial industry, with most of the software development following the Microservices architecture for Spatial and Nonspatial application development in the industry (Krämer, 2018). It takes the form of a one-stop geoportal to give access to data and information and thematic maps derived from the cropland data layers, which are layers of crop-specific land cover classification product from the US Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) (US State Department - NASS, 2019). Similarly, *CropWatch,* China's global crop monitoring portal, uses remote sensing data combined with field data to determine key crop production indicators and to produce thematic maps at the regional scale (CropWatch, 2019). Conversely, applying management-oriented models for monitoring crop conditions and forecasting yields has been an integral part of agricultural monitoring systems for decision-making processes (Wu, et al., 2014).

Sri Lanka's agriculture sector is governed by the Agriculture Ministry, but the most significant contribution to the sector is from large, medium, and small-scale private sector farms and farmers. It has been identified that the Sri Lankan agricultural sector requires a common platform to manage the country's farmers, farms, and harvest, along with other key factors like fertilizer, seeds, plants, and pesticides (Nissanka, 2021). The creation of such a platform is essential for leveraging the full potential of spatial and non-spatial data in national agriculture development strategies, ensuring that resources are allocated efficiently and that governmental and non-governmental entities can collaborate more effectively. This, in turn, would lead to a more resilient and prosperous Sri Lanka.

A detailed study conducted by the Department of Agriculture and Sri Lanka Telecommunication Regulatory Commission with the support of most of the agriculture-related government institutions, development banks, and agriculture-based large-scale businesses in Sri Lanka laid down a road map "Sri Lanka E-Agriculture Strategy" in the year 2016 (Department of Agriculture, SLTRC, 2016). The said strategy was developed following the framework prepared by the Food and Agriculture Organization (FAO) (Food and Agriculture Organization of the United Nations, 2016). The study identified the need for a common platform to manage entire agriculture stakeholders. The study also emphasizes integrating all the stakeholders in a single platform using common communication protocols, and a geographically enabled integrated IoT platform has been highlighted to enable online trading through farmer to buyer, eliminating man in the middle (Department of Agriculture, SLTRC, 2016). Technical Assistance to the Modernization of Agriculture Programme, Sri Lanka (TAMAP) under EU Sri Lanka Rural Development Cooperation also highlighted the importance of an internet-based value chain and supply chain management platform enabling farmers to directly link with buyers. These studies emphasize having a geographical-based crops and farm management system for decision-making, enhancing productivity and harvest (Kamiss, 2019); (Ranawaka, 2019).

This research focused on creating a cutting-edge, open-source agricultural information system that consolidates both spatial and non-spatial data concerning Sri Lanka's agricultural sector with citizen demographics, including population and census figures. By centralizing agricultural spatial data and integrating it with non-spatial datasets, such as statistics and other relevant information, this platform aims to serve governmental and non-governmental organizations. It facilitates the management of various agricultural components, including farmers, farms, crops, fertilizers, pesticides, seeds, retailers, and the overall value chain.

METHODOLOGY

The initial step in the creation of the platform involved a rigorous evaluation of existing models in the market and current industry practices. This led to a gap analysis, depicted in Figure 1. Drawing from this analysis and insights from international best practices, as introduced earlier, a conceptual model for Agricultural-based value chain management was developed. This model integrates essential modules of the agriculture sector into a unified platform. For the development of this platform, a cloud-based microservice architecture was chosen due to its adaptability, effectiveness, and strategic value (Sauerwalt, 2018). An "all in one" cloud server was preferred, enabling the operation of LAMP servers (Linux, Apache, MySQL, and PHP) on a singular server that houses both web and application/database servers, fitting any cloud environment and supporting a multitenant marketplace. This design accommodates the platform's use by multiple users, each maintaining separate databases (FLEXERA, 2017). Considering the preference of agricultural institutions and organizations for private data handling and their hesitance to share information publicly, a specialized solution was proposed. This involves hosting each entity's private agricultural data in distinct non-spatial databases, with data access restricted to the data owners through the platform, as illustrated in Figure 2. This figure outlines the master context diagram for the AgriMIS deployment.

This deployment assists different organizations in hosting their data on a separate database instance provided by the cloud service provider, which will ensure personal data protection according to the Personal Data Protection Act, No 9 of 2022, gazette by the parliament of the Democratic Socialist Republic of Sri Lanka (Gazette of the Democratic Socialist Republic of Sri Lanka, 2022). Also, the microservice architecture enables distributed, independent maintenance and independent deployment of the applications on the cloud architecture (Söylemez Mehmet., 2022). While the platform is hosted on different cloud environments, Figure 3 shows how different users and data sources are hosted and managed on the cloud without disrupting services and compromising users and their organizational data. User Services and Data Management have been defined as four different critical services on the server engine: user management services, user messaging services, authentication services, and customer data services. All these services are connected via the service registry to provide different services to the interface, extracting spatial and non-spatial data from different Databases when and where needed. Figure 4 depicts the mechanism of how different Geospatial services have been handled by the platform through the Geospatial Service Registry. The Geospatial Service Registry provides four different services to the users by separately handling Public Data Management Services, Geo-Coding Services, Geospatial Calculation Services and Realtime Communication Services. These services allow the user to host their data separately and use commonly available spatial and nonspatial data on the platform when and where needed. This technology allows the platform to balance the load while providing faster services in a highly secure environment.

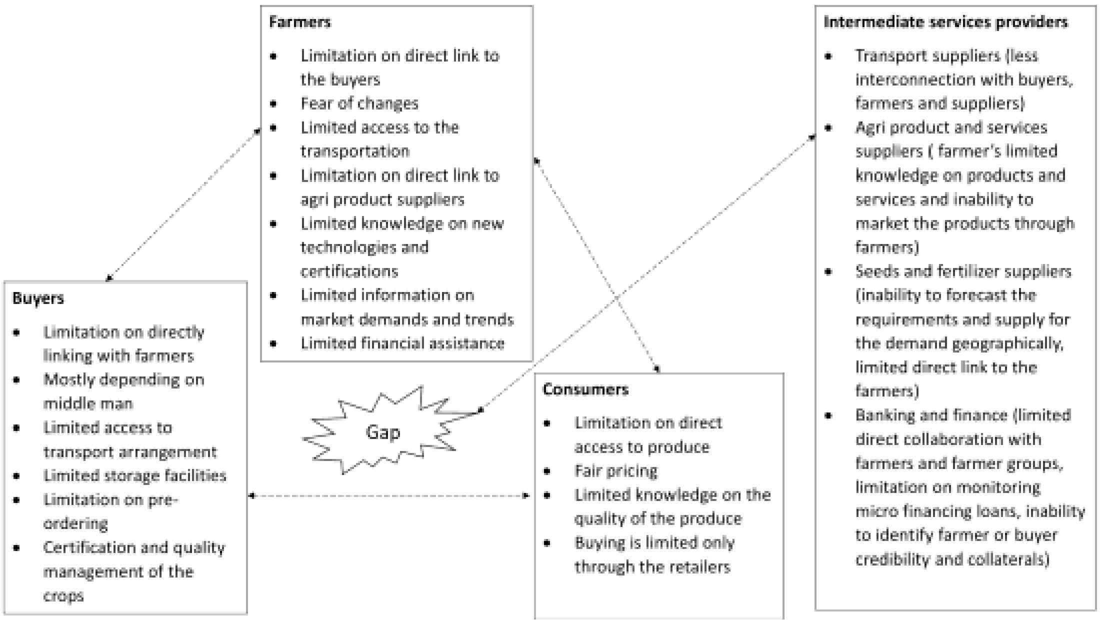

Figure 1: Gap analysis on the current agriculture value chain management.

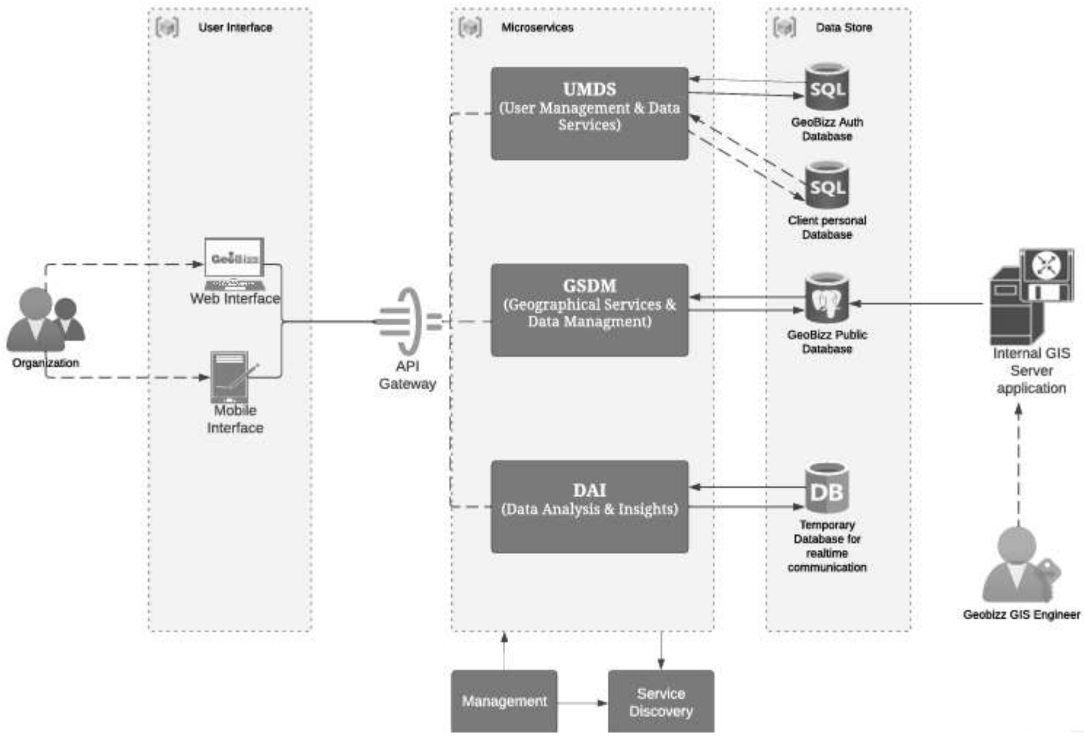

Figure 2: Master Context Diagram for the Microservices Architecture of the AgriMIS.

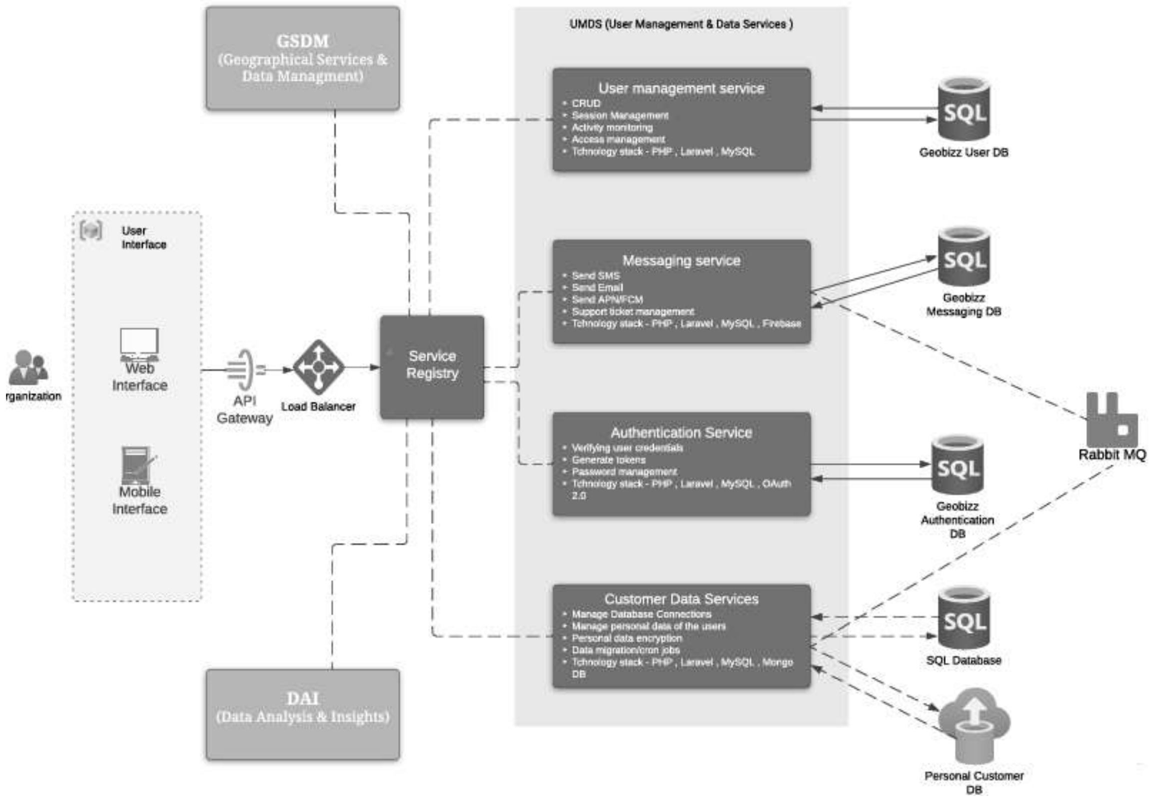

Figure 3: Multiple Database Services with Multitenant User Management Context Diagram.

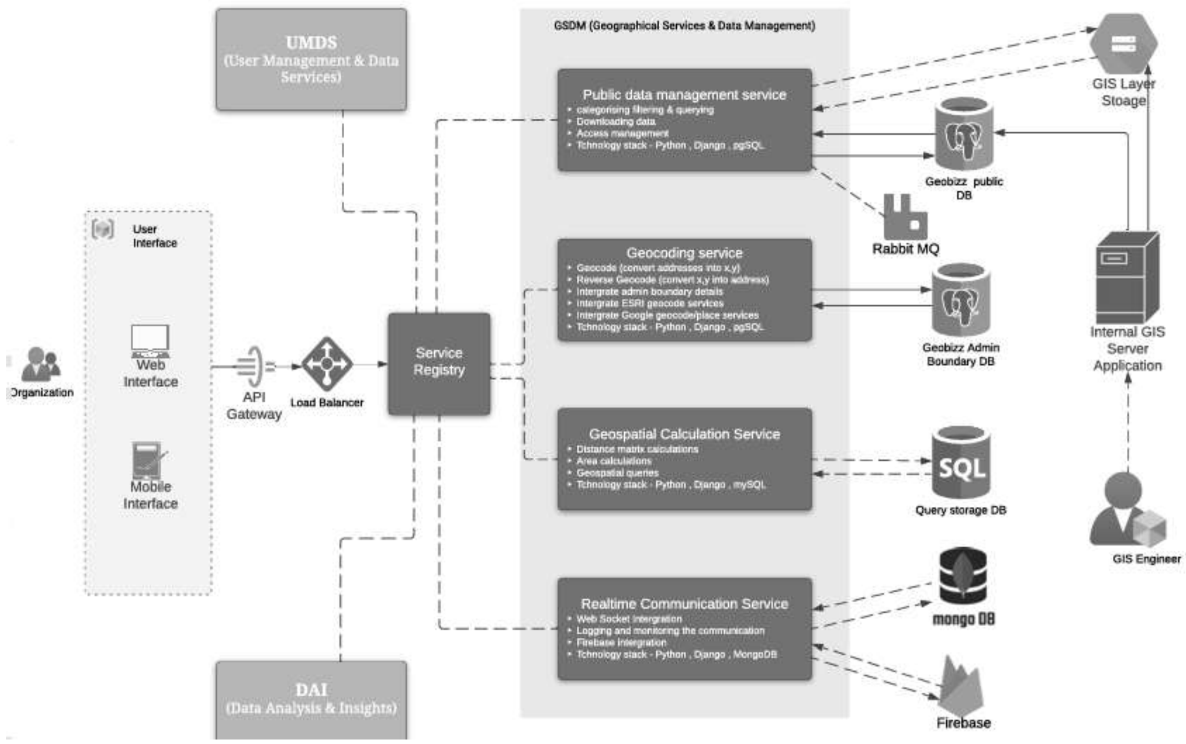

Figure 4: Geographical Services and Data Management Context Diagram.

Technologies used for AgriMIS platform development

The platform was developed according to ISO 19115 for metadata (International Standard Organization, 2014) and OGC standards for geospatial data exchange (Open Geospatial Consortium, 2023)et al., 2023). It was also developed according to the OWASP 10 and CIS 20 international security standards to maintain its security and integrity.

Platform development was conducted based on given technologies; WebGIS platform development (Golang, Jscript, GeoJSON, Python), Database (MongoDB), Framework (Laravel, React Native) and AES-256-CBC Cipher encryption with two factor authentication.

Database Development

The database was developed using MongoDB DBMS (Database et al.) and SQL services. The AgriMIS platform has two central pre-defined databases for spatial data and nonspatial attributes related to spatial data for standard agriculture-based information (publicly available data) and a personalized DB for each organization is presented in Figure 3, where customized attribute data belonging to each organization and institute is interconnected with spatial data on the spatial DB, which will host vector and raster data (De Silva, De Silva, & Dayawansa, 2019).

Hosting Environment

After development was completed, the platform was hosted on Google Cloud Platform (GCP) and potential privately owned data on Azure Cloud to test in a hybrid hosting environment. The reason for having a hybrid hosting model was to test the platform's interoperability and scalability of cross-platform data sharing (Sandesh, 2021). Table 1 shows the configuration of the hosting environment.

Table 1: Hybrid hosting configuration using GCP and Azure.

ID	Description	Minimum Configuration
A	Azure DNS	Zones x 2 The number of queries depends on the expected inbound traffic
B	Azure Application Gateway	HTTP(S) load balancing SSL termination Autoscaling Web Application Firewall V2
C, D	Azure Virtual Machine (Core Application)	vCPU x 4 16GB Memory 32GiB Managed disk Ubuntu OS
E	Google Compute Engine Instance (Spatial Data API)	vCPU x 2 8GB Memory 10GiB Persistent disk Core Debian OS
F	Google Cloud SQL (Spatial Data)	vCPU x 2 7.5 GiB RAM High Availability enabled 20GiB SSD
G	Azure Database for MySQL (Core DB)	vCore x 2 Locally Redundant Storage General Purpose 10GB Storage
H	Azure Storage Account	30GB General purpose V2 Blob Storage
I	Google API Services	Depends on the number of requests to APIs

RESULTS AND DISCUSSION

Proof of Concept

The platform underwent testing using the qualitative method instead of the quantitative method. The choice of the qualitative method was driven by the research's objective to explore the "Why" and "How," concentrating on experiences to comprehend motivations and reasons, rather than focusing on the "What" and "How Often," which is typical of the Quantitative approach (Oranga & Matere, 2023).

AgriMIS platform

The AgriMIS platform consists of 2 interrelated and integrated modules: 1. a WebGIS platform to manage agriculture-related spatial and nonspatial data and private data of each organization or institute, spatial and statistical analysis, including report generation; and 2. a customizable native Android-based mobile application to collect field data, sending and receiving data to and from through REST APIs.

Information and data available on the platform

On the platform, Google Maps were used as the base map and spatial data on 10K topographic maps of Sri Lanka were also integrated into the platform. Also, the platform has been enriched with a significant amount of spatial information in layers, as depicted in Table 2. All the spatial information hosted on the platform is in the GeoJSON format. Reasons for selecting GeoJSON instead of KML files were that GeoJSON is much more flexible, easy to handle, low capacity and JavaScript manipulation is much easier, has low weightage and is easy to download on a base map (Li, Hu, Zhu, Li, & Zhang, 2017); (Gelernter & Maheshwari, 2019).

The AgriMIS platform is the only public domain platform available in Sri Lanka with preloaded spatial layers, administration boundaries, census data, and household data integrated into a single platform. The platform provides unique services to users compared to similar solutions available in the region, including Sri Lanka.

Mobile Application

As shown in Figure 5, an Android-based mobile application was developed to fulfil the requirements of agriculture research and development officers (ARDO) / Field agents, Farmers, Collectors / Buyers, Retail shops, Food processors and Transport suppliers. Using the mobile app, farmers and farms can register with farm details, including the farm's location, crops, land extent and location, expected harvest and date, fertilizer used, and fertilizer requirement, as shown in Figure 5.

The developed mobile app is a “Native” app (Al-ratrout, Tarawneh, Altarawneh, & Yousef, 2019), where data can be collected from the most rural areas without GSM coverage and stored on the internal database. When GSM coverage is received, temporarily stored data are automatically synchronized into the WebGIS platform.

AgriMIS Web-GIS desktop application

The AgriMIS platform is a browser-independent WebGIS application. Once farmers and farms are registered through the mobile app, the platform automatically categorizes them into relevant clusters as required and defined by the users. For example, users can define farmer layers by crop type, company, authority, water usage, fertilizer usage, and administration boundaries, with unlimited options, as in Figure 6.

The POC was conducted with the assistance of the Climate Smart Irrigated Agriculture Project, a World Bank-funded project under the Ministry of Agriculture, www.csiap.lk. Selected districts – Anuradhapura, Kurunegala and Hambantota; farmer group – organic farmers; financial institution – Bank of Ceylon; filed agents – CSIAP; administration boundary level – GND; disaster data – flood data. The platform also provided preloaded census data up to the GND level, as in Figure 6. Through the mobile application developed, CSIAP field staff members entered farmer and farm details along with crop type, fertilizer usage, pesticide usage, expected harvest, financial institute from which the grant was disbursed, and nearest tank from which the farm derives water.

As shown in Figure 6, captured data through the mobile app are being categorized into different layers on top of the GND boundaries. The platform allowed the CSIAP and World Bank to identify the farmer spread across each GND, production based on the geographical area with crop type, expected harvest, quantity, quality and expected pricing precisely covering the Anuradhapura District. To be more précised, the micro

Table 2: Spatial data preloaded in the platform.

Points	Lines	Polygon
Bank and ATM	**Roads**	**Landslide**
All the banks and own ATMs in the		**Flood**
country, bank-wise	**Railway lines**	**Wind**
Education		**Drought**
All the schools and class		**Soil**
Finance -institutions		**Forest**
Food and Beverages		**Plantation**
Fuel Stations		**Paddy**
Government -institutions		**River -basins**
Health		**Tanks**
All the hospitals and pharmacies		**Wildlife**
Insurance companies		**Tea -plantations**
National parks		**Rubber -plantations**
Public places		**Coconut -plantations**
Supermarkets		**District - Boundaries**
Fruit and veg -shops		**DSD -boundaries**
Agriculture -product shops		**GND -boundaries**
Urban centres		

Figure 5: All-in-one mobile application with offline facility.

Figure 6: Registered farmers with different crop types depicted on the base map at the GND administration boundaries with GND level census data.

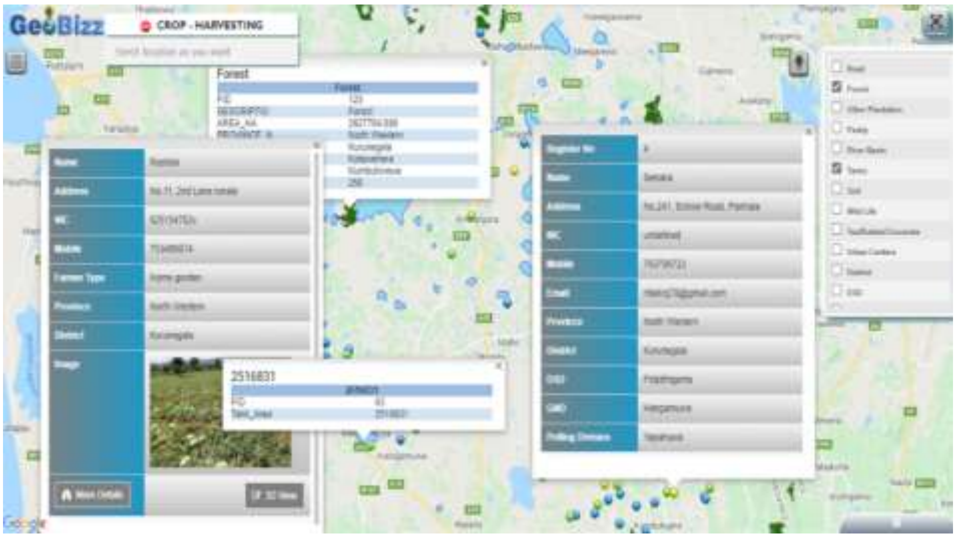

Figure 7: Farmer details depicted on the map with available tanks in Kurunegala district.

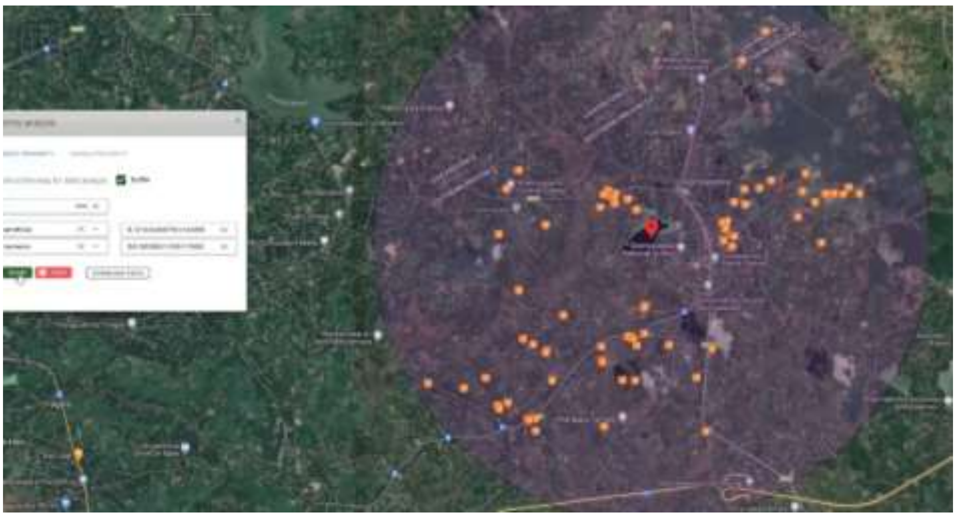

Figure 8: A proximity analysis against a particular tank and farmers who are benefiting from the tank.

As in Figure 8, the platform allows users to overlay the farmer layer with the preloaded tank layer and identify how many farmers benefit from a particular tank within a given proximity. This will enable decision-makers to determine whether that particular tank's capacity and volume need to be expanded to accommodate the water needed for cultivation.

Analytical functions of the platform

The platform can conduct a considerable amount of analysis such as suitability analysis, behaviour analysis, statistical analysis, hotspot analysis, proximity analysis, elevation analysis, route analysis and traffic analysis. Apart from the above, mathematical forecasting modelling (for queries) is enabled with the platform for users to define equations as they wish (user can make their models). Based on the farmer, farm and crop details, the platform can predict the fertilizer requirement up to the GND level (including up to the farm level) as in Figure 9, so that the authorities can identify the exact fertilizer requirement up to GND level and arrange the purchasing and distribution more accurately. The platform calculates the number of farmers (registered), cultivated area, crop type, and fertilizer requirement (predefined) for unit land, with a simple calculation platform providing the forecasted fertilizer requirement for the selected administration area. Since the farmer details, crop details and extent of cultivation are recorded through the mobile app, predictions and forecasting were significantly accurate for the decision-makers.

Supporting Tools for Users

The platform provides a live weather monitoring facility through www.accuweather.com on the WebGIS platform and on the mobile application so that the field officers and farmers will get an insight into the forecasted weather and plan the crop planting, fertilizing, and harvesting accordingly. The platform has been equipped with a precision messaging system to warn and educate farmers nationwide on disasters, including adverse weather, pest attacks, diseases, and new technologies, seeds, and remedies. Also, the platform allows users to select particular geographical areas and send messages

Statistical analysis tools were developed on top of the platform to have Decision Support Systems, and the platform also facilitated the CSIAP project team to integrate their own DSS system through APIs and create dashboards and reports on the project, as in Figure 10.

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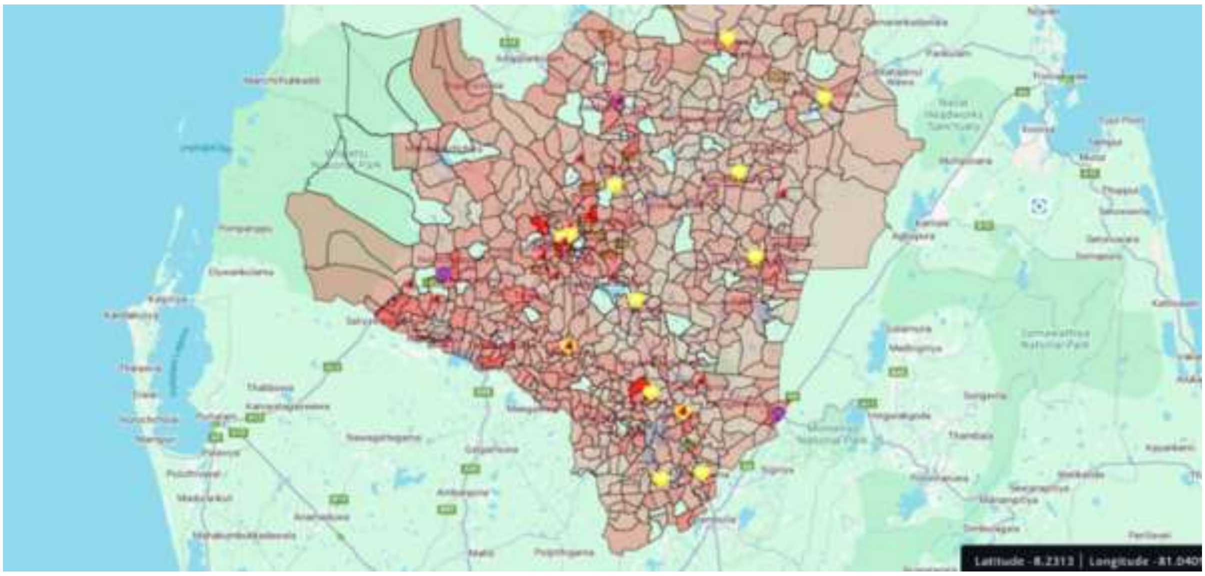

Figure 9: A suitability analysis was conducted on fertilizer requirements against the farmer population and the extent of lands overlayed with fertilizer distribution centres.

Figure 10: Decision Support System integrated with the AgriMIS platform to generate statistical reports.

Given the imperative for modernizing agriculture in countries heavily reliant on this sector, the integration of technological solutions becomes paramount. A cornerstone of such modernization efforts is the development of a common geospatial platform, exemplified by the AgriMIS initiative, aimed at transforming the agricultural landscape of agriculture-based countries like Sri Lanka. This research elucidates the multifaceted benefits of implementing a digital backbone through WebGIS platforms, mobile applications, and AgriMIS to revolutionize the agriculture sector. The central thesis of this discussion hinges on the premise that incorporating a unified geospatial platform can significantly enhance the management of spatial and non-spatial agricultural data, streamline information dissemination, and foster a more efficient marketplace for agricultural stakeholders. The AgriMIS, serving as an integrative tool, encapsulates the essence of digital transformation in agriculture, offering a blueprint for managing the sector's comprehensive data requirements, including privately owned data. Furthermore, the manuscript delves into the platform's role in decision-making processes. The provision of a robust analytical toolset enables decision-makers to conduct thorough analyses, thereby facilitating informed and educated decisions. This aspect is particularly crucial in a sector where decisions are time-sensitive and have far-reaching implications on yield, pricing, and overall market dynamics. The AgriMIS also addresses the technological and infrastructural prerequisites for the successful implementation of such a platform. It underscores the importance of accessibility, security, and affordability, ensuring that the benefits of digital transformation in agriculture are equitably distributed across all stakeholders, including smallholder farmers.

CONCLUSION

The integration of a common geospatial platform, as demonstrated by the AgriMIS initiative, presents a transformative opportunity for agriculture-based countries like Sri Lanka. By serving as the digital backbone for the agriculture sector, this platform not only streamlines the management of both spatial and non-spatial agricultural data but also revolutionizes the marketplace by eliminating intermediaries, thus fostering direct connections between farmers and buyers. This innovation paves the way for enhanced income opportunities for local transportation services and agricultural product suppliers, while also ensuring that the benefits of digital transformation in agriculture are accessible, secure, and affordable for all stakeholders, including smallholder farmers. Moreover, the AgriMIS platform empowers decision-makers with robust analytical tools, enabling them to make informed, timely, and effective decisions critical for enhancing yield, pricing, and market dynamics. The readiness of this platform underscores the urgency for decision-makers to embrace and deploy it comprehensively, to herald a new era of modernization in the agriculture sector. By doing so, countries like Sri Lanka can expect to witness a significant leap in agricultural efficiency, sustainability, and economic viability, marking a milestone in the journey towards a digitally empowered agricultural future.

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