WEB GIS DEVELOPMENT FOR DROUGHT RISK AND DAMAGE MANAGEMENT AT THE FARM LEVEL IN THAILAND

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***Abstract*:** *Drought regularly causes devastating impacts on the Thai agriculture sector, where over thirty percent of the country's population is employed. Compensation following a drought disaster by the Royal Thai Government must adhere to the rules and procedures of the Ministry of Agriculture and Cooperatives, with the key condition for payment being the verification of actual crop damage by local committees. However, with limited monetary and human resources, effective management of drought-prone areas and crop damage at the plot level is crucial for Thailand's economic development. This research aims to develop a web GIS application to support the management of drought-risk areas and assess drought-related damage at the farm level in Thailand. The application includes features such as a drought risk map, a drought situation summary, plot-level drought monitoring, and data download capabilities. Accessible through any web browser, this platform enables users to conveniently access and utilize its features from anywhere. The data is meticulously analyzed and processed using satellite imagery and artificial intelligence (AI) technologies, ensuring accuracy, reliability, and timeliness which curated and maintained by GISTDA of Thailand. The system architecture comprises a client-side user interface, webserver, map server, and database, utilizing the Leaflet JavaScript library for web mapping. Users can access the web application at https://cropsdrought.gistda.or.th. The study's findings demonstrate the web application's effectiveness in supporting decision-making and managing drought-prone areas and plot-level crop damage. Users can easily access geospatial information without requiring GIS expertise, empowering agricultural extension officers and farmers to identify drought-prone areas and make informed crop cultivation decisions. Despite the application's effectiveness, user feedback, particularly from farmers, highlights a strong demand for a mobile app. Future iterations should prioritize the development of a mobile application component to enhance usability, especially in remote areas.*

Keywords: Agriculture, Drought, Geographic Information Systems, Open source, Web Application.

1. Introduction

Currently, the severity of impacts from climate change has increasingly affected agricultural areas in the country, causing continuous damage to most farmers in the country. Due to limitations in the process of verifying crop damage from natural disasters, especially drought, in assisting affected farmers, which requires significant resources including budget, implementation time, and manpower, assistance and compensation for farmers are delayed. Farmers are unable to recover themselves in the appropriate time frame. This has led to the concept of introducing science and technology to help with operations, namely the management of drought-risk areas and crop damage at the plot level. It is necessary to have tools that help officials and farmers access technology to prepare, cope with, and adapt to reduce impacts and damage in a timely manner, enabling decisions on crop cultivation and coping with natural disasters. In the past, the use of geographic information system data in managing drought-risk areas and crop damage has not been fully efficient due to GIS programs being specialized and involving complex multi-step processes, requiring significant implementation time. Currently, displaying geographic information system data on the internet network is becoming more widespread, convenient to use, reduces analysis time, and processes through programs that require specialized expertise. It can also effectively support decision-making as users can easily access geographic information through the internet network. From these issues, this research develops a web application with a geographic information system to monitor drought situations and crop damage on a weekly basis as a tool to support decision-making and water management for government agencies and a decision-making tool for farmers' cultivation to appropriately cope with natural disasters and reduce potential damage to cultivation areas.

2. Literature Review

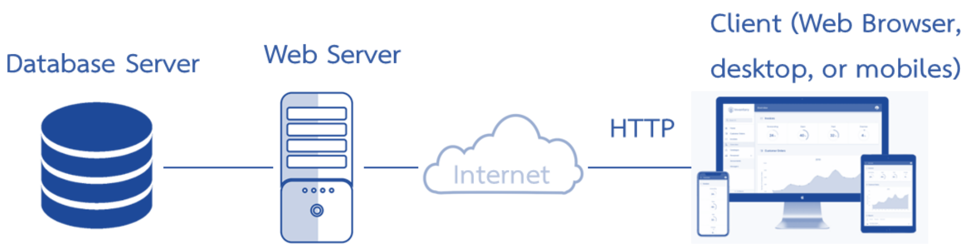
2.1 Web-based Geographic Information Systems (Web-based GIS)

The development of a web application with a geographic information system as a tool to support decision-making and management of drought-risk areas and plot-level crop damage in Thailand has studied concepts, theories, documents, and research related to Web-based GIS.

Web-based GIS refers to geographic information systems that provide services via the internet, including web-based geographic information systems. However, since the World Wide Web (WWW), which is used through web browsers, is widely used on the internet, web-based geographic information systems are therefore the most widespread form of internet-based geographic information systems.

The architecture of web-based geographic information systems in this research consists of at least 2 parts: the client part and the web server part. The client and server parts communicate via HTTP, which is the main protocol used for communication between them. The client uses HTTP to send requests to the server, and the server processes and sends results back to the client via HTTP as well.

Currently, web-based GIS and desktop GIS are increasingly related. Web-based GIS relies on desktop GIS to create data sources, and desktop GIS has expanded its functions to support the use of web-based data sources. For example, ArcGIS Desktop users can use web-based base maps from providers like USGS or Microsoft Bing Maps without having to copy the data to their own computers.



Source: Fu P. and Sun J. (2011)

Figure 1: Simple architecture of web-based GIS system components consisting of 3 parts

2.2 Definitions Related to Drought

Drought in Thailand is mostly caused by dry spells and rainfall interruptions. A dry spell is a condition where rainfall is less than normal or does not occur according to the season. This results in drought occurring in two periods during the year:

1) Drought during the winter to summer transition (second half of October to mid-May) often occurs in upper Thailand (North, Northeast) and parts of the Central and Eastern regions, with rainfall gradually decreasing until the rainy season begins in mid-May of the following year. This type of drought occurs annually.

2) Drought during the middle of the rainy season (late June to July) is a case of rainfall interruption, often occurring in specific areas or sometimes covering a wide area across almost the entire country.

Agricultural drought is a drought that impacts agriculture as a result of meteorological drought. It considers the interruption of rainfall that causes soil to lose moisture, affecting certain agricultural crops. This is because plants have different tolerances to climate variability, and the water requirements and growth stages of plants respond differently to drought. If the drought is severe enough to widely impact agricultural productivity, it is considered a drought disaster.

Dry spell refers to a condition where there is little or no rainfall for a period that should normally have rain (a state of rainfall significantly less than normal or no rainfall according to the season). This depends on the seasonal status of that particular location.

Rainfall interruption refers to a period where the amount of rainfall does not exceed 1 millimeter per day for more than 15 consecutive days during the rainy season. The months with the highest chance of rainfall interruption are late June to early July.

For drought in Thailand, it mostly occurs from dry spells or rainfall interruptions. Drought in Thailand occurs in 2 periods:

1) Winter to summer transition, which starts from the second half of October onwards in upper Thailand (North, Northeast, Central, and East). Rainfall gradually decreases until the rainy season begins in mid-May of the following year. This type of drought occurs annually.

2) Mid-rainy season, approximately from late June to early July, when rainfall interruption occurs. This type of drought occurs in specific areas or sometimes covers a wide area across almost the entire country.

3.**Methodology**

3.1 Research Framework

This research develops a web application with a geographic information system as a tool to support decision-making and management of drought-risk areas and plot-level crop damage in Thailand. It involves studying problems, background, and importance, creating a geographic information database in both spatial and attribute data formats, and inputting data into the developed system database. This allows users to monitor drought-risk areas through the system with menu options for drought risk maps, drought situation summaries, plot-level drought situation monitoring, and data downloads. The research framework is shown in Figure 2.

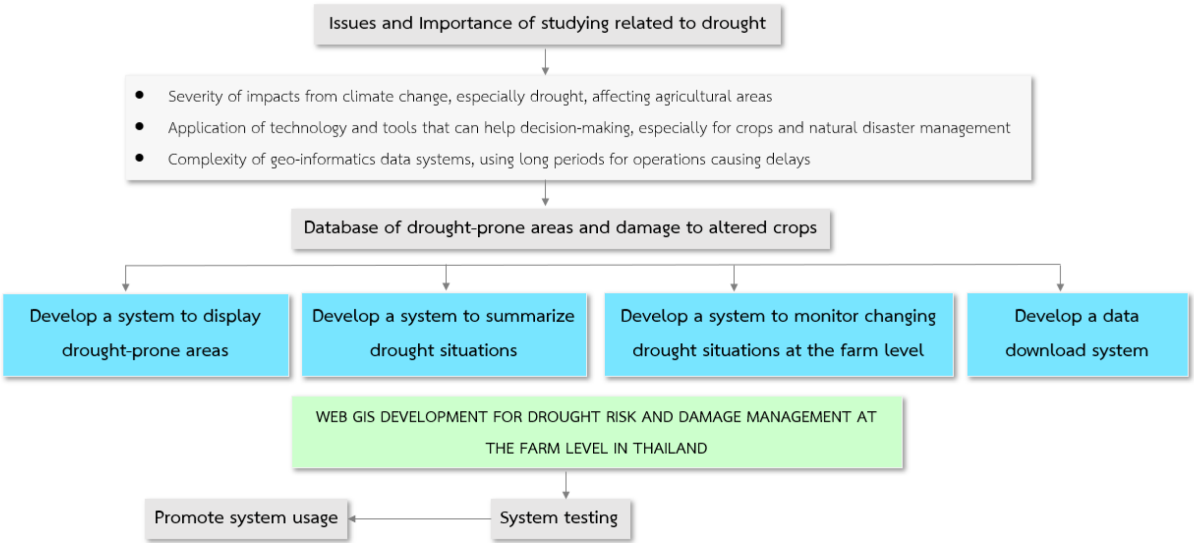


Figure **2**: Research Approach

3.2 Data and Database Preparation for Research

This study collected data related to drought-risk areas and plot-level crop damage in Thailand, which needed to be prepared as a spatial database. Additionally, there is reservoir data showing water situations from Thailand's Royal Irrigation Department, provided through web services, as well as other related spatial data.

Database preparation for system development involved designing various data layers used in the research to display results in the form of data lists in feature tables and map displays, which will be stored in the Geometry field. These are stored in a PostgreSQL database, separated into tables by data type, using PgAdmin for database management. Another format is raster files stored as GeoTIFF to create Web Map Services through Geoserver. The data service standards in the system will provide both vector and raster grid (satellite data index) data according to OGC Web Services formats such as WMS (Web Map Service), WFS (Web Feature Service), and WMTS (Web Map Tile Service). Open-source GeoServer software is used for processing and providing services through standard protocols. It will be imported into GeoServer in the form of Mosaic data to provide a single data layer covering the entire country, as shown in Table 1 and Figure 4.

Table 1: Data and Database Preparation for Research

Data	Data Characteristics	Source
Weekly drought risk area data (by region)	Vector (Shapefile)	GISTDA
Weekly drought risk area data	Raster (GeoTIFF)	GISTDA
Soil moisture data	Raster (GeoTIFF)	GISTDA
4-month advance drought risk area forecast data	Raster (GeoTIFF)	GISTDA
Crop damage data for 4 types (rice, sugarcane, cassava, corn) by plot	Raster (GeoTIFF)	GISTDA
Administrative boundary data (province, district, sub-district)	Vector (Shapefile)	GISTDA
Irrigation boundary data	Vector (Shapefile)	Royal Irrigation Department
Reservoir data	Vector (GeoJSON)	Royal Irrigation Department
Main river basin boundary data	Vector (Shapefile)	Office of the National Water Resources.
Agricultural plot data	Vector (Shapefile)	Department of Agricultural Extension

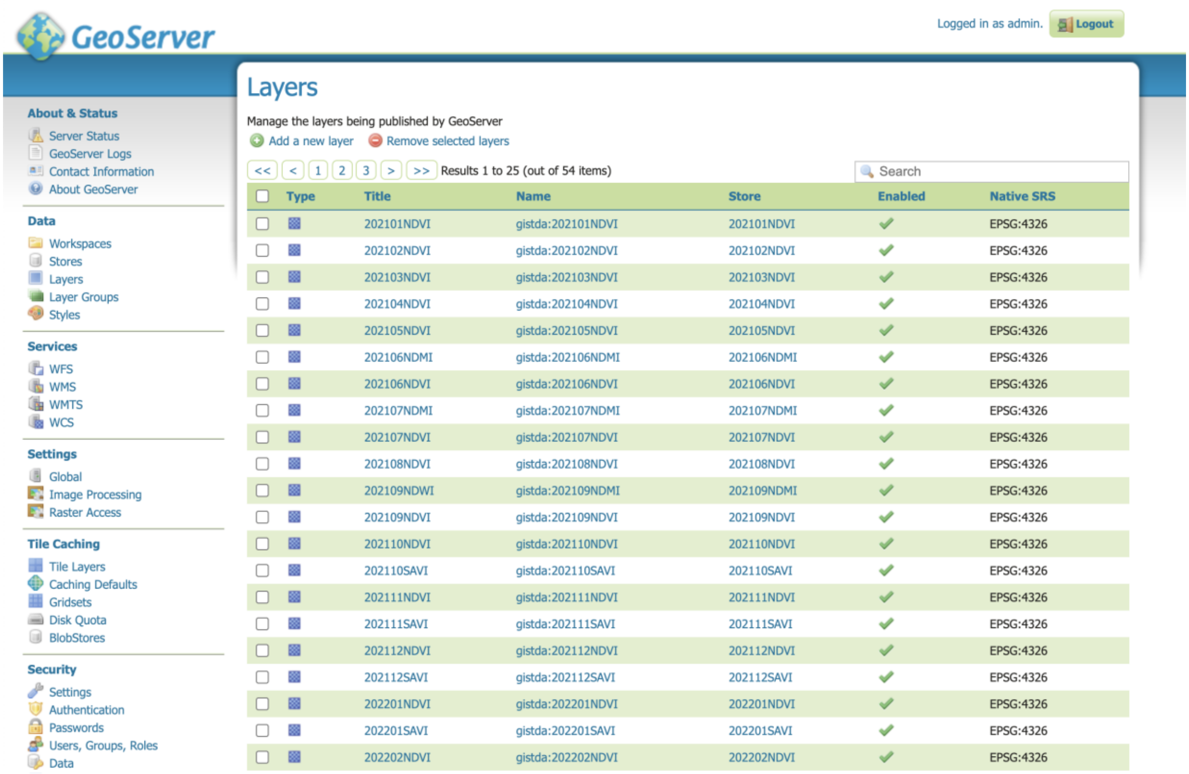


Figure **4**: OGC Web Services (WFS, WMS and WMTS)

3.3 System Development

1) Web Application Design

The structure of the web application starts with a Landing page displaying the system's 4 main menus: Drought Risk Map, Drought Situation Summary, Plot-level Drought Situation Monitoring, and Data Download. The Plot-level Drought Situation Monitoring and Data Download menus require user registration and login.

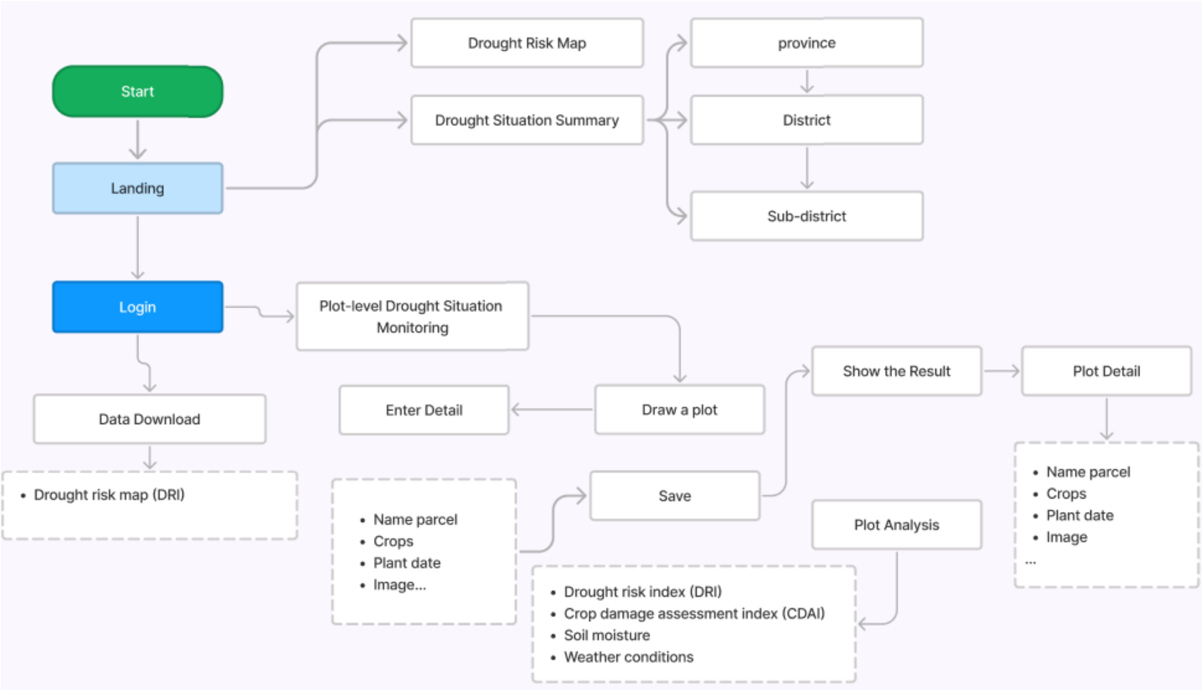


Figure **5**: Web Application Working Structure

2) System Architecture

The design of the web-based geographic information system architecture in this research consists of 4 parts: Client (user interface), developed using JavaScript Frameworks (React); Webserver, providing services and processing data in the form of Representational State Transfer API using Node.js; Map server, creating map images using GeoServer software to send data requests via HTTP to display on the web page; and Database, storing geographic information and other data used in system development using PostgreSQL software with PostGIS extension supporting spatial data. It is developed in conjunction with the Leaflet JavaScript library for internet-based map development, which is open-source software. Structured Query Language (SQL) is used to access and contact the database stored in the system. The system development is divided into 2 main parts: Back-end development and Front-end (User interface) development.

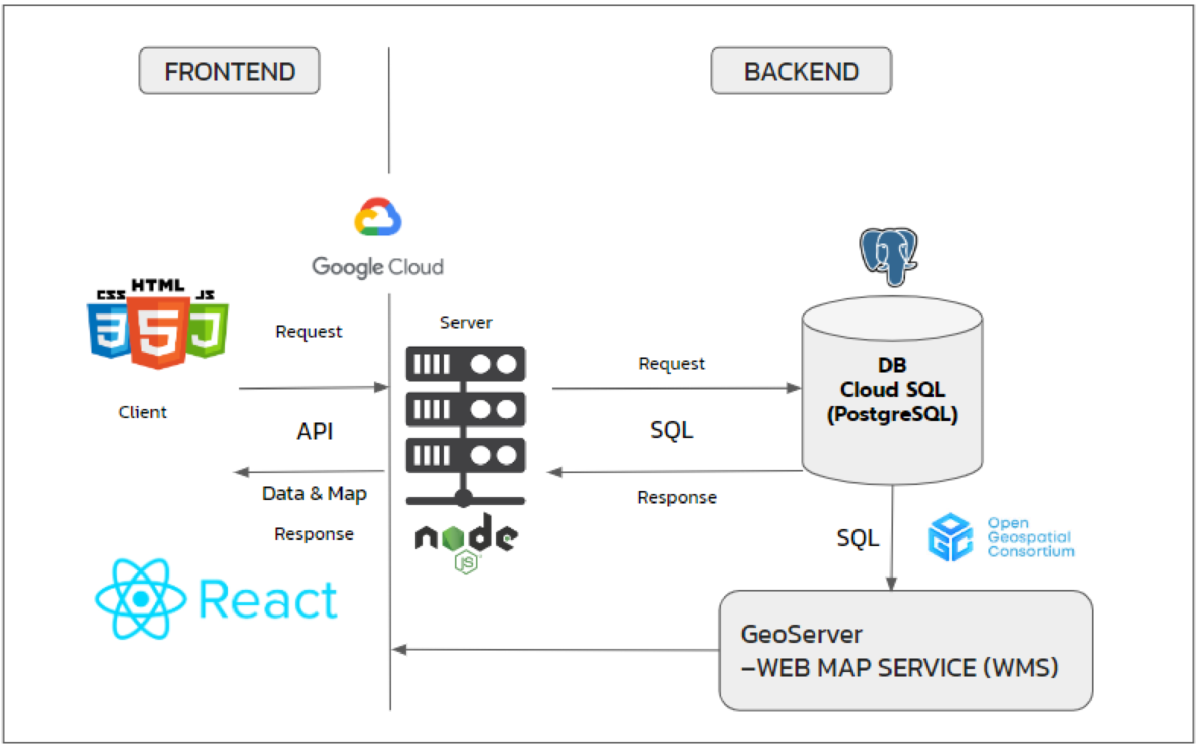


Figure **6**: System Architecture of the Web Application

3) Back-end Development

This involves developing a web application management system that serves as a data source for the database necessary for use in the application. The back-end system facilitates communication between the client or user interface and the server, and vice versa, using Structured Query Language (SQL) for database management. It consists of 3 key components: server, database, and client. Node.js is used as the web server, allowing for quick and efficient creation of a complete web server. The web server provides services and processes data in the form of Representational State Transfer API (REST API), which is a form of data transfer between server and client based on HTTP Protocol. It creates a Web Service for data exchange through web applications using the Express library built on Node.js, which is server-side programming using JavaScript. For processing, the system will be installed on GOOGLE CLOUD PLATFORM using Docker to ensure efficient system processing.

The Web Service creation will be in the form of REST (Representational State Transfer), called through HTTP Method GET and POST, and outputting data in JSON format. REST operation relies on the URL of the Request to search, process, and respond. The research uses JSON format because it is suitable for spatial data analysis work by calling data in GEOJSON format stored in the database's Geometry field for display on online maps. This includes: 1 .

Weekly drought-risk area data (by area), 2. Plot-level crop damage data for 4 types of crops. The data will be prepared in GEOJSON format and called through Web Service based on HTTP Protocol via web browsers, using Structured Query Language (SQL) to use PostGIS Raster extensions to display Zonal statistics results with administrative boundary data and plot-level Geometry. Additionally, Geoserver is used to provide spatial data services over the internet, prepared as Web Map Service (WMS).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  "errMsg": "",
  "data": {
    "jsonFeatures": [
      {
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        "pv_tn": "นครราชสีมา",
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          "coordinates": [
            [
              [
                [
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                  15.278223125
                ],
                [
```


Figure **7**: Web Service Data Structure in GEOJSON Format

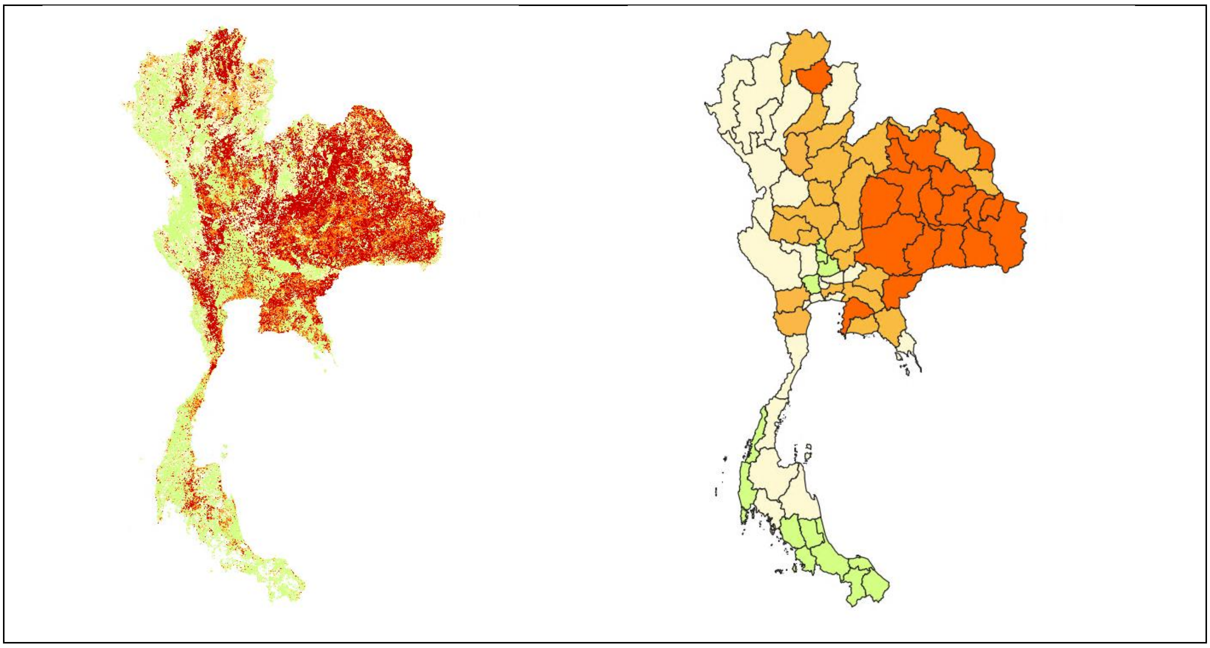
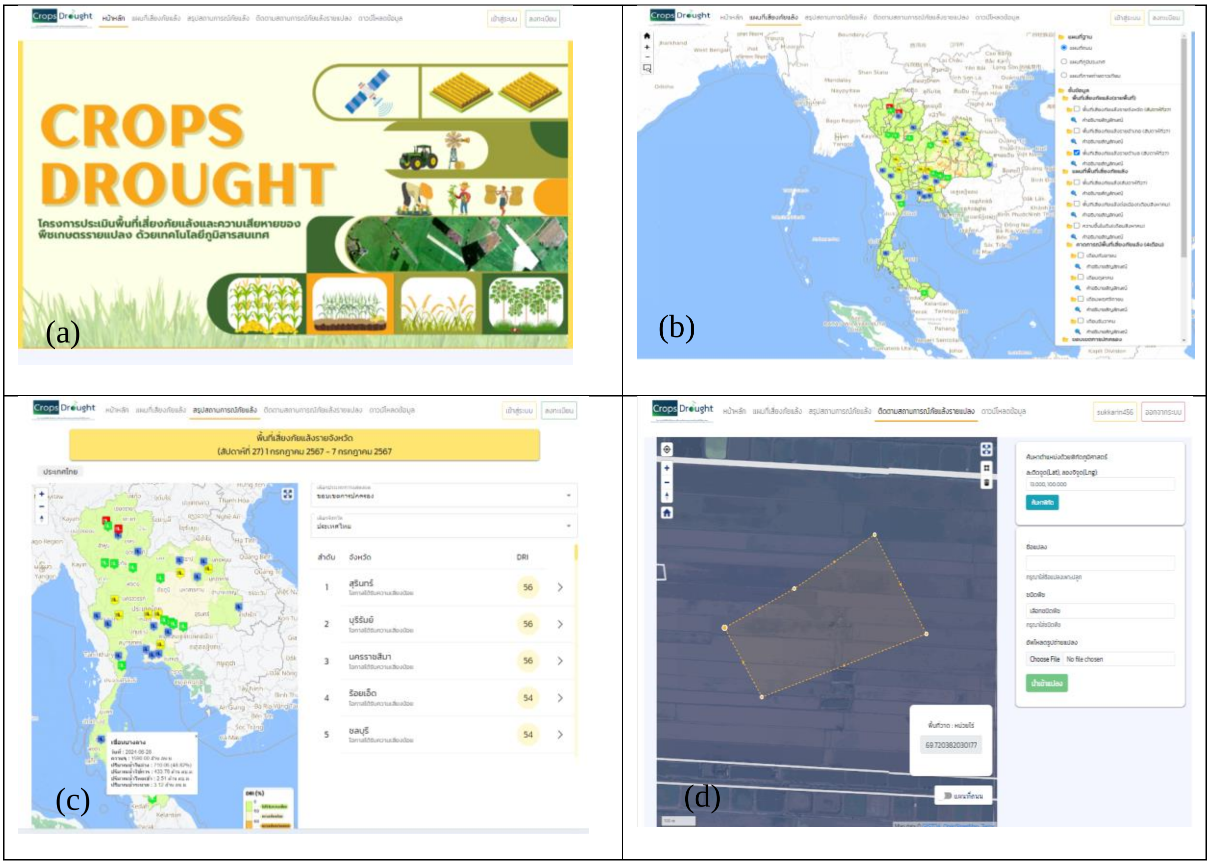


Figure **8**: Data Display in Web Map Service Format

4) Front-end Development (User Interface)

The development of the user interface involves programming for presenting spatial and attribute data on the web application using HTML and CSS techniques to create and style the web application pages, and JavaScript using JavaScript Frameworks (React) to reduce the complexity of large JavaScript code, including data transfer between web browsers and servers, or calling APIs from the back-end. For map display, Leaflet, an open-source JavaScript library for interactive online map development, is used. It can call various layers including Web Map Service (WMS) from Geoserver and GEOJSON in Web Service format prepared as REST API, called through HTTP Method GET and POST from the server to display on online maps. Additionally, Leaflet has a library for creating polygons to allow users to input spatial data for analysis. Highcharts, a JavaScript library for creating graphs on web applications, is also used to allow users to view statistical data in various graph formats. This research has designed the screen to display in various formats, supporting display on Desktop and Tablet by using React-Bootstrap, a front-end framework used in developing the user interface part of websites, making the website able to display appropriately on different devices. The main menus include Drought Risk Map, Drought Situation Summary, Plot-level Drought Situation Monitoring, and Data Download.



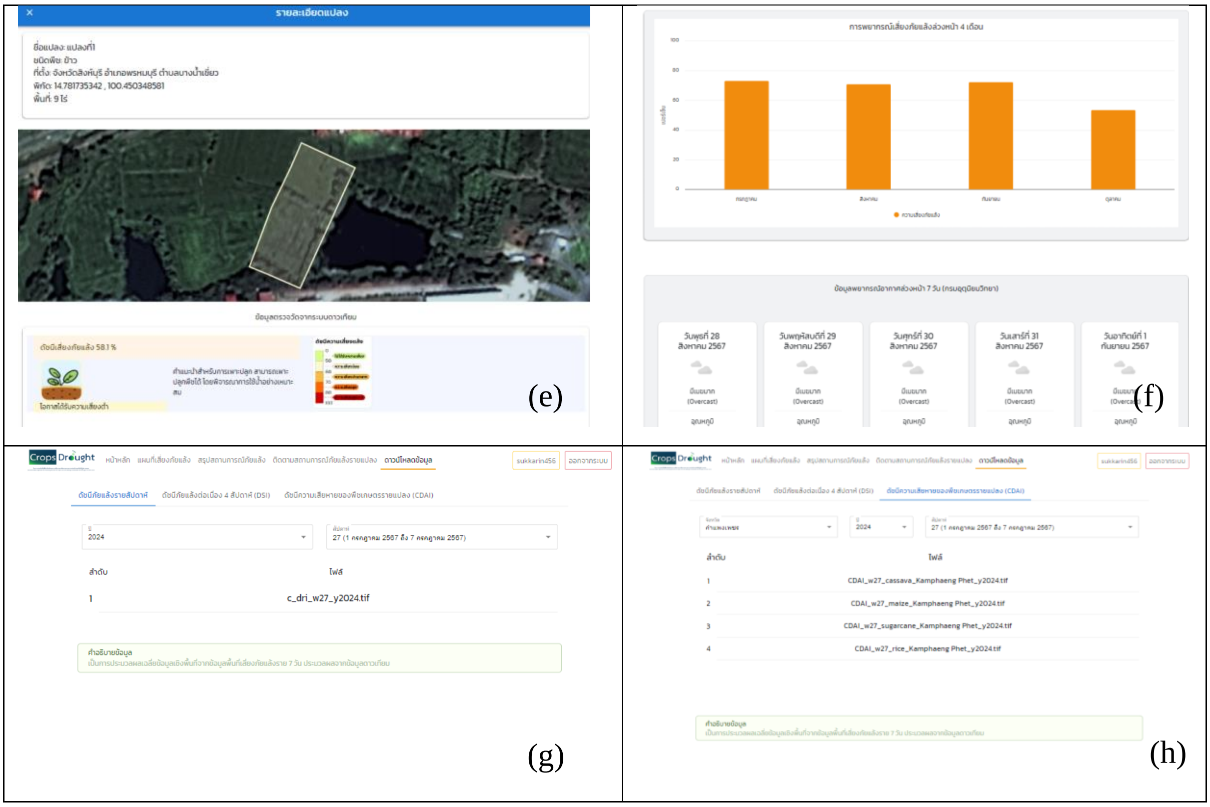


Figure 9: Display of various functions on the web application (a) Main page of the web application (b) Drought Risk Map menu (c) Weekly drought situation summary (d) Plot-level drought situation monitoring - plot drawing section (e) Plot-level drought situation monitoring - plot detail display section (f) Plot-level drought situation monitoring - 4-month drought risk forecast section (g) Weekly drought-risk area data download (h) Plot-level crop damage data download

4. Results

This research developed a web application using a geographic information system as a tool to support decision-making and management of drought-prone areas and crop damage in individual plots in Thailand. It supports crop planting decisions and natural disaster response in the form of a web application for planning and decision-making. It can be used to view trends in crop cultivation and suitability for crop planting. The web application was tested with a geographic information system program (QGIS 3.22), and user satisfaction was evaluated from primary users as follows:

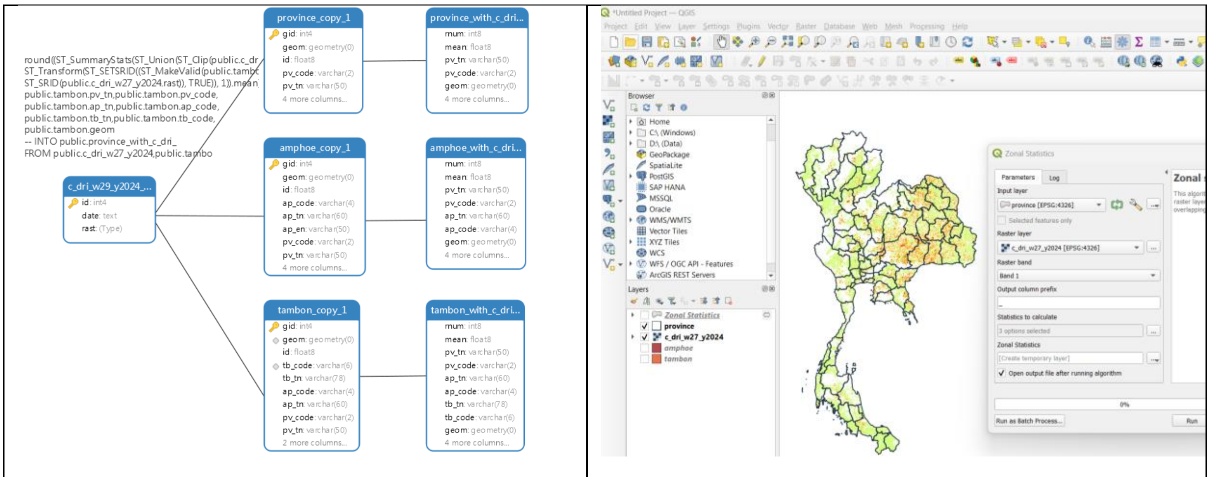
4.1 Testing the prototype web application with a geographic information system program

After development, the program was tested using the Black Box Testing method, which tests the output from processing by inputting data to check if the results are correct. All processes were tested to check their connectivity. Then, system administrators and users tested the operation. When there were operational errors, the evaluator would modify the program to work correctly as required.

This research tested the operation of the developed web application with two main functions:

1) Zonal statistics of weekly drought risk data with Thailand's administrative boundary data (provinces) using data from week 27 (July 1, 2567 - July 7, 2567) as it's the month with a high chance of rainfall interruption in Thailand. The accuracy was found to be equal in testing to 5 decimal places.

2) Zonal statistics of crop damage data for individual plots with plot Geometry data for 5 plots by writing Structured Query Language (SQL) using additional PostGIS extensions for working with Raster data. This was to test the values of results from the web application compared to the geographic information system program (QGIS 3.22), which is a desktop-installed GIS program, using the Zonal statistics tool in QGIS. The accuracy was found to be quite similar, with an average difference in calculated values using geometry between the web app and QGIS program of 0.02.



(a) (b)

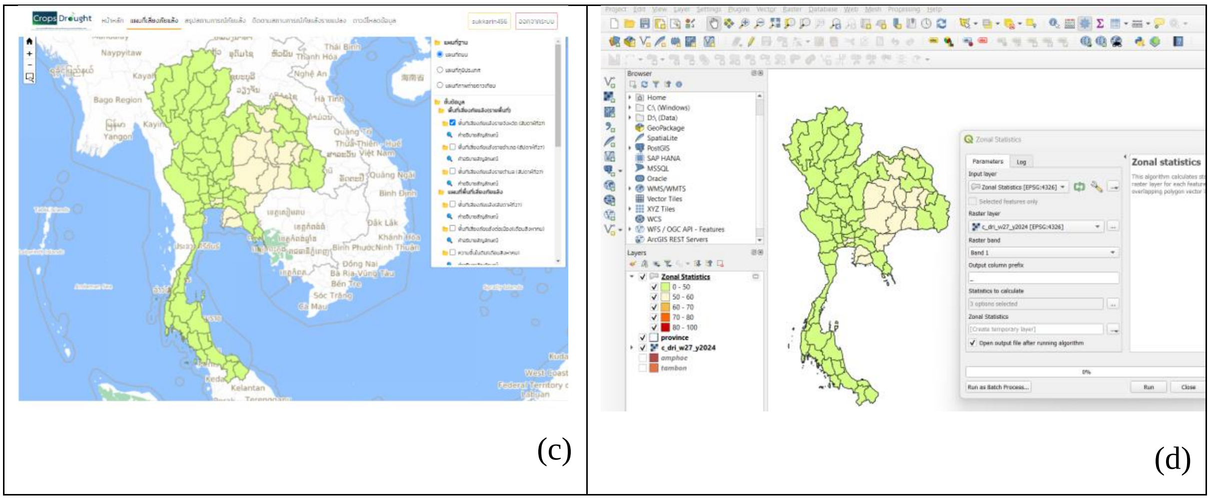


Figure 10: (a) Structured Query Language for Zonal statistics of weekly drought risk areas with administrative boundaries, (b) Zonal statistics in QGIS 3.22, (c) Zonal statistics results via web application, (d) Zonal statistics results via QGIS 3.22

Figure 11: Comparison of Zonal statistics results between the web application and QGIS 3.22, using administrative boundaries (provinces) and weekly drought risk area data for week 27 (July 1-7, 2024), showing the top 10 rankings

Table 2: Top 10 provinces with the highest drought risk probability for week 27 (July 1-7, 2024)

Province	Drought Risk Value	
	QGIS 3.22	Web App
Buri Ram	56.41875	56.41875
Surin	56.32729	56.32729
Nakhon Ratchasima	55.69113	55.69113
Chon Buri	54.17529	54.17529
Roi Et	53.72100	53.72100
Yasothon	53.23410	53.23411
Sa kaeo	52.96250	52.96251
Bueng Kan	52.38899	52.38899
Udon Thani	52.23264	52.23265
Maha Sarakham	51.82692	51.82692

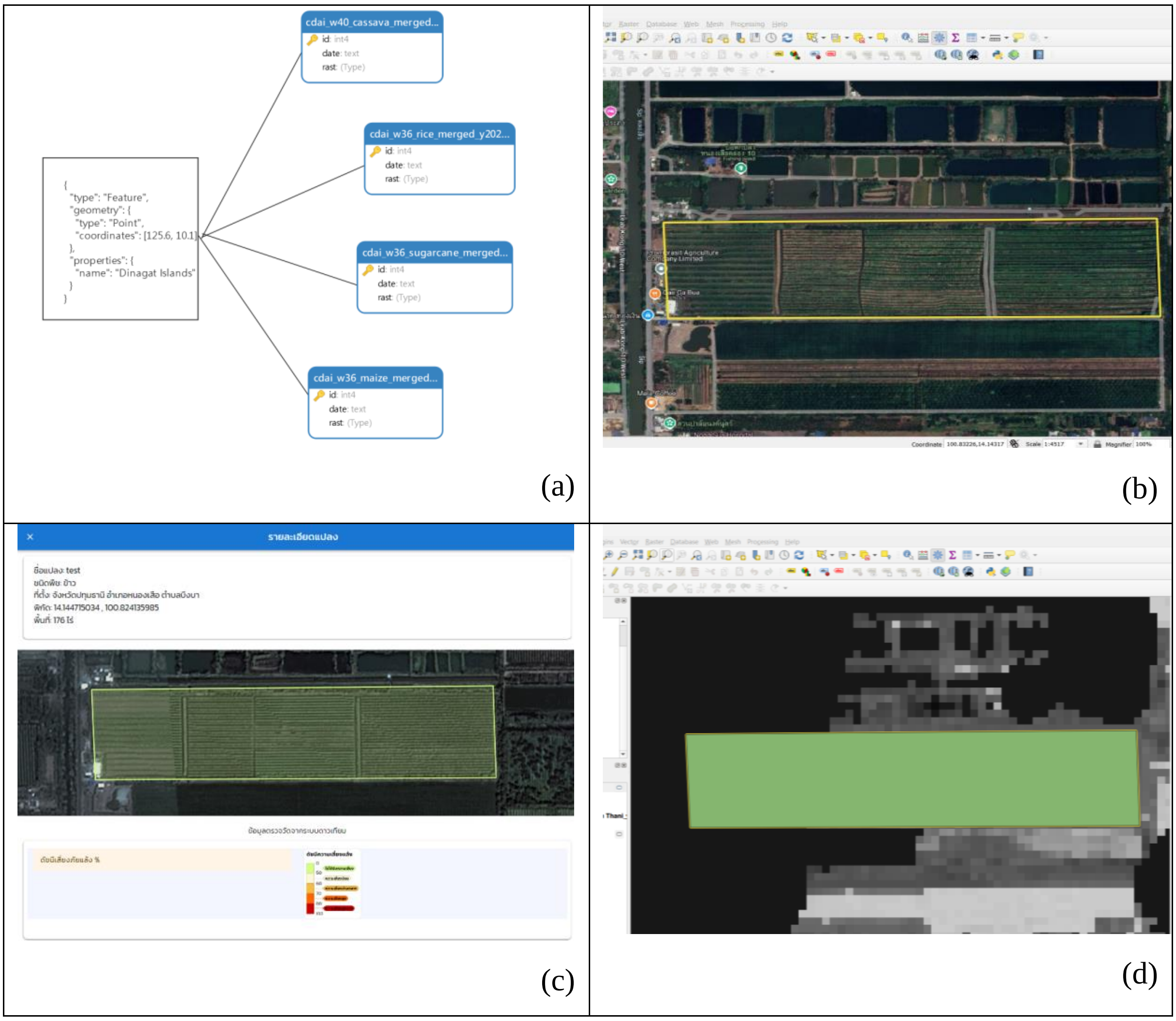


Figure 12: (a) Structured Query Language for Zonal statistics of crop damage data for rice, sugarcane, cassava, and corn with plot-specific geometry, (b) Zonal statistics in QGIS 3.22, (c) Zonal statistics results via web application, (d) Zonal statistics results via QGIS 3.22

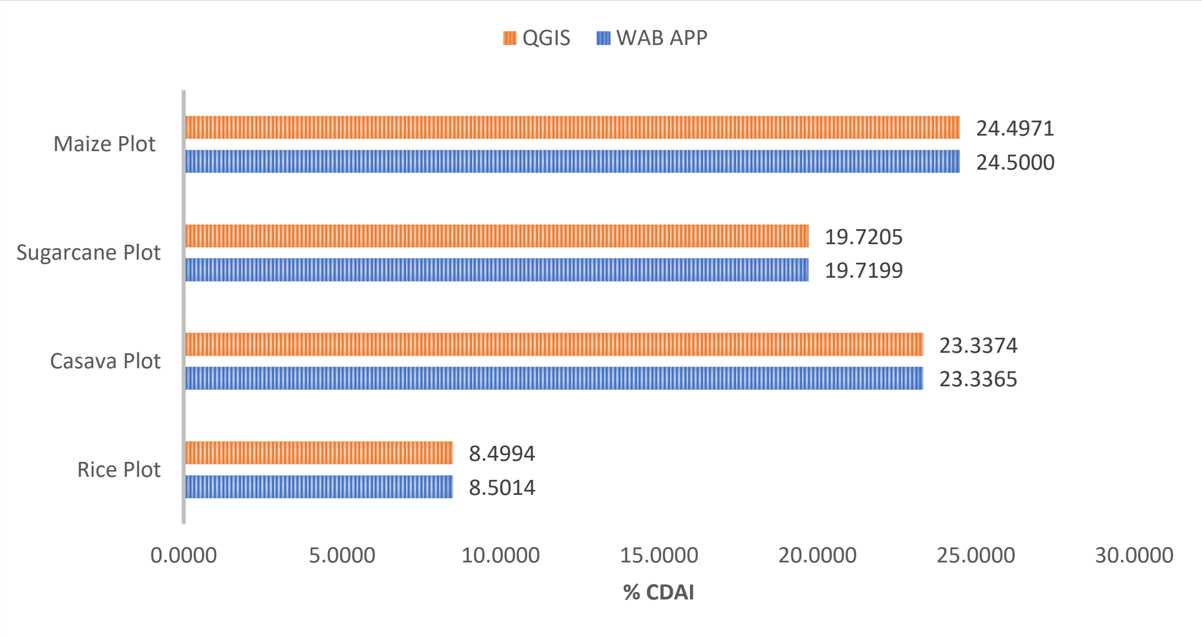
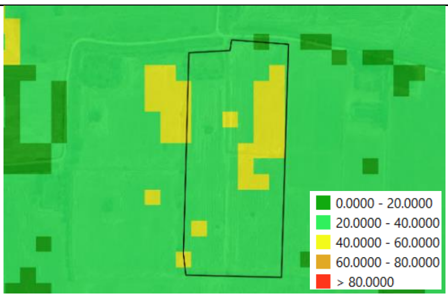


Figure 13: Comparison of Zonal statistics results between the web application and QGIS 3.22, using plot-specific geometry and crop damage data for week 27 (July 1-7, 2024)

Table 3: Crop damage data values for 5 test plots

No.	MAP Crop damage data (CDAI)	Damage at the farm level Value
1		8.4994

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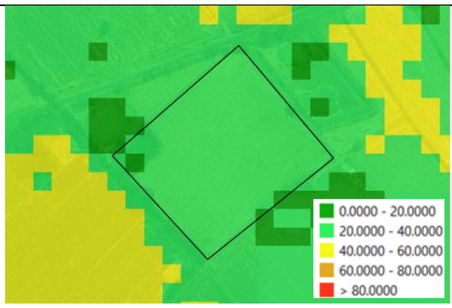
<tr><td>2</td><td>
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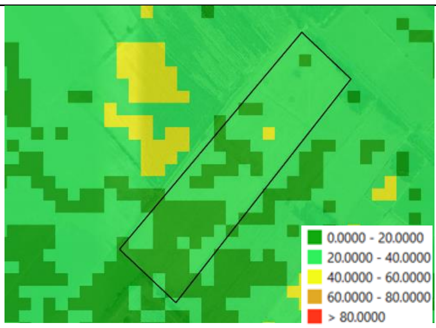
<tr><td>3</td><td>
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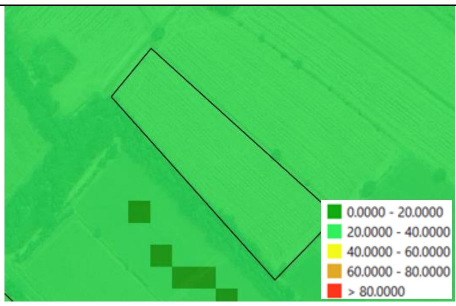
<tr><td>4</td><td>
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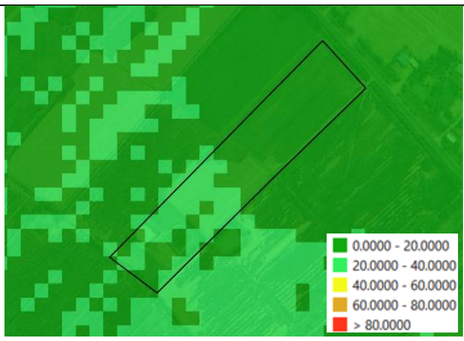
<tr><td>5</td><td>
</td><td>27.9710</td></tr>
</table>

4.2 Promoting the use of the web application

The focus was on users learning and testing the platform for assessing drought-prone areas and crop damage in individual plots using geoinformatics technology. Training was organized in 9 target provinces: Nakhon Sawan, Uthai Thani, Kamphaeng Phet, Phichit, Suphan Buri, Surin, Nakhon Ratchasima, Roi Et, and Sakon Nakhon. The training was conducted throughout March 2567, with a total of 1,013 participants divided into two groups:

The first group consisted of government agencies with drought-related missions, such as the central Department of Agricultural Extension, provincial and district agricultural offices, Royal Irrigation Department, provincial offices, provincial fisheries offices, provincial disaster prevention and mitigation offices, and local administrative organizations. This group plays an important role in using the platform to help manage areas during the dry season and prepare for drought situations.

The second group consisted of farmers, such as agricultural professionals and village agricultural volunteers. This is an important user group for self-assessing drought risks and crop damage in their plots and receiving basic advice on appropriate management approaches to prevent or reduce damage from drought.

Figure 14: Field visit to gather feedback on web application usage

4.3 Results of user satisfaction evaluation

The user satisfaction evaluation for the web application involved field visits to gather opinions from officials, farmers, and general users. A total of 288 respondents completed the questionnaire. The satisfaction evaluation results were categorized by level of satisfaction, where 1 = least satisfied, 2 = slightly satisfied, 3 = moderately satisfied, 4 = very satisfied, and 5 = most satisfied.

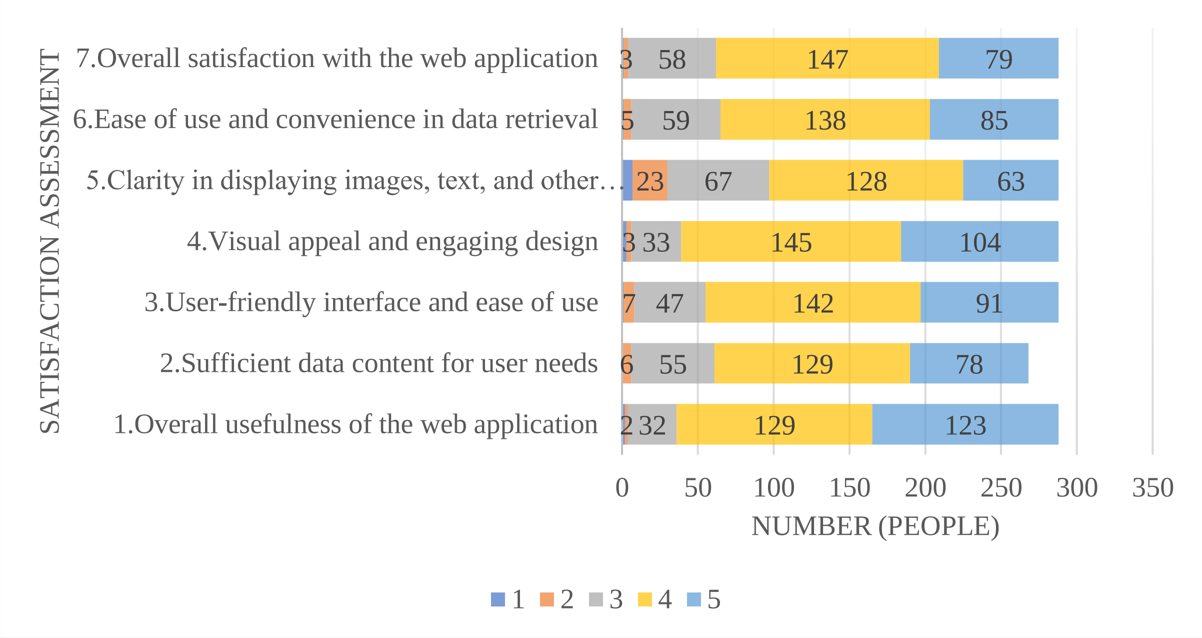


Figure 15: Web application user satisfaction assessment results

The evaluation results showed that users were mostly very satisfied with the usefulness of the web application (44.79%) and the content provided (43.71%).

For the first question about the usefulness of the web application, 44.79% of respondents were very satisfied (level 4), followed by 43.71% who were most satisfied (level 5). Only 0.69% were least satisfied (level 1).For the second question about the sufficiency of content, 48.13% were very satisfied (level 4), followed by 29.10% who were most satisfied (level 5).For the third question about the ease of reading and using the web application layout, 49.31% were very satisfied (level 4), followed by 36.10% who were most satisfied (level 5).Overall, 48.54% of respondents were very satisfied (level 4), 30.92% were most satisfied (level 5), and only 0.74% were least satisfied (level 1).Most users will use the application to monitor drought situations in cultivation areas, followed by coping with and preventing drought situations in the area, and planning for cultivation.

5. Conclusion

5.1 Web Application Development

The development of a web application utilizing Geographic Information Systems (GIS) serves as a decision support tool for managing drought-prone areas and crop damage on a plot-by-plot basis in Thailand. This application aids in making informed decisions about crop cultivation and appropriate responses to natural disasters. The project encompasses the design of the web application and the structuring of its system architecture. It involves the development of both the back-end system management and the front-end user interface of the prototype web application. The application features drought risk mapping, drought situation summaries, plot-specific drought monitoring, and data download capabilities. Accessible via web browsers through the internet, this tool offers user-friendly operations, reducing the time required for analysis and processing through specialized software. It effectively supports decision-making by providing easy access to geographical information through the internet.

5.2 Data and Database Creation

The service utilizes data analyzed and processed from satellite imagery in conjunction with artificial intelligence technology. The Geo-Informatics and Space Technology Development Agency of Thailand has already compiled this information into a database. The functionality testing was conducted in two ways:

1. Comparing the results of Zonal statistics in the web application with those from the QGIS 3.22 Geographic Information System software. This comparison used administrative boundary data (provinces) and weekly drought risk area data, showing equivalent accuracy to five decimal places.

2. Comparing Zonal statistics results from the web application with QGIS 3.22, using plot-specific geometry data and crop damage information. The results were closely aligned, with an average difference of 0.02 between the web application and QGIS calculations using geometry.

5.3 Dissemination, Implementation, and Promotion of Usage

The user satisfaction assessment of the system revealed that evaluators were highly satisfied with the prototype web application. This developed web application can effectively support decision-making for appropriate crop cultivation. Users can easily access geographic information without requiring expertise in Geographic Information Systems. It enables agricultural extension officers and farmers to assess drought-prone areas and crop damage on individual plots, facilitating informed decisions about suitable crop cultivation.

6. Recommendation

6.1 Recommendations for Web Application Development

1. Develop a system capable of locating places or plot positions by inputting coordinate values (Coordinate System) for x and y axes in the UTM system.

2. Incorporate recommendations for suitable crop cultivation based on predicted scenarios, such as suggested plant species.

3. Enhance the tool to provide comprehensive reports, summarize data in tabular format, export map images, and generate PDF and Excel file outputs.

6.2 Recommendations for Data and Database Creation

1. Develop a system that can import multiple plot data simultaneously in shapefile format and integrate with other government agency systems, such as those of the Department of Agricultural Extension and the Department of Lands.

2. Improve system accuracy with more comprehensive and consistent data details.

3. Develop a system capable of displaying soil series data.

4. Develop data services in Web Service format to allow relevant units to access and further analyze the data.

6.3 Recommendations for Dissemination, Implementation, and Promotion of Usage

1. Further develop the application into a mobile app to increase usage versatility.

2. Gather additional stakeholder requirements to ensure platform improvements meet user needs optimally, categorizing users to cover both policy-level and field operation-level groups.

7.Acknowledgements

We extend our gratitude to the National Research Council of Thailand for providing research and innovation funding. We also thank various agencies for their generous provision of research data, including the Department of Agricultural Extension, GISTDA, and the Royal Irrigation Department. Our appreciation goes to the agricultural extension officers and farmers who cooperated in evaluating the satisfaction of this web application.

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