

A WebGIS Decision Support System for Wadi El Natrun Rural Land Management

Sayed Ahmed¹ Ahmed Kotb¹ Ehab Samir¹ Marwa Moustafa¹ Eslam Farg¹ Ahmed Abd Elhay² Sayed M. Arafat¹

1- National Authority of Remote Sensing and Space Science, Cairo, Egypt

2- Survey Dept., Benha Univ. Faculty of Engineering, Benha, Egypt.

Abstract—Recently, the Egyptian government benefits from the digital transformation by developing different platforms to help manage and monitor the routine process. Rural land management is one of the critical issues that could significantly improve the economy. As far as we know, rural land management affects farmers and may cause agricultural land loss and waste of irrigation resources. Many attempts have been investigated to address this issue in Egypt. Therefore, we design and implement a WebGIS decision support system for rural land management in Wadi El-Natrun valley (WNDSS), El-Beheria governorate. The proposed WNDSS was developed using the client/server model and contains several functions, including data extraction, statistical analysis, and visualization via an interactive map. RESTful Web Service Application Programming Interfaces (APIs) were utilized as the communication interface between client and server. Finally, we use the browser to get the data by predefined API and to present the rural farms with Google Map API and jQuery JavaScript library. The online system provides several tools for governorate managers to (a) precise survey data, (b) powerful change detection suite, (c) Normalized Difference Vegetation Index (NDVI) multi-temporal, (d) multi-date land use land cover information, (e) statistics reporting tools, (f) tabular or spatial query for associated data.

Keywords—Web-based decision supports system, WebGIS, rural land management, interactive maps, statistical analysis.

I. INTRODUCTION

In recent years, digital transformation offers massive opportunities to the governments to effectively simplify the routine process [1]. The modern economy depends on utilizing communication technology and innovative ideas to support industrial and agricultural activities to introduce simple yet effective digital solutions vital for each enterprise and organization worldwide [2]. The availability of accurate multi-source data enables optimal land water resources management, which becomes a priority at the national level in Egypt. The increasing interest in utilizing Geographical Information Systems (GIS) as a thematic tool due to its ability to combine and analyze many different sources boosts data analysis accuracy and effectiveness.

In the broader context, GIS capabilities have evolved over recent years to develop efficient and easy applications such as land management, hydrological monitoring, etc. Traditional GIS analysis tools perform binary or multi-criteria using vector and raster data with no predefined sophisticated parameter or model. However, some limitations had been shown, such as difficulties in performing certain functions or spatial mismatch. To address these issues,

numerous statistical and machine learning (ML) approaches such as Decision Trees (DT), Support Vector Machine (SVM), and Neural Networks (NN) had been employed for geostatistical analysis. Recently, several public institutions produce different thematic data layers that follow different standards, which limited the chances to be migrated in the same applications.

The massive development of new cities and agricultural communities in Egypt aims to improve the quality of people life. Fair and comprehensive rural policies are vital factors that influence agriculture development dynamics. In rural management, the analysis of environmental, social, and legal criteria combined by land-use datasets has an essential effect on sustainable development [3]. However, the process of analyzing and visualizing such big and complex heterogeneous data is quite challenging. The process requires an effective platform that enables decision-makers easy access to the required information and statistics with no need for specialized knowledge in GIS [4].

Determining the rural land value is highly essential for governorates in Egypt. Several academic studies had explored the mass valuation using statistical and machine learning techniques. Therefore, we designed a WebGIS system with dynamic and interactive maps enriched with pop-ups information (textual, multimedia) and spatial queries capabilities for the El-Behira governorate to explore more information. This system provides the opportunity to manage and promote rural land information for successful and sustainable agriculture for Wadi El- Natrun valley and on a national scale when adopted. In the paper, we introduced WebGIS system that integrates HTML, Google Map APIs, and jQuery technologies to build a visualization framework, which including Postgres [5], web server, RESTful web service. A WebGIS decision support system, currently in use (wn.narss.sci.eg:8080), was implemented to assist farmers and government land value and maintain resources sustainability. Finally, the performance of the proposed WebGIS system was also evaluated. The evaluation results show that the proposed system presented in this paper is efficient.

The rest of the paper is organized as follows. In Section II, we outline related work briefly. In Section III, we introduce the proposed WebGIS system in detail. Section IV is dedicated to performance analysis. Finally, we highlight the concluding remark and future work in section VII.

II. RELATED WORK

This section highlights the influential role of Decision Support Systems (DSSs) in serving the planning and management level in decision making in a rapidly changing environment [5]. DSS introduces an interactive automated system to help decision-makers establish simple management procedures and decisions based on accurate analysis incorporated with real data and experts' knowledge. DSSs have been widely applied in several domains, including agricultural, urban, petroleum, and many more.

DSSs had evolved during the last twenty years due to the massive development in data processing techniques, computation facilities, and networking. DSS takes advantage of the popularity of the World Wide Web (WWW), where a standard web browser can serve as a graphical user interface (GUI) [6]. The utilization of geospatial technology in DSS enabled people with no experience in GIS to effectively utilize geo-DSS in related issues.

DSS had been applied to several domains such as electrical energy, supply chain management, information security planning, inventory management, and land assessment. By early 1990, building a DSS was boosted by the wide availability of data warhorse, on-line analytical processing (OLP), and data mining techniques. In 1993, Xerox Corporation deployed the first GIS maps on the WWW. In [4], adaptive DSS was proposed to provide a road map to enable practitioners to make better decisions. In [7, 8], the geospatial DSS system was implemented to achieve the high quality of drought-related data. The proposed DSS offers a wide range of data mining techniques with full control to users. In [9], a Geospatial Cyber-infrastructure platform was utilized to build a novel DSS that facilities collection, management, and processing for both static and dynamic datasets. Another spatial DSS based on the Geospatial Cyber-infrastructure platform focuses on soil sealing. Another Web GIS platform [10] was introduced to monitor and investigate soil at multi-scale in order to raise public awareness.

III. SYSTEM DESIGN AND DEVELOPMENT

This section discusses the design of the proposed WebGIS decision support system with feedback from the rural land administration office, El-Beheria governorate, Egypt.

A. Data requirements.

We split the data into four main categories: Satellite data, crop and soil characteristics data, ownership data, and survey data (see Table 1).

We used a very high-resolution Pleiades image that covers the study area that was acquired in March 2017 and freely downloaded Sentinel-2 data for the last five years, respectively. The very high-resolution Pleiades image was preprocessed and geo-referenced using ERDAS imagine software (ver.14). The registration error was calculated using more than 15 ground control points (GCPs) for the Pleiades image, which were approximately 0.04 pixels or 4 cm.

The ownership data was provided by local authorities, the information includes the ownership status, owner name, contact info, file No. of each farm, and payment status.

Survey data will not change frequently. The survey was carried out between 2018 and 2020 by using differential GPS LEICA GS15 with Real-time kinematic (RTK) technique. The GPS-derived raw data were processed using Leica Geo Office (LGO) software and unified the coordinates in World Geodetic System (WGS-84) coordinate format. The accuracy of the result may be affected by several parameters such as signal distraction caused by the topography of the study area. We integrated static survey technique to minimize these errors and achieve accurate positions results. Overall, all GPS observations having GDOP > 3 were not considered in the final analysis.

Crop characteristics data were collected through field investigation. Several field trips were conducted to collect crops, soil distribution, buildings, and crops detailed information.

TABLE I. PROJECT DATA REQUIREMENT DESCRIPTION.

Category	Items	Acquisition approach	Refresh rate
Satellite data	Pleiades image collected at 3-2017. Sentinal -2 images collected for the last 5 years		-
crop characteristic	Crop distribution details Soil distribution Building distribution details wells and irrigation nets	Field survey	Monthly
Survey data	farms GPS Boundary points acquired by ATK	Field survey	-
Ownership data	Complete ownership information	Local Managers	Frequently

We adopted Python language to process the various data types. Python rich libraries help writing a clean and maintainable code version as well as eliminate the need to write from scratch. Python libraries [11], NumPy, SciPy, and pandas, were used to convert the non-spatial data to the desired format. For the spatial data, Quantum GIS (QGIS) software [12] was used to append to the shape file containing the boundaries of the farm. QGIS software is freely accessible and handy in editing tasks.

We combined the spatial and non-spatial data and stored in the GeoJSON format as it preserves the spatial topology and lightweight [13]. GeoJSON is a type of a JavaScript Object Notation format that encodes geographic data structures. Mapshaper [14] introduced by Harrower and Bloch in 2006 was used to reduce the GeoJSON file size even further by simplifying the spatial datasets interactively.

Essential data that hardly change, such as survey and ownership data, were stored in the system database in advance to decrease users' workload and simplify the user experience. On the other hand, data that need periodic updates had to be added to the system frequently. The python scripts were adopted to store the collected data on the server and update it automatically.

B. System objectives

Attention to the end user's requirement is mandatory in planning the proposed decision support system [15]. WNDSS is developed as WebGIS based rural land system for managers. In simple terms, it will provide managers with a better understanding of the overall rural land management. The developers utilized a user-friendly environment to tackle the complexity of the decision-making process. The overall goals for developing WNDSS include the following:

- Provide the managers with true field knowledge to assist in making more reliable decisions as well as building a user-friendly, Web-based, decision support system.
- Systemize and visualize rural land ownership information with up-to-date website development technology for practical advice.
- Conduct research on the possibilities of using Internet resources and real-time data to assist irrigation systems achieve higher performance.

C. System Architecture

WNDSS has two main execution parts; the first part creating the http request object and depending on the sent http request, appropriate response object been created and sent out to the browser as illustrated in Fig 1. Both request object and response object creation steps are discussed in details in the following sections:

• Request Object Creation Steps:

The creation process of the request object has four major steps described in details below.

• Fill Route:

WNDSS requests are mapped to route tables. Route tables specify which controller and action to be invoked to handle the received request. If the received request is the first-time request, then the first thing to do is to fill the route table with routes collection.

• Fetch Route:

Based on the sent URL, Module "UrlRoutingModule" searches the route table to prepare and create "RouteData" object that has all the details of which controller and action to be invoked.

• Request Context Created:

From the previous step, the created "RouteData" object is used to create the "RequestContext" object.

• Controller Instance Created:

This request object is sent to "WNDSSHandler" instance that creates instance of the controller class.

And once the controller class object is created, then it calls the method "Execute" of the controller class.

• Response Object Creation Steps:

The creation process of the response object has two major steps described in details below.

• Execute Action:

The "ControllerActionInvoker" class determines which action to be executed and executes the action.

• Result Sent:

The action method creates and executes the requested type of result which can be a view result, file result, JSON result or any other result type.

D. System Modules

The proposed WebGIS DSS contains three main components: a storage layer, a web layer, and a user interface (UI) layer, as illustrated in Fig. 2. The web layer is considered a pathway between the UI layer and the storage layer. For the web framework, java servlet web [16], Apache Shiro [17], and Java Tomcat [18] were chosen as it supports quick development and has a pragmatic, clean design. The utilized framework was useful during development and testing phases.

As shown in Fig.3, WNDSS contains six distinct modules namely: 1) Survey Module, 2) Landuse land cover Module, 3) Statistical Reporting Module, 4) Authentication Module, 5) NVDI time series Module, and 6) Change detection Module. The system was hosted in National Authority of Remote Sensing intranet and was accessible by all El-Behira governorate users with authentication module.

1) Survey Module

WNDSS system provides a very important module named Survey Module. The main objective of the Survey Module is to provide and visualize all business information related to farms in an efficient way. Survey module provides end users with information like farm location, farm area, farm code, and farm owner. It also provides them with an image that displays the farm boundaries. Survey Module was built using Google Maps JavaScript APIs

2) Landuse land cover Module

WN System provides another very important module named Land-use/ Land-cover module which can be considered as the detailed version of the survey module. Land-use/Land-cover modules provide more details about the farms to the decision maker such as details of land use areas for every farm (i.e. the same farm can contain different classes like Agriculture, Buildings, Water, ..., etc.). Same as Survey Module, Land-use/Land-cover Module was implemented by using Google Maps JavaScript APIs.

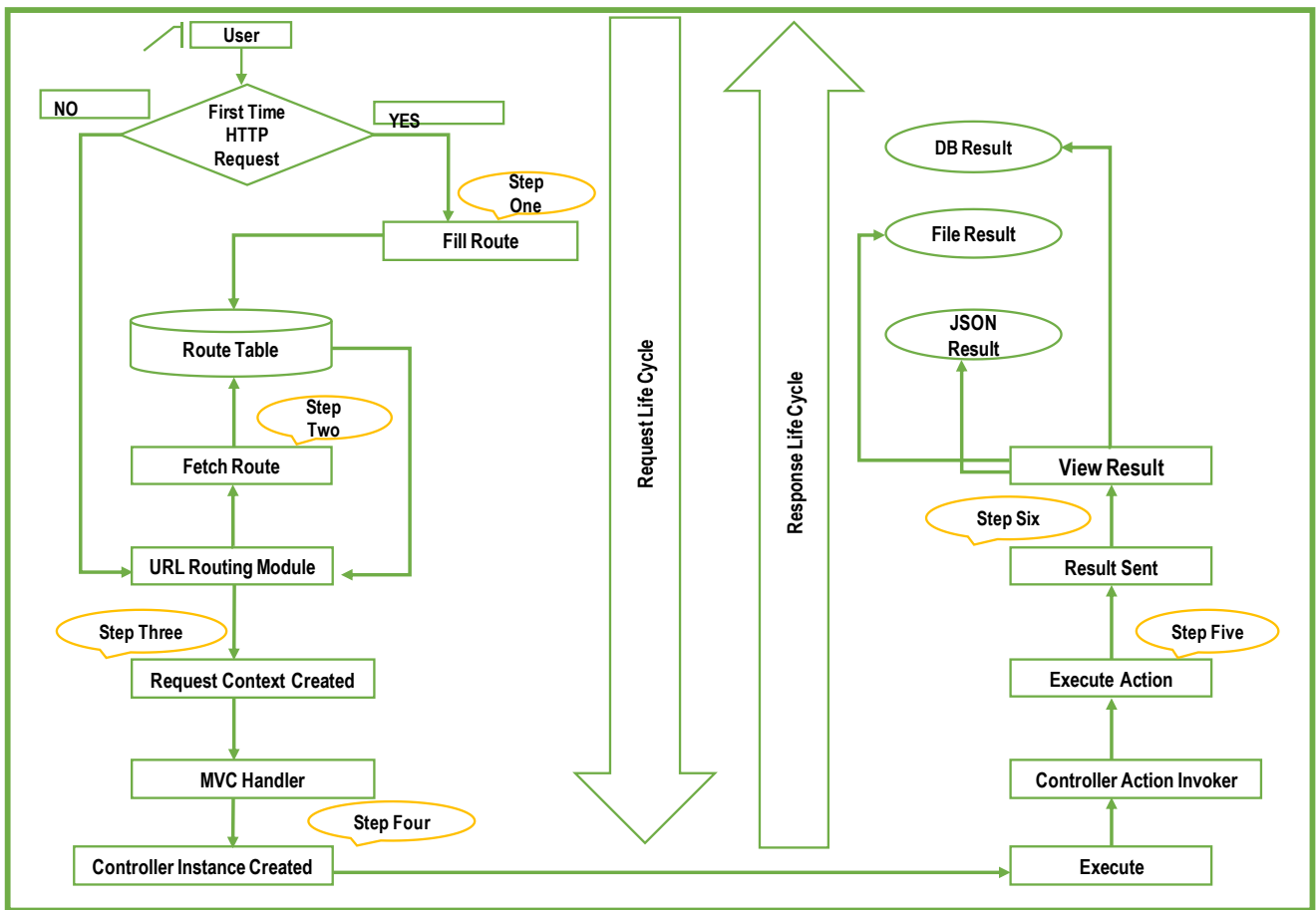


Fig. 1. WNDSS System Architecture

3) Statistical Reporting Module

This module was built using Google Charts JavaScript APIs. The main goal of this module is to provide statistical reports concerning the lands status. The land statuses for two main regions are provided. No authentication is required to access this functionality.

4) Authentication Module

This module was designed to provide security and access privileges to the system. The authentication module was built based Apache Shiro APIs. Apache Shiro is a powerful and easy-to-use Java security framework that performs authentication, authorization, cryptography, and session management. According to the user privilege, some functionalities are allowed to be accessed and others are not.

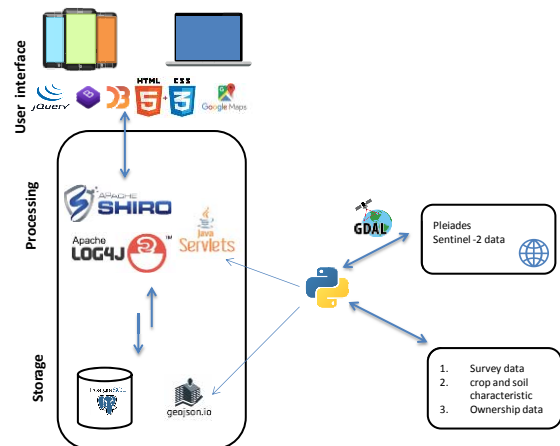


Fig. 2. Technologies used for implementation, transforming and publishing data in the proposed WNDSS application.

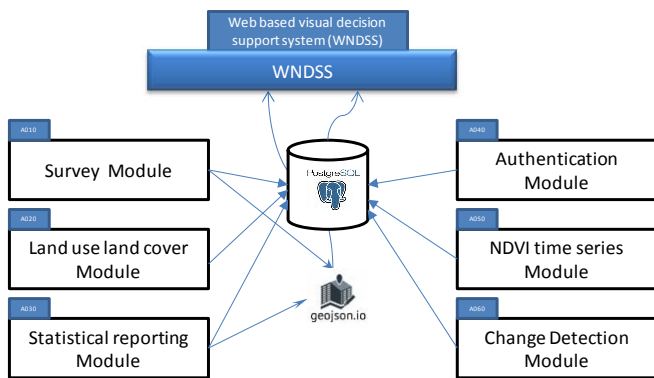


Fig. 3. WNDSS Web GIS decision support system model.

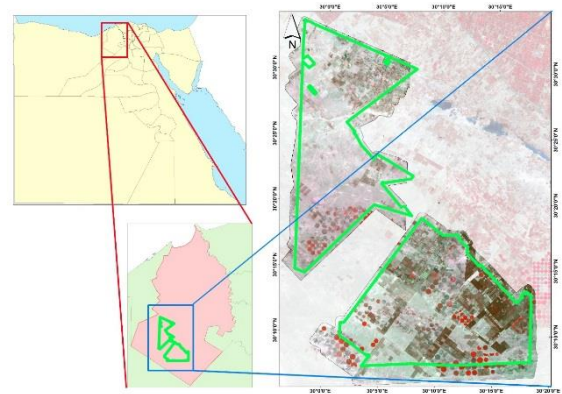


Fig. 4. Location map for Wadi El-Natron, El Beheria, Egypt as study area

5) Normalized Difference Vegetation Index (NDVI) time series Module

NDVI time-series module was built by using slider capabilities of the jQuery JavaScript framework. This capability provides the end-user with the ability to monitor the changes in a specific area within more than 15 different dates. The importance of this feature comes from providing the decision maker with the ability of monitoring the progressive growth in the specified area and not only the changes between the two dates.

6) Change detection Module

The proposed system provides a great capability for monitoring changes in a specific area on two different dates. Change detection module depends on high resolution images generated by two different missions (Sentinel and Pleiades), it gives the user the ability to swap between the provided images and monitor differences between them. The Change Detection module was built based on jQuery JavaScript library especially Slider Capabilities.

IV. RESULTS AND DISCUSSION

This section is organized as follows: Section A provides a brief description for the study area. Section B presents the functionality and limitations of the proposed WebGIS decision support system.

A. Study area

The proposed WebGIS decision support system is applied in Wadi El-Natron valley, El Beheria governorate, Egypt (Fig. 4). Geologically, the area is a depression which is located below the sea and Nile River level by 23 m (75 ft) and 38 m (125 ft), respectively. Wadi El-Natron valley has several alkaline lakes, rich salt deposits, salt and freshwater marshes.

B. Results

We successfully implemented the WebGIS decision support system to help farmers and the Egyptian governmental authorities manage Wadi- El Natrun rural land. The proposed system contains dynamic and interactive maps enriched with pop-ups information and several spatial queries capabilities designed to exploration facilities. The proposed system home page is composed of three main thematic parts as follows (1) The upper left enables WN users to search for a specific location on the map, either in decimal or degree format, (2) the middle part to access dynamic and interactive web map (Fig. 5), and (3) the lower-left part displaying access for complement layer for the dynamic map. A visual interactive spatial query allows authorized users to learn more about a specific farm, highlighted farms in red through the interactive map interface to query. The obtained data can be directly saved as KML format.



Fig. 5. Home page of the proposed WebGIS decision support system where different layer can be selected. The map image shows the different rural ownership farms.

The proposed WebGIS decision support system provides multiple forms of information organized through interactive maps and pop-ups. A pop-up window for Farms Survey Information appears by clicking on any farm polygon. The main farm information is included in the pop-up window and it can be accessed only by registered WN users. This information includes farm names, farm owners, farm type, farm area, and farm survey image, as shown in Fig. 6 (a) that demonstrates the accurate survey points obtained by the survey team. In addition, some related information is also introduced, such as farm land-use, farm change detection, farm legalization procedures request, and farm inspection report preview. By clicking on the land-use button, another

pop-up window including detailed information for farm land-use data fields appears for registered WN users, such as farm land-use different areas, farm name, farm land-use layout image as shown in Fig.6 (b). Fig. 6 (b) also highlights the spatial search functionality which enables users easily access spatial query.



Fig. 6. Farms detailed information a) Survey data, b) land use-land cover detailed information

To show the dynamic change process of the farms between very high-resolution Pleiades image and the sentinel-2 image acquired in March 2017 and 2020 respectively, the farm change detection slider tool shown in Fig.7 is utilized to swap between the two raster images for the same area in order to highlight change zones. The tool provide a powerful change detection module for the users

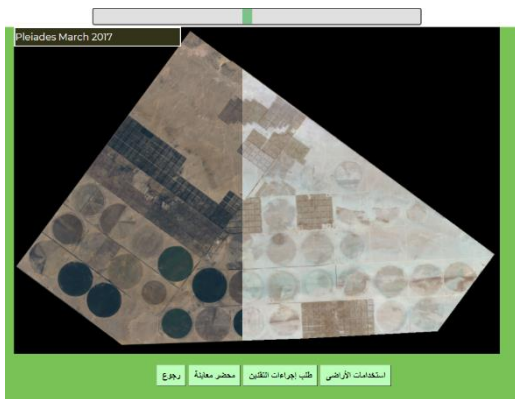


Fig. 7. Farm change detection slider tool for farm.

Another time series change detection tool (Fig.8) was implemented by calculating NDVI, using sentinel-2 images for the last five years. The implemented tool enables users of the proposed WebGIS decision support system to visually highlight temporal agriculture changes in an interactive map. Also, an animated change tool was implemented for the study

area over the past five years to enable users to play/pause, go to the start time period, end-time buttons.



Fig. 8. Time Slider for NDVI for WN Area.

The authorized user can run a tabular search to query farms different criteria, such as farm name, farm file number, farm owner, etc., as shown in Fig. 9. The search results include farm information and the capability to modify farm data fields. Also, from the search results, registered WN users can view the farm on the map.



Fig. 9. Tabular Search tool .

V. CONCLUSION

The rapid development in communication technology offers massive opportunities to develop new tools to help governorate and smallholders by providing an online, enhanced DSS to improve farming sector management. This paper discusses the user as well as the structural considerations for developing modern WebGIS decision support systems of El-Beheria governorate, Egypt. The main goal of the proposed system was to provide managers easy access to (a) rural land accurate survey data, (b) a suite of powerful change detection module for each farms using either raw satellite images (c) multi-temporal change detection module based on calculated NDVI, (d) multi-date land use land cover information, (e) reporting statistics for ownership information combined with the land use /land cover data (f) tabular or spatial query for farms. The briefly described online tools are currently available to registered users.

Finally, we plan to integrate more information, such as underground water, seasonal crop mapping, irrigation requirement mapping etc. We also indented to enhance the

system performance's security modules and reliability to allow a faster visualization experience for the users. .

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REFERENCES

- [1] R. Sujatha, C. Navaneethan, R. Kaluri, and S. Prasanna, "Optimized Digital Transformation in Government Services with Blockchain," *Blockchain Technology and Applications* (pp. 79-100). Auerbach Publications, 2020.
- [2] S. Shkarlet, M. Dubyna, K. Shtyrkhun, and L. Verbivska, "Transformation of the Paradigm of the Economic Entities Development in Digital Economy," *WSEAS Transactions on Environment and Development*, vol. 16, pp. 413-422, 2020.
- [3] M. E. Shokr, "Environmental Applications of Remote Sensing in Egypt: A Review and an Outlook," in *Environmental Remote Sensing in Egypt*. Springer, 2020, pp. 95-126.
- [4] F. F. Chen, "Decision support for lean practitioners: A web-based adaptive assessment approach," *Computers in Industry*, vol. 60, no. 4, pp. 277-283, 2009.
- [5] F. Wilson, "Computer support for strategic organizational decision-making," *The Journal of Strategic Information Systems*, vol. 3, no. 4, pp. 289-298, 1994.
- [6] J. P. Shim, M. Warkentin, J. F. Courtney, D. J. Power, R. Sharda, and C. Carlsson, "Past, present, and future of decision support technology," *Decision support systems*, vol. 33, no. 2, pp. 111-126, 2002.
- [7] S. Goddard, S. K. Harms, S. E. Reichenbach, T. Tadesse, and W. J. Waltman, "Geospatial decision support for drought risk management," *Communications of the ACM*, vol. 46, no. 1, pp. 35-37, 2003.
- [8] S. K. Harms, S. Goddard, S. E. Reichenbach, W. J. Waltman, and T. Tadesse, "Data mining in a geospatial decision support system for drought risk management," in *Proceedings of the 1st national conference on digital government*, 2002: Citeseer, pp. 9-16.
- [9] F. Terribile *et al.*, "A geospatial decision support system for supporting quality viticulture at the landscape scale," *Computers and Electronics in Agriculture*, vol. 140, pp. 88-102, 2017.
- [10] G. Langella *et al.*, "Soil Monitor: an internet platform to challenge soil sealing in Italy," *Land Degradation & Development*, 2020.
- [11] W. McKinney, *Python for data analysis: Data wrangling with Pandas, NumPy, and IPython*. "O'Reilly Media, Inc.", 2012.
- [12] B. Lacaze, J. Dudek, and J. Picard, "GRASS GIS Software with QGIS," *QGIS and Generic Tools*, vol. 1, pp. 67-106, 2018.
- [13] H. Butler, M. Daly, A. Doyle, S. Gillies, S. Hagen, and T. Schaub, "The geojson format," *Internet Engineering Task Force (IETF)*, 2016.
- [14] M. Harrower and M. Bloch, "MapShaper. org: A map generalization web service," *IEEE Computer Graphics and Applications*, vol. 26, no. 4, pp. 22-27, 2006.
- [15] C. J. Fernandez and T. N. Trolinger, "Development of a Web- Based Decision Support System For Crop Managers: Structural Considerations and Implementation Case," *Agronomy journal*, vol. 99, no. 3, pp. 730-737, 2007.
- [16] J. Murach and A. Steelman, *Murach's Java Servlets and JSP*. Mike Murach & Associates, 2014.
- [17] J. Ochoa, "Security for Java Web Applications Using Apache Shiro," 2014.
- [18] S. Agrawal and R. D. Gupta, "Development and comparison of open source based Web GIS Frameworks on WAMP and Apache Tomcat Web Servers," *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. 40, no. 4, p. 1, 2014.