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Exploring the Role of Geographic Information System (GIS) Applications in Enhancing Agricultural Sector Management

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Abstract*—This research explores the application and impact of Geographic Information Systems (GIS) in improving agricultural sector management in the Philippines, with a focus on government agencies operating at regional, provincial, and municipal levels. As a spatial data analysis tool, GIS integrates hardware, software, and data to facilitate the visualization, interpretation, and management of geographically referenced information. In the context of agriculture, GIS supports precision farming, resource optimization, and evidence-based policy-making, offering a more dynamic alternative to traditional agricultural management methods.The study employs a quantitative, exploratory research design using a self-structured survey instrument administered to selected government employees. Respondents were selected through purposive sampling based on their familiarity with GIS and roles in the agricultural sector. Descriptive statistical analysis was conducted to examine perceptions of GIS roles, benefits, and challenges in agriculture. To maximize the benefits of GIS in agricultural management, its effective deployment requires strategic investments in digital infrastructure, workforce training, and up-to-date geospatial data. These efforts will be essential in addressing national food security goals and in fostering sustainable agricultural development amid climate and population pressures.

Indexed Terms*— Geographic Information System, Spatial Analysis, Crop Monitoring, Sustainable Agriculture, Farm planning, Agricultural Sector

I. INTRODUCTION

Geographic Information System (GIS) combines hardware, software, data, and personnel to capture, store, analyze, and display geographically referenced information. This integration enables governments to transcend traditional methods, using location as a fundamental organizing principle to understand complex relationships and make data-driven decisions. GIS, in combination with digital technologies and through new and emerging areas of applications, is enabling the realization of precision farming and sustainable food production goals. Geographic Information Systems (GIS) Provide a powerful solution by integrating geographic data with other relevant information, allowing governments to visualize, analyze and manage spatial patterns and relationships.

These techniques have proven to be effective in the accurate mapping, identification, and categorization of greenhouses using aerial imagery and satellite data. The potential integration of this technique into the improvement of policymaking was not discussed. The research observed the notable rise in adoption of GIS software and technologies in the field of agricultural management and precision in other countries. Understanding these benefits can help promote sustainable agriculture [1]. Systematic mapping analysis and spatial data derivation has been utilized in several domains such as estimating crop growth and production, extracting parameters related to cropland, detecting weeds and diseases, and monitoring availability of water and nutrients in plants. This research aims to explore the role of GIS in our current government agricultural sectors, an overview on its significant challenge and necessitates attention from the government to maximize the benefits and implement it.

The world population is projected to grow close to 10 billion by 2050; we need to produce about 50% more food compared to 2013 production to meet the global demand [2]. Geographic Information Systems (GIS) have emerged as a transformative tool in the agricultural sector, enabling the integration, analysis, and visualization of spatial data to support decision-making processes. It also provides a robust platform for managing agricultural resources by combining geospatial data with advanced analytical tools [3]. This integration allows farmers, policy makers, and stakeholders to optimize land use, monitor crop health, and improve resource allocation.

The ability of GIS to handle large datasets and provide real-time insights has made it indispensable in modern agricultural practices. Prediction Crop monitoring and yield prediction are critical components of agricultural management, and GIS has proven to be a valuable tool in this regard. Studies by [4] highlight the use of GIS in conjunction with remote sensing technologies to monitor crop health and predict yields. By analyzing vegetation indices and weather patterns, GIS can provide early warnings of potential crop failures, allowing farmers to take proactive measures. This capability is particularly important in regions vulnerable to climate change, where timely interventions can mitigate losses. Moreover, [5] emphasized the utilization of RS and GIS methodologies in the field of precision agriculture. In order to address the limitations of traditional subsistence production practices, it is imperative to adopt sustainable production approaches that promote efficiency and improved agronomic practices [6].

The strategies encompassed in this approach consist of the cultivation of crops that are resilient to climate conditions, the utilization of crop types that have high yields, the implementation of methods for predicting crop yields, the adoption of integrated pest management techniques, and the incorporation of biodiversity solutions into sustainable food production systems [7,8]. In order to implement these innovative interventions effectively, it is imperative to possess complete and current datasets encompassing both spatial and non-spatial information. Additionally, the utilization of advanced GIS technologies capable of amalgamating and synthesizing various types of data, such as spatial, social, demographic, economic, and environmental, is crucial [9,10]. The synthesis process would yield geographical knowledge that is grounded in evidence, enhancing our comprehension of agricultural sustainability and facilitating more effective policymaking and decision-making endeavors [11].

The future of GIS in agriculture looks promising, with advancements in technology such as artificial intelligence (AI), machine learning, and the Internet of Things (IoT) further enhancing its capabilities. As highlighted in [12], the integration of GIS with these technologies will enable more sophisticated analyses and predictive modeling, paving the way for smarter and more sustainable agricultural practices. Additionally, the increasing availability of open-source GIS tools is expected to democratize access, making these technologies more accessible to GIS operators of various government agencies in the country as well as the farmers and landowners.

II. OBJECTIVE OF THE STUDY

The main objective of the study is to explore the role of GIS applications in improving Agricultural Sector Management in the Philippines.

General Objectives:

A. To describe the demographic profile of the respondents in terms of:
   a. Age group
   b. Gender
   c. Occupation
   d. Locality
   e. Working experience in Agriculture
B. To determine the different roles of GIS in Agriculture

C. To identify the benefits of GIS in Agricultural Decision-making
D. The negative effect or consequences of the GIS in Agricultural sector management

III. METHODOLOGIES

Research Design

This study undertakes exploratory research utilizing a quantitative methodology. The researchers administer a Survey within government offices in agricultural sectors to investigate the significant impact of Geographic Information Systems (GIS). The researchers will employ descriptive statistics to summarize and illustrate the overall trends and patterns within the data.

Research Locale

The research was conducted across the regional, provincial, and municipal levels of the government's agricultural sector, mostly employees from National Irrigation Administration (NIA) and Department of Agriculture (DAR) in the Province of Bulacan, Region III, Republic of the Philippines.

Research Instrument

A self-structured questionnaire governs this study. The Survey contained two sections, the first section included several demographic questions namely age, gender, occupation, locality, and years of work experience in agriculture. The second section comprised the exploration of GIS as a tool for management into three parts: Roles of GIS in Agriculture, Benefits of GIS in Agricultural Decision-Making, and Negative Effects or Consequences of GIS in Agriculture. Each part composed with a series of questions, this question shall give an in-depth overview of the utilization of GIS if it is an adversary or a benefit in enhancing the management of the agricultural sector.

To ensure the validity and reliability of the research instrument, the questionnaire was reviewed by a registered psychometrician. The review focused on assessing the clarity, relevance, and structure of the items to ensure they effectively captured the intended data. Based on the psychometrician's feedback, necessary revisions were made to enhance the instrument's overall quality and appropriateness for the target respondents.

The Survey utilize a 4-point Likert scale, as outlined in the following table:

Rating	Description
4	Strongly Agree
3	Agree
2	Disagree
1	Strongly Disagree

Research Participants

The researchers employ a purposive sampling method, a technique that involves selecting participants based on predetermined criteria. These criteria include:

1. The participant must be a government employee in the agricultural sector;
2. The participant must possess knowledge of Geographic Information Systems (GIS) usage;
3. The participant must be willing to take part in the survey.

Data Gathering and Procedure

The study was executed by sending the online link (https://forms.gle/9Vj54XZbApRnU6v2A) through social networking sites such as Messenger, Viber, and Instagram to random employees of the agricultural sector in Region III from the government agencies particularly NIA and DAR.

Upon obtaining consent, The Survey was administered using the online survey portal Google Forms. Subsequently, the researcher will perform a statistical analysis to interpret and analyze the responses submitted by the participants.

Data Analysis

Descriptive statistical methods were employed to analyze the collected data. These included percentage, mean, and standard deviation. This approach summarizes the central tendencies and variability in participant responses to better understand general trends and differences.

The percentage calculation followed the standard formula: % = (F/N) X 100.

where,

- F = answer
- % = percentage
- N = total number of respondents

The mean and standard deviation was computed using the 4-point Likert scale as response value.

The mean was calculated as: $\mu=\sum(V \times \%)$.

where,

- μ = mean
- % = percentage
- V = response value

Meanwhile, the standard deviation was calculated as: $\sigma=\sqrt{\sum[\% \times (V-\mu)2]}$

where,

- μ = mean
- σ = standard deviation
- % = percentage
- V = response value

The results were then interpreted in relation to the research objectives and existing literature, with key findings presented through structured tables, graphs, and charts for clarity. Detailed explanations accompanied each visualization to ensure accurate and accessible data communication.

IV. RESULTS AND DISCUSSION

1. *Demographic Information*

a. Age Group

Table 1. The survey collected 23 responses across different levels of locality. Regarding demographic background in the context of age, the majority users of the GIS Software were between 31 to 35 years old, the second largest group was 26 to 30 years old and the third group were 20 to 25 years old.Table 1. The survey collected 23 responses across different levels of locality. Regarding demographic background in the context of age, the majority users of the GIS Software were between 31 to 35 years old, the second largest group was 26 to 30 years old and the third group were 20 to 25 years old.

Age Group	No. of Respondents	Percentage
20-25 years	3	13%
26-30 years old	8	34.8%
31-35 years old	9	39.1%
36-40 years old	1	4.4%
41-45 years old	0	0%
Above 45 years old	2	8.7%
Total	23	100%

b. Gender

Table 2. Demographic background in the context of gender 65.2% of responses were male and 34.8% were female.

Gender	No. of Respondents	Percentage
Male	15	65.2%
Female	8	34.8%
Total	23	100%

c. Occupation

Table 3. Result of the survey according to Occupation, 69.6% of the respondents were Engineer, 17.4% were Agricultural Officer and 13.3% were GIS Specialist.

Occupation	No. of Respondents	Percentage
Agricultural Officer	4	17.4%
GIS SPecialist	3	13%
Engineer	16	69.6%
Total	23	100%

d. Locality

Table 4. For Locality level there were 65.2% from Provincial Office, 30.4% from Regional Office, and 4.4% from Municipal Office.

Locality	No. of Respondents	Percentage
Regional Office	7	30.4%
Provincial Office	15	65.2%
Municipal Office	1	4.4%
Total	23	100%

e. Working Experience in Agriculture

Table 5. In terms of working experience, 39. 1% of the respondents were in the range of 4-6 years' experience, 30.4% had 7-10 years of experience, 17.4% had 1-3 years' experience, 8.7% had less than a year of experience, and 4.4% had more than 10 years of working experience in agriculture.

Years of experience in Agriculture Sector	No. of Respondents	Percentage
6-12 months	2	8.7%
1-3 years	4	17.4%
4-6 years	9	39.1%
7-10 years	7	30.4%
More than 10 years	1	4.4%
Total	23	100%

2.1 Roles of GIS in Agriculture

Table 6. The analysis revealed that Strongly Agree has 69.6% of respondents recognized GIS attributes to farm planning and zoning decision; Useful in Soil analysis and Land Suitability Mapping; Supporting precision farming through spatial data; and Improving irrigation planning and water resource management. In Addition, 56.5% of respondents agreed that Geographic Information System (GIS)

significantly helps in monitoring crop health and productivity.

Roles of GIS in Agriculture	4	3	2	1	M	SD	VD
Responses by Percentage (%)							
GIS helps in monitoring crop health productivity	56.5	43.5	0	0	3.57	0.51	Majority Strongly Agree
GIS useful in soil analysis and land suitability mapping	69.6	30.4	0	0	3.70	0.47	Majority Strongly Agree
GIS supports precision farming through spatial data	69.6	30.4	0	0	3.70	0.47	Majority Strongly Agree
GIS improves irrigation planning and water resource management	69.6	30.4	0	0	3.70	0.47	Majority Strongly Agree
GIS attributes to farm planning and zoning decisions	69.6	26.1	4.3	0	3.65	0.57	Majority Strongly Agree

Note: Items with a mean (M) greater than 3.66 were classified as overmean or positive deviation, indicating strong consensus among respondents.

2.2 Benefits of GIS in Agricultural Decision-Making

Table 7. Based on the analysis, it can be concluded that Geographic Information Systems (GIS) play a vital role in modern agriculture by enabling informed decision-making through the provision of clear and accurate land information with 65.2%. Additionally, GIS significantly enhances productivity through precision agriculture practices with 56.5% and contributes to cost reduction by optimizing field operations. Furthermore, GIS supports environmentally sustainable farming practices, as recognized by 52.2% of respondents.

Benefits of GIS in Agricultural Decision Making	4	3	2	1	M	SD	VD
Responses by Percentage (%)							
GIS helps make smart choices by providing clear, accurate information about land	65.2	34.8	0	0	3.65	0.49	Majority Strongly Agree
GIS reduces operational costs by optimizing field activities	52.2	47.8	0	0	3.52	0.51	Majority Strongly Agree
GIS enhances productivity through precision agriculture techniques	56.5	43.5	0	0	3.57	0.51	Majority Strongly Agree
GIS supports environmental sustainability in farming	52.2	47.8	0	0	3.52	0.51	Majority Strongly Agree
GIS provides real - time data that improves crop management	39.1	56.5	0	4.3	3.30	0.70	Majority Agree

Note: Items with a mean (M) greater than 3.51 were classified as overmean or positive deviation, indicating strong consensus among respondents.

2.3 Negative Effects or Consequences of GIS in Agriculture

Table 8. The analysis also explored perceptions of potential negative effects or consequences associated with the use of Geographic Information Systems (GIS) in agriculture. Poor quality of outdated maps can mislead decision making with 60.9%, High cost of GIS technology hinder its adoption by stakeholders and GIS required advanced technical skills with 39.1%, In accurate GIS predictions may result in crop losses with 30.4%

Negative Effects/Consequences of GIS in Agriculture	4	3	2	1	M	SD	VD
Responses by Percentage (%)							
High cost of GIS technology hinders its adoption by stakeholders	39.1	52.2	8.7	0	3.30	0.63	Majority Agree
GIS required advanced technical skills	39.1	47.8	13	0	3.26	0.69	Majority Agree
Over reliance on GIS may reduce traditional farming knowledge	13	43.5	34.8	8.7	2.61	0.84	Majority Agree
Poor quality of outdated maps can mislead decision making	60.9	30.4	8.7	0	3.52	0.67	Majority Strongly Agree
In accurate GIS predictions may result in crop losses	30.4	52.2	17.4	0	3.13	0.69	Majority Agree

Note: Items with a mean (M) greater than 3.16 were classified as overmean or positive deviation, indicating strong consensus among respondents.

The computed means provide direct insight into the overall sentiment for each survey item. For instance, in the Roles of GIS in Agriculture (Table 6) and Benefits of GIS in Agricultural Decision Making (Table 7), the means range from 3.30 to 3.70, reflecting strong agreement among respondents. Conversely, the Negative Effects/Consequences of GIS in Agriculture (Table 8) yields much lower means (2.61 to 3.52), indicating general disagreement with those statements.

Standard deviation values further reveal the consistency of responses. Lower values (e.g., $\sigma \le 0.51$ in Table 6) suggest uniform agreement, while higher values (e.g., $\sigma = 0.84$ for “Over reliance on GIS may reduce traditional farming knowledge” in Table 8) highlight greater variability, stems from a mix of "Agree" (43.5%) and "Strongly Disagree" (8.7%), demonstrating divided opinions.

This approach ensures clarity in interpreting the data, making it easy to identify trends, consensus, and outliers across different aspects of GIS in agriculture. These findings have important implications for policy and implementation, highlighting both the strong technical validation of GIS applications in agriculture and the institutional barriers that need addressing. The results emphasize the need for directed training programs, improved data infrastructure, and inter-departmental coordination to fully realize GIS's potential in public sector agricultural programs. Additionally, the variability of responses points to the importance of context-specific implementation strategies tailored to different government agencies and regional needs.

CONCLUSION

This study set out to explore the usage and role of GIS in enhancing the agricultural sector of the Philippines. The findings of this research demonstrate hopeful indicators on the benefits of the implementation of GIS in agricultural policy and practices. GIS technologies offer more effective methodologies for analyzing spatial elements that impact agricultural production in comparison to methods that lack geographically explicit data. When effectively applied, the spatial insights generated through GIS can support the formulation of data-driven policies and interventions that promote sustainability in the sector. Despite its potential, concerns remain regarding GIS's dependability, accuracy, and policy implications.

The researchers employed a quantitative, exploratory research design integrated by descriptive statistical analysis. The data revealed that various government employees perceived GIS positively on its significance in agriculture. Key benefits include enhanced cropping monitoring, optimized farm planning, and improved irrigation management. However, the variation in responses, particularly regarding negative aspects, suggests that adoption experiences differ based on factors like work experience, locality, and technical capacity. The results highlight the need for targeted solutions to address cost barriers, improve training programs, and ensure data quality.

The study concludes that GIS holds potential in transforming Philippine agriculture practices and enhancing government decision-making. Realizing this potential will require sustained government support in the form of funding, capacity-building, and updated geospatial data infrastructure. Future efforts should focus on making GIS tools more accessible and user-friendly while maintaining their technical rigor, as well as exploring hybrid approaches that integrate GIS with traditional farming knowledge. These steps could help maximize the technology's benefits while mitigating its current limitations. Further research should also examine the integration of GIS with emerging technologies such as real-time data analytics, artificial intelligence, and drone-based systems to further advance agricultural innovation.

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