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Geographic Information System as a Pillar of Agri-Risk Strategy for an Improved Governance

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Abstract:

Agriculture is increasingly exposed to systemic risks arising from climate variability, resource depletion, and extreme weather events, posing significant challenges to global food security and rural livelihoods. Despite rapid technological advancements associated with the Fourth Agricultural Revolution, agricultural risk governance remains fragmented and largely reactive. This study examines the role of Geographic Information Systems (GIS), integrated with Remote Sensing (RS) and Artificial Intelligence (AI), as a foundational pillar for proactive agricultural risk management and improved governance. Using a comprehensive review and analytical synthesis of geospatial applications, the paper evaluates the use of GIS in crop health monitoring, yield estimation, disaster risk assessment, water resource management, and policy support. The study further proposes a triadic framework linking governments, financial institutions, and insurers, demonstrating how spatial intelligence enhances credit appraisal, insurance optimization, and targeted policy interventions. The findings highlight that GIS-enabled integration of agriculture, finance, and governance significantly strengthens resilience, improves resource efficiency, and supports evidence-based decision-making. The study underscores the growing importance of geospatial technologies in transitioning from reactive risk response to anticipatory risk governance, thereby contributing to sustainable agricultural development and long-term food security.

Keywords -Geographic Information System, Agricultural Risk Management, Climate Resilience, Precision Agriculture, Remote Sensing, Agri-Finance and Insurance, Sustainable Agriculture, Evidence-Based Governance

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INTRODUCTION

Agriculture continues to operate under increasing pressure from shrinking arable land, water scarcity, climate variability, and extreme weather events. These challenges pose serious risks to food security, farmer livelihoods, and financial stability across agricultural value chains. While technological advancements have improved productivity, risk governance in agriculture remains fragmented and reactive. In this context, geospatial technologies particularly Geographic Information Systems offer a comprehensive framework for integrating spatial data, analytics, and decision-making. GIS enables governments, farmers, bankers, and insurers to visualize risks, monitor crop dynamics, and implement targeted interventions. This paper explores GIS as a strategic enabler of agricultural risk management and improved governance through a multi-stakeholder approach.

Materials and Methods

Geospatial Data Sources

The study draws upon satellite imagery, NDVI datasets, climatic records, soil maps, hydrological data, and geo-tagged farm information collected through GIS platforms.

Analytical Framework

Spatial analysis techniques were applied to integrate multi-layer datasets covering soil characteristics, crop conditions, irrigation infrastructure, and climate variables. Temporal

analysis of NDVI and weather data was used for crop health monitoring and yield forecasting.

Stakeholder-Centric Approach: The methodology adopts a triadic framework involving governments, financial institutions, and insurers to assess GIS applications in policy formulation, credit appraisal, insurance modelling, and risk mitigation.

Results and Discussion

Despite significant technological progress marking the onset of the Fourth Agricultural Revolution, achieving agricultural resilience remains a formidable challenge worldwide. The sector continues to face critical constraints, including declining arable land, increasing water scarcity, and the intensifying impacts of climate change, all of which threaten the ability to meet the food requirements of a rapidly growing global population. In this context, geospatial technologies integrating Geographic Information Systems (GIS), Remote Sensing (RS), and Artificial Intelligence (AI) offer a robust framework for the sustainable management of agricultural resources and enhanced productivity.

In recent years, these advanced tools have been widely adopted at local, regional, and global scales to support data-driven agricultural planning and decision-making. This article highlights the diverse applications of geospatial techniques in agricultural resource management, including crop growth monitoring, yield estimation and forecasting, detection of crop diseases and pest infestations, land use and land cover analysis, flood assessment, and water resource management. It also examines the key methodologies and analytical approaches employed for monitoring and mapping these agricultural resources using satellite and spatial data.

Furthermore, the article presents a comprehensive review of existing literature on the application of geospatial technologies in agriculture, offering insights into current trends, challenges, and

opportunities. The findings underscore the potential of integrated geospatial methodologies to support sustainable agricultural practices and provide valuable guidance for researchers and practitioners seeking to leverage satellite-based information for long-term agricultural resource management.

Geographic Information System (GIS) is a computer framework which collect geographic data from sources like satellites, drones, GPS etc which is later used for managing and analysing patterns, relationships, and trends.

It is combination of hardware, software, data, people, and methods to solve problems urban planning, climate changes, agriculture, pollution etc and the list is huge for the Governments and other stakeholders to act upon.

Key functions of GIS include collecting, storing, analysing, managing, predicting for decision making, future planning for the benefit of the stakeholders. For example, Plant health can be monitored through GIS data, for pest attack, so this dataset can be used by Policy makers, bankers, Insurers for their activities viz. risk management activities. Governments, farmers and insurers are integrated in the framework for the improved governance as each stakeholder is weaved with the other entity and work for the development of other stakeholder, hence a holistic approach of framework involving triad is explored in this article for building a resilient future for a strong food security.

GIS and Agriculture

GIS in Agricultural Risk Management is revolutionizing how countries tackle climate change,

agriculture and natural disasters with satellite-driven analytics and real-time spatial data, it empowers farmers, bankers, insurers, and policymakers to make smarter, faster and more resilient decisions.

Presently countries agriculture map is no longer static, but it is real time GIS ecosystem provided by data from Earth satellites.

for example, Satellites collect the NDVI data (Normalized Difference Vegetation Index) to measure the vegetation health and assessing changes in plant health.

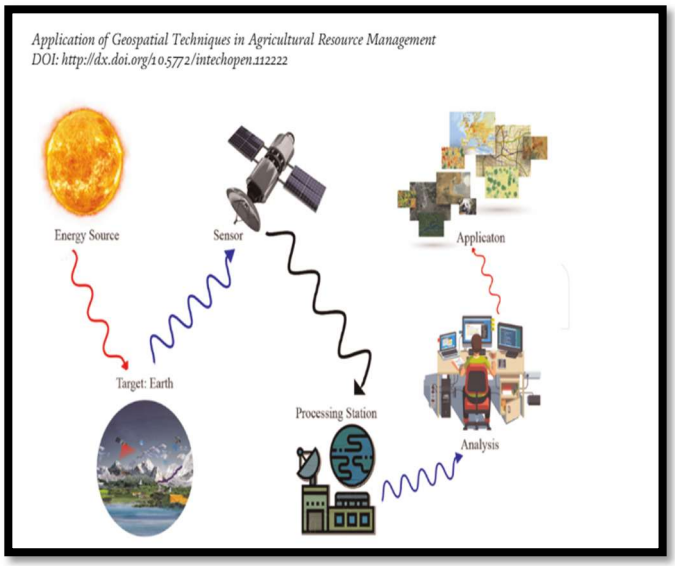
GIS and Risk Management - an overview

Due to climate change, we are witnessing extreme climates, humidity, flooding or drought situations, never experienced in the past, Gulf cities have witnessed huge flooding and deserts covered with ice are new development which we are witnessing.

Leveraging the technology in the triad of Agriculture, Insurance and Governance to align with the global priorities in food security and will meet the needs of future population and needy, thereby reducing the cost and wastage thereby reducing the uncertain future to possibility in future:

1. Precision method of Agriculture

GIS enables tailoring fertilizer, pesticide, and water use to specific field zones. This reduces risk, improve yields and reduces input costs.



2. Climate Resilience

By modelling with the datasets over a period relating to historical weather data with crop cycles, GIS helps farmers identify and shift sowing dates, choose resilient varieties, and adopt appropriate practices.

3. Insurance Optimization

GIS can help to identify the crop loss, flooding of Agri zones using satellite data, to automate the claim verification and proactive risk mitigation measures with predictive analysis.

4. Policy support

GIS data analysis is used by the Governments to direct subsidies, irrigation investments, and disaster relief to the most vulnerable Agri zones.

5. Real-Time Alerts

Mobile-linked GIS platforms send alerts on rainfall, pest outbreaks, and market prices, enabling timely farmer action.

Features of GIS in Agri-Risk Management

The following are the unique features of GIS in Agri-Risk Management:

a. Multi-Layer Mapping: Combines mapping of various parameters of soil type, climatic zones, irrigation availability and coverage, and climate changes

b. NDVI enabled Monitoring: Normalized Difference Vegetation Index to assess crop health and detect changes in health

c. Disaster Risk Analysis: data points enable to map drought, flood, and pest-prone areas for early warning signs and mitigation.

d. Yield Forecasting Models: Predicts output based on weather, soil, and crop inputs.

e. Water Stress and Irrigation Analytics: Tracks aquifer levels, canal flows, and tank health.

f. Geo-Tagged Asset Verification: Validates farm boundaries, crop acreage, and infrastructure for credit and insurance.

GIS use case & Stakeholder applications

Governments use the data points for many policy formulations, some of the areas like Resource allocation, subsidy targeting, disaster response etc

Agriculture Farmers use this for crop planning, soil data, climate data, flood / drought risks, pest alerts, weather forecasts etc.

Bankers use the data for better risk management for credit appraisal, portfolio monitoring, NPA forecasting, product innovation etc.

Insurers leverage the data for risk profiling, premium modelling, claim verification, quick settlements, geo- tagged risk coverage, reinsurance planning etc.

Many other stakeholders use for various requirements viz Farm analytics, advisory services, risk modelling, analysis for better productivity.

GIS and Role of stakeholders- Role of Policy Makers

- ✓ Strategic Planning using GIS to identify vulnerable geographies and allocate resources, irrigation schemes, and disaster relief.
- ✓ Future planning to improve the livelihood to exports, in proactive planning and building capacities in infrastructure with GIS-based risk maps.
- ✓ Monitoring and Evaluation to track performance of their development and making it future proof.
- ✓ Using GIS dashboards for real-time decision-making and budget reallocation.

Role of Bankers

Credit appraisal:

- ✓ Use GIS data to validate land ownership, crop viability, and climate risk before approving loans.
- ✓ Integrate GIS withe internal risk systems for better risk management and can enable end to end digital journeys for quicker approvals

Post-Sanction Monitoring:

- ✓ Monitor crop progress and rainfall via GIS to anticipate cash flow issues or crop losses.
- ✓ Trigger early system for insurance activation based on NDVI datasets
- ✓ Portfolio Risk Management:
- ✓ Visualize exposure and portfolio health assessments across crops, and climate zones.

Role of Insurance Companies

Claim Verification:

- ✓ Use satellite imagery data and NDVI to validate premiums, crop damage and speeding up payouts.
- ✓ Automate insurance triggers based on rainfall or pest thresholds.

Premium Modelling:

Price premiums based on GIS-derived risk scores e.g., flood-prone zones priced slightly more, drought-resilient zones priced less.

Geo-Tagged Policy Issuance:

Policies linked to farm coordinates, ensuring coverage accuracy and avoiding duplication.

Benefits overweigh Challenges

1. High Setup Costs Vs Improved productivity

GIS platforms require investment in software, satellite data, and skilled personnel which is offset by better productivity and reducing input costs.

2. Data Gaps Vs traditional predictions

Rural areas may lack updated soil or crop data, affecting accuracy but the Realtime pattern modelling is a risk mitigant compared to traditional prediction in Agri related crop or climate risks.

3. Capacity building Vs future preparedness

Insurers, Governments, Bankers and farmers need capacity building to interpret GIS outputs in the newer areas for faster, resilience in decision making.

4. Privacy Concerns Vs non availability of data
Geo-tagging farms and assets need to comply with data protection norms is better off compared to non-availability of data in these areas.

5. Interoperability Issues Vs improved data modelling and predictive analytics
Different agencies use varied GIS formats, hindering integration but the needs bridge such differences in the coming days is very evident, as technology is both a bridge and an enabler.

Application of GIS in Sustainable Agriculture
With the rapid growth of the global population, ensuring long-term food security has become a major challenge for policymakers, researchers, and agricultural producers. Geographic Information System (GIS) technology plays a crucial role in addressing this challenge by enabling the systematic analysis, monitoring, and planning of agricultural resources. By integrating spatial data with agronomic, environmental, and socio-economic information, GIS supports informed decision-making aimed at sustaining agricultural productivity while minimizing ecological degradation.
Over the past three decades, international organizations such as the Food and Agriculture Organization (FAO) have extensively employed GIS and allied geospatial technologies to promote sustainable food systems across the world. These technologies assist in identifying optimal land use patterns, assessing soil and water resources, and developing climate-resilient agricultural practices. GIS also supports the transition toward environmentally responsible farming methods, including organic and precision agriculture, by helping farmers select suitable crop types and cultivation areas based on local conditions.
GIS applications in sustainable agriculture extend across multiple domains. They are widely used to monitor water availability, track groundwater levels, and predict drought conditions, thereby enabling efficient water management. Crop yield estimation and forecasting are enhanced through the integration of satellite imagery, weather data, and field observations. Additionally, GIS helps evaluate the economic and environmental impacts of human interventions and natural events such as floods, pest outbreaks, and land degradation.
Another significant advantage of GIS lies in its ability to integrate agricultural data from diverse sources, facilitating comprehensive spatial analysis. This integrated approach improves coordination among government departments, research institutions, and development agencies through shared data platforms and interactive mapping tools.
By embedding spatial intelligence into agricultural planning and policy formulation, GIS strengthens the sustainability and resilience of farming systems. As geospatial technologies continue to advance, their contribution to ensuring sustainable agriculture and long-term food security is expected to grow, making GIS an indispensable tool for the future of global agriculture.

Conclusion
When policy makers, bankers, and insurers collaborate through GIS, they move from reactive firefighting to proactive risk governance. The synergistic framework enables every stakeholder to move from a position of uncertain future to risk mitigant future thereby reducing the losses on future risks and equip them to guard against the future risks. This also ensures that timely credit, Government subsidy, other allocation of resources and insurance are targeted, monitored, and optimized building a resilient agricultural economy ensuring food security for the present and future humankind.

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