Power System Technology
ISSN:1000-3673

Received: 16-02-2026 *Revised: 05-03-2026* *Accepted: 26-04-2026*

The Utilization of Remote Sensing and GIS Integration for Rainfall Distribution Modeling and Drought Prediction in Agricultural Regions

Putu Aryastana [1*], Moh Hamdani [2], Festus Evly R.I. Liow [3]

[1] *Program Studi Rekasaya Infrastruktur dan Lingkungan, Fakultas Pascasarjana Universitas Warmadewa, Indonesia*

[2] *Badan Riset dan Inovasi Nasional, Indonesia*

[3] *Program Studi Teknik Industri, Institut Teknologi Minaesa Tomohon, Indonesia*

**Correspondence Author:* aryastanaputu@warmadewa.ac.id

Abstract: Rainfall variability and drought events pose significant challenges to agricultural sustainability and food security in many regions. Accurate monitoring and prediction of rainfall distribution are therefore essential for effective agricultural planning and water resource management. This study aims to examine the utilization of remote sensing and Geographic Information Systems (GIS) integration for rainfall distribution modeling and drought prediction in agricultural regions. The research employs a qualitative literature review approach to analyze and synthesize findings from previous studies related to the application of geospatial technologies in climate monitoring and drought assessment. The analysis focuses on the role of satellite-based precipitation data, GIS spatial modeling techniques, and environmental indicators used in drought prediction frameworks. The results indicate that remote sensing provides extensive spatial coverage and continuous observation capabilities that enable the monitoring of rainfall variability across large geographic areas. When integrated with GIS-based spatial analysis, these datasets can be transformed into detailed rainfall distribution models that support the identification of drought-prone agricultural zones. The study also finds that effective drought prediction requires the integration of multiple environmental variables, including soil moisture, vegetation conditions, and land surface temperature. Overall, the integration of remote sensing and GIS technologies offers a comprehensive geospatial framework that improves rainfall analysis, supports drought early warning systems, and enhances decision-making for sustainable agricultural management.

Keywords: Remote sensing, GIS, rainfall distribution, drought prediction, agricultural regions.

1. Introduction

Rainfall variability represents one of the most critical climatic factors influencing agricultural productivity, water resource availability, and regional food security. In many agricultural regions, particularly those characterized by seasonal precipitation patterns, uneven rainfall distribution can

Received: 16-02-2026 Revised: 05-03-2026 Accepted: 26-04-2026

significantly affect crop growth cycles and irrigation management. Climate change has further intensified rainfall variability, increasing the frequency and severity of drought events across various parts of the world (Liu et al., 2020). These changes create substantial challenges for farmers, policymakers, and environmental managers who depend on accurate climate information to plan agricultural activities. Traditional rainfall monitoring methods, which rely heavily on ground-based meteorological stations, often suffer from limited spatial coverage and uneven data distribution, especially in rural and developing regions (Hasnaoui et al., 2025). Consequently, the need for more comprehensive and spatially detailed approaches to rainfall monitoring and drought prediction has become increasingly urgent in order to support sustainable agricultural planning and climate adaptation strategies (Weslati & Serbaji, 2024).

Remote sensing technology has emerged as a powerful tool for environmental monitoring due to its ability to capture large-scale spatial data consistently and efficiently. Satellite-based observations provide valuable information related to atmospheric conditions, land surface characteristics, and precipitation patterns across broad geographic areas (Ihinegbu & Ogunwumi, 2022). In the context of rainfall analysis, remote sensing allows researchers to estimate precipitation intensity, track cloud formation, and analyze long-term climatic trends. However, while remote sensing offers extensive spatial coverage, the raw data often require advanced analytical frameworks to transform satellite-derived observations into meaningful hydrological insights (Kemarau et al., 2025). This is where Geographic Information Systems (GIS) play a crucial role, as GIS platforms enable the integration, processing, and visualization of spatial datasets to generate predictive environmental models. The integration of remote sensing data with GIS-based spatial analysis therefore provides a comprehensive approach for understanding rainfall distribution and its implications for agricultural sustainability.

Numerous previous studies have explored the use of remote sensing technologies to analyze rainfall distribution and monitor drought conditions. Several researchers have utilized satellite precipitation datasets to evaluate spatial rainfall variability and identify drought-prone regions (Kazemi Garajeh et al., 2023). Other studies have incorporated GIS-based interpolation techniques to model rainfall patterns across agricultural landscapes. These studies have demonstrated that remote sensing can significantly enhance rainfall estimation accuracy compared to traditional ground-based observations alone (Hussain et al., 2025). Additionally, GIS-based spatial modeling has been widely applied to analyze environmental hazards, including drought risk assessment and water resource management. Despite these advancements, many existing studies focus primarily on either rainfall estimation or drought monitoring separately, rather than developing integrated frameworks that combine rainfall distribution modeling with predictive drought analysis within agricultural systems.

Another limitation observed in prior research concerns the scale and integration of datasets used for environmental modeling. Some studies rely heavily on single-source satellite datasets without incorporating complementary geospatial variables such as land use patterns, soil moisture conditions, topographic variation, or vegetation indices. These environmental factors play a crucial role in determining how rainfall interacts with agricultural landscapes and how drought conditions develop over time. Furthermore, several existing drought prediction models are designed for general climatological assessments and are not specifically tailored to agricultural decision-making processes (Adisa et al., 2020). As a result, farmers and local agricultural planners often lack precise spatial tools capable of identifying early warning signals of drought within specific crop production

Received: 16-02-2026 Revised: 05-03-2026 Accepted: 26-04-2026

zones.

Based on these limitations, a clear research gap emerges regarding the development of integrated spatial models that simultaneously analyze rainfall distribution patterns and predict drought risk using combined remote sensing and GIS approaches. There remains a need for methodological frameworks that not only map rainfall variability but also translate these patterns into actionable drought prediction indicators for agricultural management. Additionally, many agricultural regions still lack high-resolution spatial analyses that incorporate multiple environmental variables to improve drought forecasting accuracy. Addressing this gap requires the integration of multi-source satellite data, spatial interpolation techniques, and GIS-based modeling approaches capable of capturing both climatic and landscape characteristics influencing drought formation.

Therefore, this study aims to develop an integrated rainfall distribution modeling framework using remote sensing data and Geographic Information System (GIS) analysis to support drought prediction in agricultural regions. The novelty of this research lies in the combined application of satellite-derived precipitation data, spatial analysis techniques, and drought risk modeling within a unified geospatial framework designed specifically for agricultural landscapes. By integrating rainfall distribution analysis with drought prediction indicators, this research seeks to provide a more accurate and spatially explicit understanding of climate variability impacts on agricultural systems. Ultimately, the findings of this study are expected to contribute to improved drought early warning systems, enhanced agricultural planning, and more resilient food production strategies in regions vulnerable to climate variability.

Literature Review

Remote Sensing for Rainfall Monitoring and Environmental Observation

Remote sensing technology has become an essential tool in modern environmental monitoring due to its capability to collect large-scale spatial data efficiently and continuously. Satellite-based observations enable researchers to estimate precipitation patterns, atmospheric conditions, and hydrological processes across extensive geographic areas (Danodia et al., 2021). Unlike conventional meteorological stations that provide point-based measurements, remote sensing offers spatially distributed data that can capture rainfall variability across complex landscapes. Several satellite missions provide precipitation datasets with varying spatial and temporal resolutions, enabling detailed analysis of rainfall distribution in regions with limited ground-based observations. The application of remote sensing in rainfall monitoring is particularly valuable in agricultural regions where climate variability significantly affects crop productivity (Chowdhury et al., 2025). Through the analysis of cloud dynamics, atmospheric moisture, and precipitation intensity, remote sensing data allow researchers to identify rainfall anomalies, seasonal trends, and potential drought conditions. Consequently, remote sensing has become a critical component in climate monitoring systems, providing the foundational data necessary for hydrological modeling, environmental assessment, and disaster risk management.

Geographic Information Systems (GIS) in Spatial Climate and Hydrological Modeling

Geographic Information Systems (GIS) provide a powerful platform for integrating, analyzing, and visualizing spatial datasets related to climate and environmental processes. In rainfall distribution studies, GIS enables researchers to process satellite-derived precipitation data and combine it with other geospatial variables such as topography, land use, soil characteristics, and vegetation cover

Received: 16-02-2026 Revised: 05-03-2026 Accepted: 26-04-2026

(Patel & Patel, 2024). Through spatial analysis techniques such as interpolation, spatial overlay, and raster modeling, GIS allows the creation of detailed rainfall distribution maps and environmental risk assessments. The use of GIS in hydrological studies has expanded significantly due to its ability to transform large and complex datasets into interpretable spatial models. Within agricultural contexts, GIS-based analysis helps identify regions vulnerable to water scarcity, irregular precipitation patterns, and potential drought conditions (Sarkar et al., 2020). By integrating multiple environmental variables into a single analytical framework, GIS enhances the accuracy of spatial climate modeling and supports data-driven decision-making for agricultural planning, water resource management, and climate adaptation strategies.

Drought Prediction Models in Agricultural Systems

Drought prediction has become an important research focus due to the increasing frequency of climate-related hazards affecting agricultural production systems worldwide. Traditional drought assessment methods typically rely on historical rainfall records and meteorological observations to identify periods of water deficit (Shahzaman et al., 2021). However, these approaches often lack spatial precision and may not fully capture the complex interactions between climatic factors and land surface conditions. Recent developments in environmental modeling emphasize the integration of climatic, hydrological, and ecological indicators to improve drought prediction accuracy. In agricultural regions, drought conditions are influenced not only by rainfall deficits but also by factors such as soil moisture availability, evapotranspiration rates, vegetation health, and land management practices (Arabameri et al., 2022). Integrating remote sensing datasets with GIS-based spatial modeling has enabled the development of more sophisticated drought prediction frameworks capable of identifying early warning signals of water stress within agricultural landscapes. These integrated approaches provide valuable insights for farmers, policymakers, and environmental managers seeking to mitigate the impacts of drought on food production and rural livelihoods (Senapati & Das, 2024).

2. Method

Research Design

This research adopts a qualitative literature review design to examine scholarly publications that discuss the application of remote sensing and GIS technologies in rainfall distribution analysis and drought prediction. The design allows the researcher to critically analyze and synthesize various methodological approaches, analytical models, and research findings from previous studies. By employing this design, the study not only summarizes existing research but also evaluates the strengths, limitations, and scientific contributions of prior work. This process facilitates the identification of emerging research patterns and theoretical developments within the field of geospatial climate analysis and agricultural drought assessment.

Data Sources and Literature Selection

The data used in this study consist of secondary data derived from academic literature, including peer-reviewed journal articles, scientific conference proceedings, scholarly books, and relevant research reports. Literature was collected from reputable academic databases that provide high-quality scientific publications in the fields of environmental science, geospatial technology, and agricultural climate studies. The literature search process was conducted using several primary keywords such as remote sensing for rainfall estimation, GIS-based rainfall distribution modeling, drought prediction in agricultural regions, and spatial climate analysis. Only publications that directly discuss the application of remote sensing datasets, GIS spatial analysis techniques, or drought monitoring in agricultural environments were considered for inclusion in this study.

Literature Screening and Inclusion Criteria

A systematic screening process was applied to ensure that only the most relevant and credible sources were included in the analysis. The first stage involved initial identification of literature based on titles and keywords that matched the research topic. The second stage involved abstract screening, where the relevance of each publication to rainfall distribution modeling, remote sensing applications, or drought prediction was evaluated. The final stage consisted of a full-text review, where the complete content of the selected articles was carefully examined to ensure that they provided significant methodological or conceptual contributions to the study. Publications that did not address spatial analysis, rainfall monitoring, or drought prediction within agricultural contexts were excluded from the final dataset.

Data Extraction and Thematic Analysis

After the relevant literature had been selected, the next stage involved systematic data extraction from each source. Key information collected from the literature included research objectives, data sources used (such as satellite precipitation datasets), GIS analysis methods, modeling approaches, and the main findings related to rainfall distribution and drought prediction. The extracted data were then analyzed using thematic analysis, which involved categorizing the findings into several thematic groups such as satellite-based rainfall estimation methods, GIS spatial modeling techniques, and drought prediction frameworks in agricultural systems. This thematic categorization enabled the identification of similarities, methodological differences, and emerging research trends within the existing body of literature.

Synthesis and Interpretation

The final stage of the research involved synthesizing and interpreting the analyzed literature to construct a comprehensive understanding of the integration between remote sensing and GIS for rainfall distribution modeling and drought prediction. At this stage, findings from different studies were compared and integrated to identify methodological advancements, practical applications, and limitations of previous research. The synthesis process also facilitated the identification of research gaps and opportunities for further investigation in the field of spatial climate modeling for agricultural systems. Ultimately, the results of this synthesis provide a conceptual foundation for understanding how geospatial technologies can support improved drought early warning systems and more effective agricultural resource management.

Power System Technology
ISSN:1000-3673

Received: 16-02-2026 *Revised: 05-03-2026* *Accepted: 26-04-2026*

3. Result and Discussion

Result

Trends in the Use of Remote Sensing for Rainfall Distribution Analysis

The analysis of the reviewed literature indicates a significant increase in the use of remote sensing technologies for rainfall distribution analysis in agricultural regions. Many studies emphasize that satellite-based precipitation datasets provide broader spatial coverage compared to traditional ground-based rain gauge measurements (Ali et al., 2025). Remote sensing platforms allow researchers to monitor precipitation patterns continuously across large geographic areas, including regions with limited meteorological infrastructure. This capability is particularly important in agricultural zones where rainfall variability directly influences crop productivity and irrigation planning (Hakam et al., 2023) As a result, satellite-derived rainfall data have become an essential source for environmental monitoring and climate analysis.

Several studies demonstrate that remote sensing datasets are capable of capturing spatial variability in precipitation patterns across different agricultural landscapes. These datasets enable researchers to identify areas experiencing rainfall deficits or irregular precipitation patterns that may lead to drought conditions (Nandgude et al., 2023). Furthermore, the temporal resolution of many satellite systems allows the monitoring of seasonal rainfall fluctuations, which is crucial for understanding agricultural water availability during planting and growing seasons. By examining multi-year satellite precipitation records, researchers can also detect long-term climatic trends that influence rainfall variability.

In addition, the reviewed studies reveal that remote sensing data are frequently combined with other environmental indicators to improve rainfall monitoring accuracy. Variables such as vegetation indices, soil moisture conditions, and land surface temperature are often integrated into rainfall assessment models (Kumar et al., 2024). These complementary datasets provide additional insights into how rainfall interacts with agricultural landscapes. Consequently, remote sensing has become a critical data source for spatial rainfall analysis, enabling more detailed observation of climatic conditions affecting agricultural productivity.

Table 1. Trends in the Use of Remote Sensing for Rainfall Distribution Analysis

Aspect	Description / Findings
Usage Trend	The use of remote sensing technology for rainfall distribution analysis has increased significantly, especially in agricultural regions.
Spatial Coverage Advantage	Satellite-based precipitation datasets provide broader spatial coverage compared to traditional rain gauge measurements.
Continuous Monitoring	Remote sensing platforms allow continuous monitoring of rainfall patterns across large geographic areas, including regions with limited meteorological infrastructure.
Agricultural Benefits	Satellite-derived rainfall data are essential for irrigation planning and managing crop productivity due to rainfall variability.
Spatial Variability	Remote sensing datasets capture spatial variability in precipitation across

Received: 16-02-2026 *Revised: 05-03-2026* *Accepted: 26-04-2026*

Aspect	Description / Findings
	different agricultural landscapes, helping identify areas with rainfall deficits or irregular patterns.
Temporal Resolution	Many satellite systems provide temporal resolution that enables monitoring seasonal rainfall fluctuations, which is important for water availability during planting and growing seasons.
Long-Term Trend Analysis	Multi-year satellite precipitation records allow detection of long-term climatic trends affecting rainfall variability.
Integration with Other Environmental Data	Rainfall data are often combined with other environmental indicators such as vegetation indices, soil moisture, and land surface temperature to improve monitoring accuracy.
Benefits of Combined Datasets	Additional datasets provide insights into how rainfall interacts with agricultural landscapes, enhancing spatial rainfall analysis.
Conclusion	Remote sensing has become a critical data source for spatial rainfall analysis, enabling more detailed observation of climatic conditions affecting agricultural productivity.

Application of GIS in Rainfall Distribution Modeling

The literature analysis shows that Geographic Information Systems (GIS) play a fundamental role in transforming raw precipitation data into spatial rainfall distribution models. GIS platforms allow researchers to organize, process, and visualize geospatial datasets in a structured analytical environment (Szewczak et al., 2020). Through spatial analysis techniques, rainfall data obtained from remote sensing or meteorological stations can be converted into detailed distribution maps that illustrate precipitation variability across agricultural regions. These spatial models provide a visual representation of rainfall patterns, making it easier to identify areas with different levels of precipitation intensity.

Many studies apply GIS-based interpolation techniques to estimate rainfall distribution across areas where direct measurements are unavailable. These interpolation methods enable researchers to generate continuous rainfall surfaces from discrete observation points or satellite-derived precipitation grids (Chandel, 2025). The resulting spatial models provide detailed information about rainfall gradients and geographic variations in precipitation patterns. Such spatial representations are particularly useful in agricultural planning, as they help identify regions that receive insufficient rainfall and may require additional water management strategies.

Furthermore, GIS-based rainfall modeling often incorporates multiple environmental layers that influence precipitation distribution. Topography, land cover, soil characteristics, and watershed boundaries are commonly included in spatial analyses to improve the accuracy of rainfall distribution models. By integrating these environmental variables into a GIS framework, researchers can better understand how geographic factors shape rainfall patterns across agricultural landscapes. The reviewed literature highlights that this integrative capability makes GIS an essential tool for spatial climate analysis and environmental modeling.

Received: 16-02-2026 Revised: 05-03-2026 Accepted: 26-04-2026

Table 2. Applications of GIS in Modeling Rainfall Distribution

Aspect	Description / Findings
Role of GIS	GIS transforms raw precipitation data into spatial rainfall distribution models by organizing, processing, and visualizing geospatial datasets in a structured analytical environment.
Spatial Analysis & Visualization	GIS allows spatial analysis of rainfall data from remote sensing or meteorological stations, producing detailed distribution maps that illustrate precipitation variability across regions.
Interpolation Techniques	GIS-based interpolation converts discrete rainfall measurements or satellite-derived grids into continuous rainfall surfaces, providing detailed spatial information about rainfall gradients.
Agricultural Applications	Spatial rainfall models help identify regions with insufficient rainfall, informing irrigation planning and other water management strategies in agricultural landscapes.
Integration of Environmental Layers	GIS models often incorporate topography, land cover, soil characteristics, and watershed boundaries to improve accuracy and understand geographic influences on rainfall distribution.
Benefits of GIS Modeling	Integrative GIS capability enables researchers to generate precise and comprehensive rainfall distribution maps, supporting decision-making in agriculture, water resource management, and climate studies.

Identification of Drought Indicators in Agricultural Areas

Drought conditions in agricultural regions are typically identified through a combination of climatic and environmental indicators. One of the most frequently used indicators is rainfall deficit, which occurs when precipitation levels fall below the long-term average for a specific period. Many studies analyze rainfall anomalies derived from remote sensing datasets to detect early signs of drought development. These anomalies help determine whether a region is experiencing abnormal reductions in precipitation that may threaten agricultural production.

In addition to rainfall deficits, land surface indicators are important for assessing drought conditions. Vegetation health, soil moisture levels, and evapotranspiration rates are often used to evaluate how rainfall shortages affect agricultural ecosystems. Satellite-derived vegetation indices are commonly applied to monitor plant stress caused by insufficient water availability. When vegetation conditions deteriorate simultaneously with declining rainfall levels, areas experiencing increasing drought severity can be identified.

Furthermore, combining multiple drought indicators improves the reliability of drought monitoring systems. Instead of relying solely on precipitation data, many researchers integrate climatic, hydrological, and ecological indicators to assess drought risk more comprehensively. This multidimensional approach provides a more accurate representation of drought conditions in agricultural landscapes. By examining several environmental variables simultaneously, early warning signals of water stress that may affect crop production can be detected.

Received: 16-02-2026 Revised: 05-03-2026 Accepted: 26-04-2026

Table 3. Key Indicators for Identifying Drought in Agricultural Areas

Indicator Type	Specific Indicator	Measurement / Data Source	Purpose / Function
Climatic Indicator	Rainfall Deficit	Rain gauge, Satellite precipitation datasets	Detect regions with below-average precipitation; provide early warning for drought
Vegetation Indicator	Vegetation Health / NDVI	Satellite-derived vegetation indices	Monitor plant stress due to insufficient water; identify areas of crop vulnerability
Soil Indicator	Soil Moisture	Remote sensing soil moisture datasets, in-situ sensors	Assess water availability in the soil; detect water stress on crops
Hydrological Indicator	Evapotranspiration Rate	Remote sensing, meteorological models	Understand water loss from soil and vegetation; evaluate overall drought severity
Integrated Indicator	Multi-variable Index	Combination of rainfall, vegetation, soil, and hydrological data	Provide comprehensive assessment of drought risk; improve early warning reliability

Integrated Remote Sensing and GIS Approaches for Drought Prediction

The final result of the literature analysis highlights the growing adoption of integrated remote sensing and GIS frameworks for drought prediction in agricultural regions. Many studies emphasize that combining satellite-derived environmental data with GIS-based spatial modeling enables more comprehensive drought assessment. Remote sensing provides large-scale environmental observations, while GIS offers analytical tools for integrating and interpreting these datasets within a spatial context (Kulkarni et al., 2020). This integration allows researchers to analyze how rainfall variability interacts with landscape characteristics to influence drought formation.

Several studies demonstrate that integrated geospatial models can identify spatial patterns of drought vulnerability across agricultural regions. By combining rainfall distribution data with environmental variables such as land use patterns, soil characteristics, and topographic features, researchers can develop spatial risk maps that highlight areas susceptible to drought conditions (Mullapudi et al., 2023). These maps provide valuable information for agricultural planners and policymakers who need to allocate water resources efficiently and implement drought mitigation strategies.

The reviewed literature indicates that integrated remote sensing and GIS models contribute to the development of early warning systems for drought events. Through continuous monitoring of climatic and environmental indicators, these systems can detect changes in rainfall patterns and environmental conditions before severe drought impacts occur. Such predictive capabilities are particularly valuable in agricultural regions where timely decision-making is essential to minimize crop losses (Zhang et al., 2023). Consequently, the integration of remote sensing and GIS technologies represents an important advancement in spatial climate analysis and agricultural drought management.

Table 4. Integration of Remote Sensing and GIS for Drought Prediction in Agricultural Regions

No	Data Source (Remote Sensing)	GIS Analysis Method	Environmental Variables Integrated	Output of Analysis	Contribution to Drought Prediction
1	Satellite-based precipitation datasets	Spatial interpolation and rainfall surface modeling	Rainfall intensity, temporal rainfall variability	Rainfall distribution map	Identifies areas with rainfall deficit that may indicate early drought conditions
2	Land surface temperature imagery	Raster overlay and spatial correlation analysis	Temperature anomaly, evapotranspiration potential	Temperature anomaly map	Detects abnormal surface heating associated with water stress
3	Vegetation index data (NDVI/EVI)	Vegetation health monitoring through GIS classification	Vegetation condition, plant stress indicators	Vegetation health map	Identifies agricultural areas experiencing vegetation degradation due to water scarcity
4	Soil moisture satellite data	Spatial overlay and multi-layer environmental analysis	Soil moisture level, soil water availability	Soil moisture distribution map	Indicates areas with declining soil water availability affecting crop growth
5	Multi-source satellite datasets	Integrated spatial modeling and drought risk mapping	Rainfall variability, vegetation health, soil moisture, land use patterns	Drought vulnerability map	Provides spatial prediction of drought-prone agricultural zones

Discussion

The findings of this study demonstrate that the integration of remote sensing and Geographic Information Systems (GIS) plays a significant role in improving the understanding of rainfall distribution patterns in agricultural regions. Remote sensing technologies provide spatially continuous precipitation data that enable the monitoring of rainfall variability across large geographic areas. This capability is particularly valuable in regions where ground-based meteorological stations are limited or unevenly distributed. By utilizing satellite-derived precipitation datasets, researchers can observe rainfall dynamics with greater spatial coverage and temporal consistency. The results indicate that such datasets contribute to more comprehensive rainfall assessments, allowing researchers to identify areas that experience significant rainfall variability. In agricultural contexts, this information is essential because precipitation patterns directly influence crop growth cycles, irrigation requirements, and seasonal agricultural planning.

Another important finding highlighted in this study is the role of GIS in transforming large volumes of climatic data into meaningful spatial information. GIS-based spatial analysis techniques enable researchers to visualize rainfall distribution through detailed geographic models that represent precipitation intensity across different regions. These models help identify spatial patterns that may not be easily recognized through traditional statistical analysis alone. The use of GIS also allows the integration of multiple environmental datasets within a single analytical framework. By combining rainfall data with other spatial variables such as land use, soil characteristics, and topographic features, researchers can better understand the environmental factors that influence precipitation distribution and water availability within agricultural landscapes.

The results further indicate that rainfall variability alone is not sufficient to fully explain drought conditions in agricultural systems. Drought formation is a complex environmental phenomenon influenced by multiple climatic and ecological variables. The literature reviewed in this study highlights that rainfall deficits must be analyzed together with other indicators such as soil moisture conditions, vegetation health, and evapotranspiration levels. These environmental indicators provide additional information about how rainfall shortages affect agricultural ecosystems. For instance, vegetation stress detected through satellite-based vegetation indices often reflects the impact of prolonged water scarcity on crop productivity. Therefore, the integration of multiple environmental indicators becomes crucial for accurately identifying drought-prone areas.

The findings reveal that the integration of remote sensing datasets with GIS-based spatial analysis provides a more comprehensive framework for drought monitoring and prediction. Remote sensing contributes large-scale environmental observations, while GIS enables the processing and interpretation of these datasets within spatial analytical models. This integrated approach allows researchers to analyze the relationships between rainfall variability, environmental conditions, and agricultural vulnerability. As a result, integrated geospatial models can generate spatial drought risk maps that highlight areas with higher susceptibility to water shortages. These spatial models provide valuable insights that can support agricultural planning and resource management decisions.

Another significant implication of the study is related to the potential use of integrated remote sensing and GIS models in developing drought early warning systems. Early detection of drought conditions is essential for minimizing the negative impacts of water shortages on agricultural production. By continuously monitoring climatic variables and environmental indicators, geospatial analysis systems can detect early signs of rainfall anomalies and vegetation stress before severe drought conditions occur. Such predictive capabilities allow farmers, agricultural planners, and policymakers to implement mitigation strategies, including water allocation planning, crop selection adjustments, and improved irrigation management practices.

Overall, the discussion highlights that the integration of remote sensing and GIS technologies represents a promising approach for advancing climate monitoring and drought prediction in agricultural regions. The synthesis of the reviewed literature suggests that geospatial technologies can significantly enhance the accuracy of rainfall distribution modeling and drought assessment. By combining multiple environmental datasets within a spatial analytical framework, researchers can develop more reliable predictive models for climate-related agricultural risks. Consequently, this integrated approach contributes not only to scientific advancements in environmental modeling but also to practical applications in sustainable agricultural management and climate resilience planning.

Conclusion

This study highlights the significant role of integrating remote sensing technology and Geographic Information Systems (GIS) in improving rainfall distribution modeling and drought prediction in agricultural regions. The findings from the qualitative literature review indicate that satellite-based remote sensing data provide extensive spatial coverage and continuous monitoring capabilities that

Received: 16-02-2026 Revised: 05-03-2026 Accepted: 26-04-2026

are essential for analyzing rainfall variability across large geographic areas. Compared to conventional ground-based measurements, remote sensing offers more comprehensive datasets that allow researchers to observe spatial precipitation patterns with greater detail. When combined with GIS-based spatial analysis, these datasets can be transformed into meaningful geographic models that illustrate rainfall distribution and environmental conditions affecting agricultural landscapes.

The results demonstrate that drought prediction in agricultural systems requires the integration of multiple environmental indicators rather than relying solely on rainfall data. Variables such as soil moisture, vegetation health, land surface temperature, and evapotranspiration significantly influence the development of drought conditions. The integration of these variables through GIS-based spatial modeling enables researchers to identify drought-prone areas more accurately and to generate spatial drought risk maps. Such models provide valuable information for understanding how climatic variability interacts with landscape characteristics to influence agricultural water availability and crop productivity.

In conclusion, the integration of remote sensing and GIS technologies offers a comprehensive analytical framework for climate monitoring and drought risk assessment in agricultural regions. This integrated geospatial approach not only enhances the accuracy of rainfall distribution analysis but also supports the development of early warning systems for drought events. By providing spatially explicit information on climatic and environmental conditions, the application of these technologies can assist policymakers, agricultural planners, and farmers in making more informed decisions regarding water resource management and agricultural adaptation strategies in response to climate variability.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this study.

Acknowledgment

The authors would like to sincerely thank everyone who has contributed to the successful completion of this study.

References

1. Adisa, O. M., Masinde, M., Botai, J. O., & Botai, C. M. (2020). Bibliometric analysis of methods and tools for drought monitoring and prediction in Africa. *Sustainability*, *12*(16), 6516.
2. Ali, A., Jat Baloch, M. Y., Naveed, M., Nigar, A., Almalki, A. S., Rasool, A. G., Gedfew, M. A., & Arafat, A. A. (2025). Advanced satellite-based remote sensing and data analytics for precision water resource management and agricultural optimization. *Scientific Reports*, *15*(1), 27527.
3. Arabameri, A., Chandra Pal, S., Santosh, M., Chakrabortty, R., Roy, P., & Moayedi, H. (2022). Drought risk assessment: integrating meteorological, hydrological, agricultural and socio-economic factors using ensemble models and geospatial techniques. *Geocarto International*, *37*(21), 6087–6115.
4. Chandel, A. S. (2025). Mapping drought risks in agriculture: a GIS and remote sensing study of Nagele Arsi district, Ethiopia. *Cogent Food & Agriculture*, *11*(1), 2525319.
5. Chowdhury, G., Mandal, S., & Saha, A. K. (2025). An innovative ensemble approach of deep learning models with soft computing techniques for GIS-based drought-zonation mapping in Rarh Region, West Bengal. *Environmental Science and Pollution Research*, *32*(27), 16295–16323.
6. Danodia, A., Kushwaha, A., & Patel, N. R. (2021). Remote sensing-derived combined index for agricultural drought assessment of rabi pulse crops in Bundelkhand region, India. *Environment, Development and Sustainability*, *23*(10), 15432–15449.
7. Hakam, O., Baali, A., Azennoud, K., Lyazidi, A., & Bourchachen, M. (2023). Assessments of drought

effects on plant production using satellite remote sensing technology, GIS and observed climate data in Northwest Morocco, case of the lower Sebou Basin. *International Journal of Plant Production*, *17*(2), 267–282.

8. Hasnaoui, Y., Tachi, S. E., Bouguerra, H., Yaseen, Z. M., Gilja, G., Szczepanek, R., & Navarro-Pedreño, J. (2025). Integrated remote sensing and deep learning models for flash flood detection based on Spatio-temporal land use and cover changes in the mediterranean region. *Environmental Modeling & Assessment*, *30*(5), 1013–1035.
9. Hussain, N., Saifuzzaman, M., Alam, M. S., & Ahamed, M. S. (2025). Assessing the impact of Long-Term drought on agriculture in Bangladesh using multisource remote sensing data. *Earth Systems and Environment*, 1–24.
10. Ihinegbu, C., & Ogunwumi, T. (2022). Multi-criteria modelling of drought: a study of Brandenburg Federal State, Germany. *Modeling Earth Systems and Environment*, *8*(2), 2035–2049.
11. Kazemi Garajeh, M., Salmani, B., Zare Naghadehi, S., Valipoori Goodarzi, H., & Khasraei, A. (2023). An integrated approach of remote sensing and geospatial analysis for modeling and predicting the impacts of climate change on food security. *Scientific Reports*, *13*(1), 1057.
12. Kemarau, R. A., Suab, S. A., Eboy, O. V., Sa'adi, Z., Echoh, D. U., & Sakawi, Z. (2025). Integrative approaches in remote sensing and GIS for assessing climate change impacts across Malaysian ecosystems and societies. *Sustainability*, *17*(4), 1344.
13. Kulkarni, S. S., Wardlow, B. D., Bayissa, Y. A., Tadesse, T., Svoboda, M. D., & Gedam, S. S. (2020). Developing a remote sensing-based combined drought indicator approach for agricultural drought monitoring over Marathwada, India. *Remote Sensing*, *12*(13), 2091.
14. Kumar, V., Sharma, K. V., Pham, Q. B., Srivastava, A. K., Bogireddy, C., & Yadav, S. M. (2024). Advancements in drought using remote sensing: assessing progress, overcoming challenges, and exploring future opportunities: V. Kumar et al. *Theoretical and Applied Climatology*, *155*(6), 4251–4288.
15. Liu, X., Zhu, X., Zhang, Q., Yang, T., Pan, Y., & Sun, P. (2020). A remote sensing and artificial neural network-based integrated agricultural drought index: Index development and applications. *Catena*, *186*, 104394.
16. Mullapudi, A., Vibhute, A. D., Mali, S., & Patil, C. H. (2023). A review of agricultural drought assessment with remote sensing data: Methods, issues, challenges and opportunities. *Applied Geomatics*, *15*(1), 1–13.
17. Nandgude, N., Singh, T. P., Nandgude, S., & Tiwari, M. (2023). Drought prediction: a comprehensive review of different drought prediction models and adopted technologies. *Sustainability*, *15*(15), 11684.
18. Patel, R., & Patel, A. (2024). Evaluating the impact of climate change on drought risk in semi-arid region using GIS technique. *Results in Engineering*, *21*, 101957.
19. Prodhan, F. A., Zhang, J., Yao, F., Shi, L., Pangali Sharma, T. P., Zhang, D., Cao, D., Zheng, M., Ahmed, N., & Mohana, H. P. (2021). Deep learning for monitoring agricultural drought in South Asia using remote sensing data. *Remote Sensing*, *13*(9), 1715.
20. Rabie, A. B., Elhag, M., & Subyani, A. (2025). Remote sensing, GIS, and machine learning in water resources management for arid agricultural regions: a review. *Water*, *17*(21), 3125.
21. Sarkar, H., Soni, S., Ahmad, I., & Verma, M. K. (2020). Assessment of agricultural drought in upper Seonath Sub-Basin of Chhattisgarh (India) using remote sensing and GIS-based indices. *Journal of the Indian Society of Remote Sensing*, *48*(6), 921–933.
22. Senapati, U., & Das, T. K. (2024). Geospatial assessment of agricultural drought vulnerability using integrated three-dimensional model in the upper Dwarakeshwar river basin in West Bengal, India. *Environmental Science and Pollution Research*, *31*(41), 54061–54088.
23. Shahzaman, M., Zhu, W., Ullah, I., Mustafa, F., Bilal, M., Ishfaq, S., Nisar, S., Arshad, M., Iqbal, R., & Aslam, R. W. (2021). Comparison of multi-year reanalysis, models, and satellite remote sensing products for agricultural drought monitoring over South Asian countries. *Remote Sensing*, *13*(16),

Received: 16-02-2026 Revised: 05-03-2026 Accepted: 26-04-2026

3294.

24. Szewczak, K., Łoś, H., Pudełko, R., Doroszewski, A., Gluba, Ł., Łukowski, M., Rafalska-Przysucha, A., Słomiński, J., & Usowicz, B. (2020). Agricultural drought monitoring by MODIS potential evapotranspiration remote sensing data application. *Remote Sensing*, *12*(20), 3411.
25. Weslati, O., & Serbaji, M.-M. (2024). Spatial assessment of soil erosion by water using RUSLE model, remote sensing and GIS: a case study of Mellegue Watershed, Algeria–Tunisia. *Environmental Monitoring and Assessment*, *196*(1), 14.
26. Zhang, J., Ding, J., Wang, J., Lin, H., Han, L., Li, X., & Liu, J. (2023). Remote sensing drought factor integration based on machine learning can improve the estimation of drought in arid and semi-arid regions: Remote sensing drought factor integration based on machine learning can improve the estimation of drought in arid and semi-arid regions. *Theoretical and Applied Climatology*, *151*(3), 1753–1770.