Recent Trends of Machine Learning Techniques on The Growth of Agricultural Sector of Assam

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Abstract: The agricultural sector in Assam, India, holds immense potential for economic growth and rural development. However, harnessing this potential requires tackling challenges like low productivity, resource scarcity, and climate change. Machine learning (ML) emerges as a promising tool to address these hurdles and transform Assam’s agricultural sector. This review investigates the potential of machine learning (ML) techniques in driving agricultural growth within the specific context of the Assam’s economy. Utilizing comprehensive search within Scopus and Web of Science databases from 2015 to 2023, and following the PRISMA guidelines, we analyzed 37 relevant articles. Our examination focuses on the multifaceted applications of MLacross various agricultural domains in Assam, encompassing crop yield prediction, soil health analysis and economic growth. The review highlights successful ML- driven interventions in Assam’s agricultural sector, showcasing their ability to improve resource efficiency, optimize cropmanagement, and enhance market access. This review provides valuable insights forpolicymakers, researchers, and farmers seeking to leverage the power of ML for a more sustainableand prosperous Assam’s agricultural landscape.

Keywords: Machine Learning, Agriculture, Assam, Crop Yield, Soil Health, Economic growth, Rural development.

1. INTRODUCTION

Assam's agricultural sector stands at the crossroads of tremendous opportunity and formidable challenges. Despiteits potential for economic growth and rural development, issues such as low productivity, resource scarcity, and the impacts of climate change threaten to impede progress [1]. In this context, machine learning (ML) emerges asa promising tool to revolutionize agricultural practices and unlock the sector's full potential [5].
Machine Learning (ML), a subset of AI, demonstrates significant potential in advancing various aspects of Agriculture, defined as a computer program or system capable of learning specific tasks without explicit programming [1–3]. This involves decision-making based on multiple data inputs, where data refer to sets of examples. Supervised learning tasks often utilize labeled data, while unsupervised learning tasks involve unlabeled data for identifying patterns and structures [2]. Large datasets are crucial for ML accuracy, and in agriculture, acquiring diverse data can be challenging yet pivotal. IoT sensors play a crucial role in collecting agricultural data, strategically deployed to capture information on soil conditions, climate variables, crop health, and livestock metrics [4].
The widespread adoption of IoT facilitates continuous, real-time data acquisition, generating extensive datasets over time. However, data quality is paramount for representativeness in specific case studies. In crop management,studying different crop stages is crucial for accurate model development applicable to real-world scenarios.

Despite the time investment required to obtain representative datasets, it is crucial for the effectiveness and reliability of ML applications in agriculture. Collaborative efforts with farmers, agricultural institutions, and research organizations can enhance data pooling and contribute to the success of ML applications [5-8].
This review aims to investigate the potential of ML techniques in driving agricultural growth within the unique context of Assam's economy. Through a comprehensive analysis of relevant literature, we seek to highlight successful ML-driven interventions and their impact on resource efficiency, crop management, and market access.

2. METHODOLOGY

2.1. Research Design:

The research design for this systematic review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, a widely recognized and respected framework in the field of evidence synthesis as shown in figure 1. The utilization of PRISMA guidelines in the research design enhances the credibility and reliability of the systematic review, contributing to the robustness of the investigation into the potential of machine learning techniques in driving agricultural growth in Assam's unique economic context. Comprehensive searches were undertaken within two reputable academic databases, namely Scopus and Web of Science. These databases were selected due to their extensive coverage of scholarly articles across various disciplines. The search aimed to identify relevant articles published within a specific timeframe, spanning from 2015 to 2023. By limiting the search to this period, the researchers ensured that the review encompassed the most recent and up-to-date literature available, offering a contemporary understanding of the application of machine learning (ML) techniques in Assam's agricultural sector. Utilizing these well-established databases enhances the likelihood of capturing a broad and representative range of scholarly works, contributing to the robustness and comprehensiveness of the systematic review's findings and insights.

2.2 Search Strategy:

The search strategy employed for this systematic review was carefully designed to comprehensively identify relevant articles pertaining to the application of machine learning (ML) techniques in Assam's agricultural sector. A strategic combination of keywords was utilized to maximize the precision and relevance of the retrieved literature. The inclusion of terms such as "Machine Learning," "Agriculture," "Assam," "Crop Yield," "Soil Health," "Economic growth," and "Rural development" aimed to cover a broad spectrum of aspects relevant to the study's focus. This comprehensive approach ensured that articles encompassing various dimensions of ML applications in Assam's agriculture, including crop yield prediction, soil health analysis, and economic growth, were captured in the search results.

2.3 Inclusion Criteria:

A total of 37 articles were meticulously selected for analysis based on specific inclusion criteria. These articles were required to have been published between 2015 and 2023, ensuring that the literature considered was recent and reflective of the contemporary landscape of machine learning (ML) applications in Assam's agricultural sector. The selected articles were further filtered for relevance, specifically focusing on their engagement with ML techniques within the context of Assam's agricultural domain. The inclusion criteria also emphasized that the chosen articles addressed key aspects crucial for the region's agricultural development, including crop yield prediction, soil health analysis, economic growth, and rural development. This rigorous selection process aimed to ensure that the analyzed literature would provide a comprehensive and up-to-date understanding of the multifaceted applications of ML in addressing the unique challenges and opportunities within Assam's agricultural landscape.

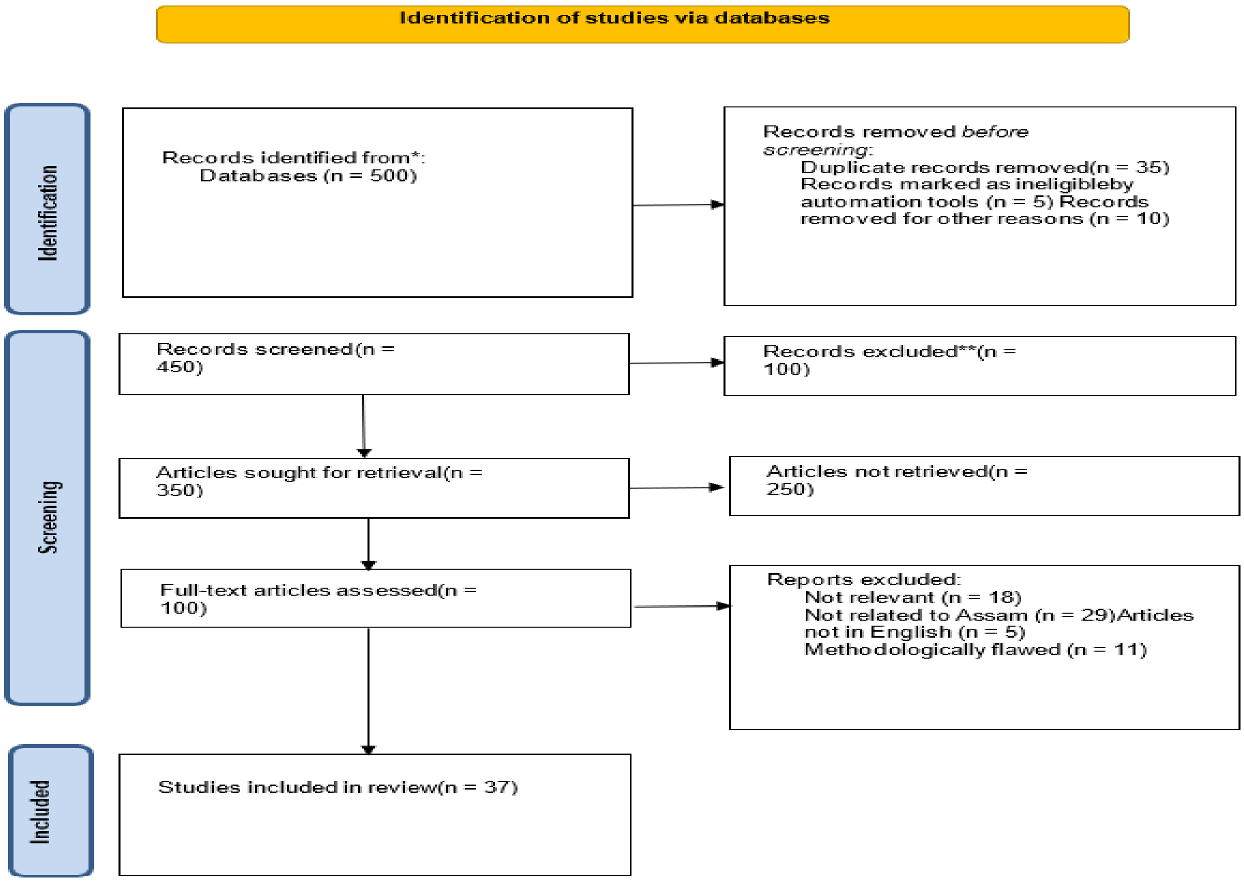

Figure1: PRISMA Framework for study

3. RESULTS

During our comprehensive analysis, we identified a total of 37 articles that conformed to the established inclusioncriteria. These selected articles encompassed a diverse array of machine learning (ML) applications, incorporatinga broad spectrum of topics within the realm of Assam's agricultural sector. The scope of these articles extended beyond a singular focus, covering a multitude of ML applications. These applications, though not exhaustively listed, included, but were not limited to:

3.1 Machine Learning in Agriculture in Assam

Machine Learning (ML) has emerged as a transformative tool in the agricultural sector, contributing to advancements in various domains. In a study by Bhuyan et al. [9], a crop recommendation system was formulatedfor the Biswanath district of Assam, aiming to optimize crop selection based on soil physical properties. By analyzing 180 soil samples and employing ML models, the study successfully developed a farmer-friendly crop recommendation system. Dwivedi et al. [10] utilized ML time series models to predict Tea Pest Looper infestationin Assam, employing Random Forest, Cubist, Extreme Gradient Boosting, and Support Vector Machine models.The study demonstrated the effectiveness of the Random Forest model in predicting Soil Organic Carbon (SOC)content in the Lakhimpur district [11]. In another context, Reyana et al. [11] presented a Multisensor Machine- Learning Approach for agriculture text classification, classifying eight crops based on sensor data. Additionally, Agarwal et al. [12] analyzed extreme annual rainfall in North-Eastern India using ML techniques, including Multiple Linear Regression, Generalized Additive Models, and the Random Forest method. Finally, Nath et al.

[13] utilized a geospatial ML technique to predict the distribution of arsenic in groundwater in Assam, identifying potential hotspots and high-risk zones. These studies collectively underscore the diverse applications of ML in addressing agricultural challenges, from crop recommendation to pest prediction, soil quality assessment, flood vulnerability mapping, and groundwater contamination prediction. Here's a comparative table for the selected studies:

Study	[9]	[10]	[11]	[12]	[13]
Objective	Formulate a crop recommendation system based on soil physical property	Simulating area infested by Helopeltis in tea gardens	Digital mapping of Soil Organic Carbon (SOC)	Accelerating Crop Yield, Multisensor Data Fusion, Machine Learning for Agriculture Text Classification	Analysis of extreme annual rainfall in North-Eastern India using machine learning techniques
Machine Learning Models	Decision Tree Classifier Model	Stacked Models	RF, Cubist, XGBoost, SVM	J48 Decision Tree, Hoeffding Tree, Random Forest	MLR, GAMs, RF
Main Findings	Results of the physical properties were fit in the machine learning model	Stacked Models perform better	RF optimal for predicting SOC	Random Forest algorithm has the lowest error measure; Multisensor data fusion enhances precision	GAM outperforms MLR and RF for predicting rainfall
Key Predictors	Soil physical properties	Temperature, time series characteristics	Topographic variables, vegetation and soil indices	Multisensor data	Latitude, longitude, altitude, temperature
Performance Metrics	Accuracy= 94%	Stacked Model (NN + TS) = 0.8512, Panel Series Neural Network = 0.9454, Seasonal Model= 1.0558	RF: R2c = 0.966, RMSEc = 0.159%, R2v = 0.418, RMSEv = 0.377%	Random Forest - RMSE at 13%, RAE at 38.67%, RRSE at 44.21%	COD and NSE of GAM predictions significantly better

3.2 Machine Learning in Agricultural Growth

Leveraging machine learning techniques for the economic growth of the agriculture sector in Assam holds significant promise in transforming the region's agrarian landscape [16-20]. Assam, with its diverse topography and agricultural practices, can benefit immensely from the application of machine learning in optimizing various aspects of farming operations [13]. These techniques can be employed in crop yield prediction, soil health analysis,pest and disease detection, and precision farming practices. Machine learning algorithms can analyze vast datasets,including historical agricultural data, weather patterns, and soil conditions, to develop predictive models for cropyields [6-10]. By understanding the intricate relationships between different variables, these models can provide valuable insights for farmers to enhance productivity and resource efficiency. Additionally, machine learning cancontribute to early detection of crop diseases and pests, enabling timely interventions to prevent significant yield losses [10-11]. Machine learning (ML) applications in agriculture have proven instrumental in optimizing input use efficiency and addressing challenges in crop cultivation. Bhoi et al. [16] conducted a study across pan-India paddy cultivation, employing a stochastic frontier approach to assess technical efficiency. The research highlighted variations in mean technical efficiency across states, with machine learning algorithms, specifically random forest models, exhibiting a mean accuracy of 0.80 in predicting farmers' efficiency classes. The study's approach, using input parameters for classification and prediction, offers a valuable technique for assessing and enhancing efficiency in paddy cultivation for each state. Additionally, Mili and Buragohain [17] examined constraints on agricultural development in Assam, emphasizing the state's reliance on agriculture for economic sustenance. Despite fertile soil and favorable climatic conditions, traditional farming practices and limited use ofmodern technology hinder agricultural growth. The study aims to identify and address these constraints, proposing measures to enhance the state's agricultural productivity. Furthermore, Bansal et al. [18] explored ML models based on satellite imagery for predicting socio-economic indicators. Evaluating temporal transferability, the study demonstrated the effectiveness of ML models in predicting an aggregate development index at the district level, showcasing the potential of satellite-based ML applications in guiding data-driven policy-making for informed decision-making at different spatial and temporal scales. These studies collectively underscore the diverse applications of machine learning in agriculture, from efficiency optimization in paddy cultivation to addressing constraints in agricultural development and predicting socio-economic indicators using satellite data.

Furthermore, the implementation of precision agriculture, facilitated by machine learning, allows for the targetedapplication of resources such as water, fertilizers, and pesticides. This not only optimizes resource utilization butalso minimizes environmental impact. The integration of IoT devices and sensors in agriculture, coupled with machine learning algorithms, can create a smart farming ecosystem that continuously monitors and manages various parameters, leading to improved decision-making for farmers [21-24]. Collaborative efforts between researchers, policymakers, and local farmers are essential to tailor machine learning solutions to the specific challenges faced by Assam's agriculture sector [16] [25]. This may involve developing customized models that
account for regional variations in climate, soil types, and crop preferences [27-31]. In summary, harnessing machine learning techniques in Assam's agriculture sector has the potential to boost economic growth by

enhancing productivity, optimizing resource utilization, and fostering sustainable farming practices. The development and adoption of these technologies can contribute significantly to the overall prosperity of Assam'sagricultural community. Numerous machine learning models are employed to delineate flood-prone areas and assess the health of tea leaves, facilitating proactive management [35-37]. Simultaneously, artificial intelligence systems forecast alternative crops based on soil and climate data, aiming to optimize land utilization and minimizeassociated risks [32-34]. Here's a comparative table for the selected studies:

Studies	Machine Learning Model / Objective	Main Findings	Key Predictors	Performance Metrics
[14]	Predicting the distribution of arsenic (As) in groundwater in Assam, India, for public health implications	Identified As hotspots in groundwater using a random forest model. 25% of the land area identified as high-risk zone.	Intrinsic and extrinsic predictor variables related to As occurrence in groundwater.	Probabilities of As at concentrations >10 µg/L, ternary hazard probability map.
[15]	Generating flood vulnerability maps for Kamrup Metropolitan District, Assam	MaxEnt machine learning and Analytical Hierarchy Process (AHP) used. MaxEnt outperformed AHP with AUC of 0.83.	Topographical wetness index, elevation, slope.	Area under the curve (AUC) for MaxEnt (0.83) and AHP (0.76).
[16]	Predicting efficiency of paddy cultivation in different states of India	Used machine learning to predict farmers' efficiency class based on input parameters. Random forest model achieved the highest mean accuracy of 0.80.	Various input parameters related to paddy cultivation.	Accuracy of machine learning models (Random forest achieved highest accuracy of 0.80).
[17]	Studying constraints of agricultural development in Assam	Evaluated constraints in Assam's agriculture. Focused on low productivity, traditional farming techniques, and low usage of modern machines.	Not specified	Not specified
[18]	Temporal prediction of socio-economic indicators using satellite imagery	Evaluated temporal transferability of a machine learning model using Indian census data for 2001 and 2011. Achieved high accuracy in predicting a district-level development index based on satellite data.	Satellite data for socio-economic indicators.	Accuracy of predicting district-level development index based on satellite data.
[19]	Crop prediction model using machine learning algorithms	Explored the impact of machine learning algorithms on optimizing crop production. Recommended the use of IoT sensor data for informed decisions.	Fifteen different machine learning algorithms.	Classification accuracy of different machine learning algorithms (e.g., 99.59% using Bayes Net).
[20]	Review of machine learning applications in agriculture	Reviewed applications of machine learning in crop, water, soil, and animal management. Highlighted impacts,	Not specified	Not specified

		outcomes, and challenges.		
[21]	Strategies for doubling farmers' income through KISAN–MITrA	Discussed strategies for doubling farmers' income in Vidarbha region of Maharashtra and Bundelkhand region of Uttar Pradesh. Emphasized moisture conservation, millets-based crop systems, and technology use.	Moisture conservation practices, millets-based crop systems, mechanization, ICT in agriculture.	Not specified
[22]	Transforming Indian Agriculture through Digital Platforms	Explored the role of digital platforms in supporting Indian agriculture. Discussed initiatives like soil health card portal, e-NAM, AI, and agri start-ups.	Digital platforms for soil health, market information, AI, climate-smart technologies.	Not specified
[23]	Project Institutions to support intensification, integrated decision making, and inclusiveness in agriculture in the East Gangetic Plain	Aimed to enhance adoption of alternative farming practices in the East Gangetic Plain through improved institutional settings.	CASI (Conservation Agriculture with Sustainable Intensification) principles, institutional settings.	Not specified
[24]	ML techniques, Deep Learning	Application in smart agriculture using WSNs and ML. Focus on labeled/structured data and deep learning for vast data.	Sensor data, ML techniques	Not specified in the provided information
[25]	Deep Learning models	Framework for spatial mapping and time series analysis using helpline data. Forecasting topic-wise demand for help.	Farmers' helpline call-log records	AUROC, Accuracy, Precision, Recall, F1 score
[26]	Artificial Intelligence	AI's role in providing information on crops, land, weather for improved crop productivity. Focus on eNAM in India.	AI, Internet, Large Data Analytics, eNAM	Not specified in the provided information
[27]	Not specified	Review of evapotranspiration approaches and concepts.	Evapotranspiration concepts	Not specified in the provided information
[28]	Regression algorithms, Remote Sensing	Prediction of soil water content and actual evapotranspiration using regression algorithms and remote sensing data.	Vegetation indices, Regression algorithms	RMSE, R^2, MAE, NSE
[29]	Random Forest, Extreme Gradient Boosting	Decision-tree models for water table depth forecasting in cranberry fields.	Precipitation, Previous WTD values, Evapotranspiration	Mean Squared Error, Coefficient of Determination, Nash-Sutcliffe Efficiency
[30]	Hybrid algorithm, Principal Components Analysis	Prediction model for daily reference	Ra, RH, Tmax, Tmin, U2	RMSE, R^2, MAE, NSE

		crop evapotranspiration in Southwest China.		
[31]	Multiple regression, Machine Learning models	Comparison to predict soil organic matter and soil moisture content from cell phone images.	Color and texture features	RMSE, R^2
[32]	Time series model	Analysis of sericulture production trend in Assam and development of a time series model for forecasting.	Mann-Kendall test, Sen’s slope	Not specified in the provided information
[33]	Hybrid machine learning	Spatial analysis of flood hazard zoning map using a novel hybrid machine learning technique in Assam.	22 flood-causative factors	AUROC, Accuracy, Precision, Recall, F1 score
[34]	WSN, ML Algorithms	Crop recommendation system using WSN and ML Algorithms.	Soil moisture, Soil pH, Rainfall, Temperature	Not specified in the provided information
[35]	1-D CNN, MLR, KNN	Estimation of tea leaf chlorophyll using 1-D CNN. Comparison with MLR and KNN.	Extracted color features	Accuracy, MAE, RMSE
[36]	NDVI, SR, TVI	Evaluation of vegetation indices for green leaf tea yield prediction. Innovative use of NDWI and TCT for waterlogging mapping.	NDVI, SR, TVI	Not specified in the provided information
[37]	Random Forest	Monitoring tea plantations during 1990–2022 in Assam using multi-temporal satellite data.	Landsat-5, Sentinel-2	Precision, Recall, F1 score

Discussion

This research underscores the transformative potential of machine learning (ML) in reshaping Assam's agriculturallandscape. Going beyond its applications in crop selection, yield prediction, and pest control, ML provides a comprehensive approach to optimizing farming practices, mitigating risks, and promoting sustainability. ML's keycontributions include facilitating data-driven decision-making by analyzing extensive datasets, enabling informedchoices in crop selection and resource allocation. Moreover, ML-driven precision agriculture ensures targeted useof water, fertilizers, and pesticides, minimizing environmental impact. The proactive risk management capabilitiesof ML, encompassing flood mapping, pest prediction, and disease detection, empower farmers to take preventativemeasures, enhancing resilience and adapting to changing environmental conditions. The economic growthpotential is evident in optimized yields, improved resource efficiency, and reduced risks, translating into increasedagricultural productivity, promoting rural development, and improving livelihoods. However, challenges such asdata availability and quality, the need for model adaptation to regional variations, and addressing infrastructure and digital literacy gaps must be addressed to fully harness the benefits of ML in agriculture. Collaborative efforts between farmers, researchers, and institutions are crucial to overcome these challenges and ensure the effective integration of ML technologies tailored to the specific needs of Assam's agriculture.

Conclusion

The transformative impact of machine learning on Assam's agriculture is becoming increasingly evident, positioning itself as a pivotal force for positive change in the region. By actively tackling existing challenges andfostering collaborative efforts, Assam has the potential to harness this game-changing technology to usher in an era of sustainable agricultural growth. The integration of machine learning holds the promise of not only improving economic prosperity but also empowering the rural communities that form the backbone of Assam's agricultural landscape. Embracing a future-oriented perspective, Assam's agricultural sector can derive immensebenefits from the adoption of data-driven solutions and the promotion of precision practices. It is imperative to adapt machine learning methodologies to the unique context and specific needs of the region, ensuring a tailoredand effective approach. Through the collaborative synergy of various stakeholders, Assam can pave the way for athriving, resilient, and future-ready agricultural sector that will continue to flourish for generations to come.

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