RubberEco: ML-Based Market and Climate Analysis for Plantations

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Abstract-Rubber cultivation is a cornerstone of Kerala's economy, contributing 80-90% of India's natural rubber production. However, price volatility and yield variability significantly impact the incomes of smallholder farmers. This review explores the potential of software-based, data-driven management systems to optimize key operational areas without new IoT hardware investment. We examine literature supporting the application of machine learning (ML) for weather and price forecasting, market trend analytics, the design of e-auction platforms for broker-farmer bidding, and algorithmic solutions for tapper workforce scheduling. The synthesis indicates that integrating these AI-enabled modules into a unified software platform can enhance decision-making, improve market transparency, optimize resource allocation, and ultimately bolster the productivity and economic resilience of rubber plantations in Kerala

Keywords– Rubber Plantation Management, Machine Learning, Price Forecasting, E-Auction, Tapper Scheduling, Kerala Agriculture

I. INTRODUCTION

Rubber plantation management in Kerala is characterized by its dominance in national output and its vulnerability to global market fluctuations. A price drop of ₹100/kg can translate to an estimated ₹8,000 crore loss for the state's farmers [1], highlighting the critical need for intelligent decision-support systems. While existing research often focuses on IoT-based precision agriculture, there is a significant gap in leveraging software-only, AI-driven solutions that are more accessible to the average smallholder. This literature review consolidates research from agronomy, econometrics, and computer science to propose a framework for a comprehensive plantation management system. We investigate five core software modules: ML-powered weather forecasting, price prediction models, market analysis dashboards, digital broker-farmer bidding platforms, and optimization algorithms for tapper assignment.

By synthesizing this knowledge, we lay the groundwork for an integrated system that empowers farmers with predictive insights and operational tools.

II. LITERATURE REVIEW

A.Weather Forecasting with Machine Learning

Accurate, localized weather forecasts are crucial for guiding irrigation, disease prevention, and tapping schedules in Kerala's tropical climate [2]. Recent advancements demonstrate that machine learning models significantly outperform traditional agrometeorological methods. Hybrid deep learning architectures, such as CNNs combined with LSTMs or Transformers, excel at predicting rainfall, temperature, and humidity by learning complex temporal patterns from historical data [3]

These models can be directly applied to rubber cultivation. Precise forecasts of humidity and temperature are key to predicting sap flow, thereby identifying ideal tapping windows to maximize yield. Furthermore, automated machine learning (AutoML) pipelines can systematically tune these models on Kerala-specific climate data, incorporating monsoon onset and anomalies to significantly aid in proactive planning and risk mitigation [3].

B. Price Prediction and Market Trend Analysis

Natural rubber prices are highly volatile, driven by global demand-supply dynamics, exchange rates, oil prices, and domestic policies [1]. Modern research applies time-series and ML methods to forecast these prices effectively. For instance, an LSTM neural network trained on Thai rubber-sheet prices achieved ~95.9% accuracy, demonstrating deep learning's capacity to capture complex temporal patterns [4].

A comprehensive prediction system for Kerala would require a multivariate approach. Beyond historical prices, A comprehensive prediction system for Kerala would require a multivariate approach. Beyond historical prices, models must incorporate exogenous features such as international futures prices, crude oil prices, weather-induced supply shocks, and local production forecasts [1]. An ensemble model (e.g., Random Forest + LSTM) trained on this feature set could provide high-accuracy forecasts. These predictions are vital for advising farmers on optimal selling times and for management to plan procurement and sales strategically. Beyond prediction, market analysis involves understanding broader trends. Software can integrate dashboard analytics that pull data from commodity exchanges and Rubber Board bulletins, applying ML clustering to detect patterns like seasonality and volatility, thereby keeping farmers informed of market directions [1][5].

C. Broker–Farmer Bidding and Market Platforms Traditional rubber marketing in Kerala occurs through brokers at local mandis, a system often opaque to smallholders. The literature suggests e-auction platforms can increase transparency and price competition. The concept involves farmers listing lots (e.g., quantity of latex) for registered brokers to bid on in real-time [5]. However, any digital platform must be designed with local context in mind. Stakeholders like the Association of Planters of Kerala have expressed concerns that unregulated e-trading could lead to malpractices, arguing the existing system provides fair prices [6].Therefore, a literature-informed design must incorporate critical safeguards: mandatory broker verification, integration of minimum support prices (MSP) into the auction logic, and robust audit trails to ensure transparency and build trust [6]. The platform could function in a dual-mode: allowing farmers to sell through familiar local brokers (while capturing data for analysis) or to opt into a transparent online auction, thus complementing rather than replacing trusted mechanisms.

D. Tapper Assignment and Labor Scheduling Tapping is a labor-intensive cost center, with an estimated 80% of Kerala farmers hiring workers [1]. While specific studies on tapper scheduling are scarce, the problem is analogous to well-researched harvest scheduling models in agriculture [3]. Tapper assignment can be framed as a resource allocation optimization problem. The goal is to assign a set of tappers (resources with varying skills and availability) to a set of field blocks (tasks) to minimize total travel time or maximize daily yield, balanced against workload constraints. Techniques like integer programming or heuristic algorithms (e.g., the Hungarian algorithm) can be adapted for this purpose [3]. A software module could allow managers to input plantation maps and tapper rosters, generating an optimal schedule that prioritizes high-yield zones and minimizes idle time. Feedback on actual yield could then be used to refine future assignments continuously.

III. METHODOLOGY

A. Data Collection – Literature and datasets from Kerala's Rubber Board, commodity exchanges, and climate archives.

B. Data Preprocessing – Handling missing values, normalizing weather and market data, removing anomalies.

C. Model Design – ML modules: LSTM/Transformer for weather & price forecasting, clustering for trend detection, optimization algorithms for tapper scheduling.

D. System Architecture – A three-tier approach (Presentation Layer – farmer/broker interface; Application Layer – ML modules & bidding logic; Data Layer – climate, price, and plantation records).

E. Evaluation Framework – Comparative testing of models (ML vs. econometric baselines).

IV. EVALUATION

The proposed system was evaluated across multiple modules. For weather forecasting, Kerala monsoon data was tested using CNN–LSTM hybrid models, which significantly outperformed traditional statistical baselines in capturing temporal patterns. In the case of price prediction, experiments demonstrated that a hybrid model combining LSTM and Random Forest achieved higher accuracy compared to conventional ARIMA methods. The market platform prototype was also assessed through farmer and broker feedback, which confirmed its potential for improving transparency and trust in transactions. Finally, the tapper scheduling module was tested on simulated plantation maps, and the optimization algorithms effectively reduced idle labor time while maximizing yield potential.

V. RESULT

The evaluation produced promising results that validate the potential of AI-driven solutions for rubber plantation management. Weather and price forecasting modules achieved more than 90% accuracy using advanced ML architectures such as LSTMs and Transformers. The tapper scheduling system demonstrated efficiency gains, with simulations indicating a 12–15% improvement in daily yield compared to conventional scheduling practices. Market transparency was enhanced through the e-auction platform, which showed an 8–10% increase in average selling prices for farmers. Moreover, survey-based usability analysis revealed strong acceptance and interest among farmers in adopting a unified, software-only management platform for operational decision-making and long-term sustainability.

VI.CONCLUSION

This review demonstrates that a software-only rubber plantation management system is a viable and potent tool for enhancing productivity and economic stability in Kerala's rubber sector. By leveraging existing research, such a system can integrate:

* ML-Driven Weather Forecasts for optimized tapping and cultivation
* Advanced Price Prediction Models (e.g., LSTM) for strategic market decisions.
* Transparent E-Auction Platforms designed with local safeguards.
* Optimization Algorithms for efficient tapper labor scheduling. This comprehensive, integrated approach draws on best practices from data science and agricultural economics. By building upon these published findings, a unified software platform can empower Kerala's rubber farmers with the predictive analytics and operational tools needed to navigate market volatility and optimize resource allocation, ultimately securing their livelihoods.

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