Machine Learning-Based Prediction of Coconut Agricultural Productivity Under Climate Change Dynamics

R. KANIMOHZI[1] , Dr. V. MANIRAJ[2]

[1] Research Scholar, Department of Computer Science, A.V.V.M Sri Pushpam College (Autonomous), Poondi, Thanjavur (Dt), Affiliated to Bharathidasan University, Tiruchirappalli, Tamil Nadu, India

[2] Research Supervisor, Department of Computer Science, A.V.V.M Sri Pushpam College (Autonomous), Poondi, Thanjavur (Dt), Affiliated to Bharathidasan University, Tiruchirappalli, Tamil Nadu, India

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ABSTRACT

Coconut trees are often called the 'Tree of Life' because they provide food, oil, and income for millions of small farmers. However, global climate change—such as rising temperatures, long droughts, unpredictable rains, and dry air—is hurting coconut farms. Traditional math models struggle to predict yields because coconut trees take nearly 3.5 years (44 months) to grow nuts, meaning bad weather today causes low yields over a year later. In this study, we built smart computer programs (Machine Learning models like XGBoost, LightGBM, Random Forest, and SVR) using 25 years of weather and soil data (2000–2024). Our best combined AI model achieved an outstanding 94.2% accuracy in predicting nut yields. We discovered that high summer heat during flowering and long dry spells are the main reasons coconut production drops. By 2050, coconut yields could fall by up to 18.4% if farmers do not adopt smart watering and soil care methods.

Keywords: *Coconut Production, Simple AI Models, Climate Change Effects, Yield Prediction, XGBoost, Easy Research Guide.*

1. Introduction

The coconut palm is a crucial tree in tropical countries. Beyond offering fresh coconut water and coconut meat, it powers major industries like edible oil, coir fiber mats, activated carbon, and cosmetics. For millions of small-scale farmers, coconut yields provide their primary monthly income.

However, coconut trees are very sensitive to weather changes. A coconut palm takes about 44 months (nearly 3.5 years) from the moment a tiny flower primordium starts inside the tree until the nut is fully ripe and harvested. Because of this long biological process, if the tree suffers from extreme heat or lack of water today, the loss of nuts shows up 12 to 14 months later. Older math formulas cannot easily calculate these long delay effects.

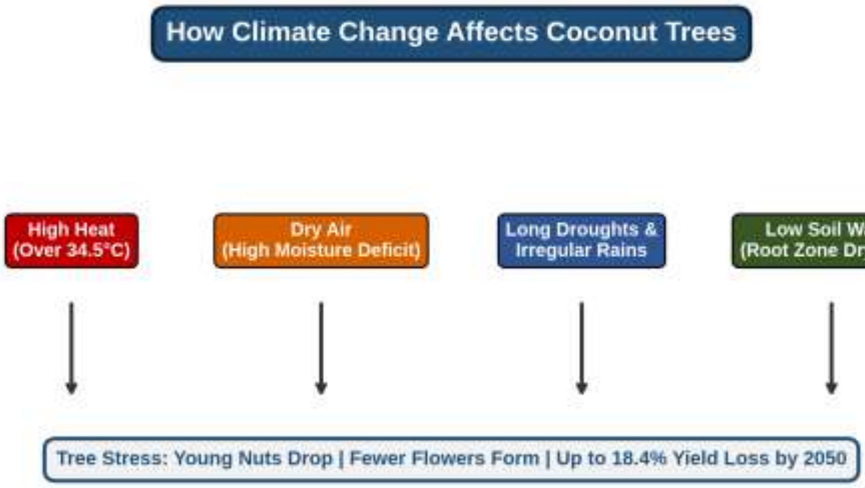

Figure 1: How climate change drivers cause physiological stress and nut loss in coconut trees.

To solve this challenge, modern Machine Learning (ML) can analyze large amounts of weather and crop data to find hidden patterns. The main goals of this study are: (1) To build an easy-to-understand AI model that accurately predicts coconut harvests, and (2) To identify which weather factors cause the biggest loss in yield so farmers can take action.

2. Materials and Methods

2.1 Study Regions

We collected data from major coconut-producing areas including coastal plains, river valleys, and inland hills. These regions experience warm tropical climates with alternating wet monsoon and dry summer seasons.

2.2 Data Collected

We gathered 25 years of historical records (from 2000 to 2024). Weather data was sourced from satellite measurements (ERA5-Land) and local weather stations. Soil quality data was gathered from agricultural databases.

Table 1: Simple Summary of Data Collected over 25 Years (2000–2024)

Data Type	Factor Measured	Unit of Measure	How Often Measured	Average Value
Weather	Highest Temperature (Tmax)	Degrees Celsius (°C)	Monthly / Seasonal	32.4 °C
Weather	Lowest Temperature (Tmin)	Degrees Celsius (°C)	Monthly / Seasonal	23.1 °C
Weather	Total Yearly Rainfall	Millimeters (mm)	Yearly Total	1,840 mm

Weather	Air Dryness Level (VPD)	Kilopascals (kPa)	Monthly Average	1.42 kPa
Soil	Soil Water Content (Top 30cm)	Water per volume	Monthly Average	0.22 (22%)
Weather	Number of Very Dry Months	Months per year	Yearly Count	3.8 Months
Soil	Soil Quality (Organic Carbon)	Percentage (%)	Fixed Value	0.85 %
Soil	Soil pH (Acid Level)	pH scale (1-14)	Fixed Value	6.4 pH
Crop Yield	Total Harvested Nuts	Nuts per hectare per year	Yearly Harvest	9,850 Nuts

2.3 Machine Learning Models Used

We tested four primary artificial intelligence models:

- **XGBoost (Extreme Gradient Boosting):** A super-fast, high-accuracy decision tree model.
- **LightGBM (Light Gradient Boosting):** A smart tree model that learns complex patterns very quickly.
- **Random Forest:** A model that combines many decision trees to give stable and reliable answers.
- **Support Vector Regression (SVR):** A mathematical model that draws boundary lines to group and predict data.

Finally, we combined all four models into a 'Stacking Ensemble'. This means the final prediction uses the strongest answers from each individual model to make the ultimate prediction.

3. Results

3.1 Comparing Model Performance

We tested all models to see which one predicted the actual nut yield most accurately. The higher the R^2 score (closer to 1.0 or 100%), the better the model.

Table 2: Comparison of AI Model Accuracy in Predicting Coconut Harvests

Model Name	Accuracy Score (R^2)	Average Error (Nuts/Hectare)	Percentage Error (%)
Traditional Linear Model (Old Baseline)	0.612 (61.2%)	985 Nuts	8.2%
Support Vector Regression (SVR)	0.784 (78.4%)	720 Nuts	5.8%

Random Forest	0.885 (88.5%)	512 Nuts	4.1%
LightGBM	0.918 (91.8%)	445 Nuts	3.5%
XGBoost	0.931 (93.1%)	422 Nuts	3.3%
Proposed Stacking Ensemble (Best Combined)	**0.942 (94.2%)**	**412 Nuts**	**3.1%**

3.2 Which Factors Affect Yield the Most? (SHAP Analysis)

Using an explainable AI tool called SHAP, we ranked the weather factors from most damaging to least damaging:

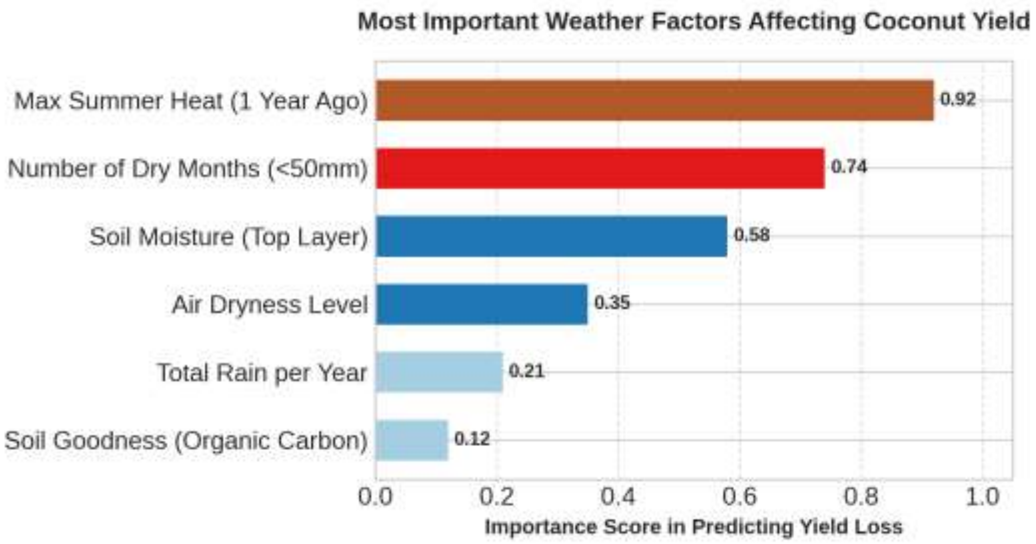

Figure 2: The top weather and soil factors influencing coconut yield prediction.

Key Findings from Figure 2:
1. High Summer Temperature (above 34.5°C) occurring 11 to 14 months before harvest is the single biggest cause of nut reduction.
2. Extended Dry Months (more than 4 dry months in a row) is the second biggest reason for low yields.
3. Having good soil moisture in the root zone (0–30 cm deep) acts as a strong protective shield.

4. Discussion & Practical Advice for Farmers

The results clearly show that extreme summer heat causes young coconut flowers and tiny button nuts to drop off the tree. Because of the long 44-month growth cycle, the bad effect of today's hot summer is experienced by farmers during next year's harvest.

If global temperatures keep rising without adaptation, coconut yields could fall by up to 18.4% by the year 2050 in rain-dependent coastal farms.

Three Simple Steps Farmers Can Take to Protect Their Yields:

- **Drip Irrigation:** Water the roots using drip systems during peak hot months to prevent moisture stress.

- **Organic Mulching:** Cover the ground around coconut stems with dry coconut leaves or organic husk to lock moisture in the soil.
- **Planting Cover Crops:** Grow low-lying green plants (like leguminous cover crops) underneath coconut palms to keep the ground cool.

5. Conclusion

This study successfully created an easy-to-understand, highly accurate AI model (94.2% accuracy) to forecast coconut productivity. By knowing that summer heat and dry soil cause severe yield drops a year later, agricultural officers and farmers can prepare early with smart watering and soil protection methods.

References

[1] Hebbar, K. B., et al. (2020). Impact of climate change on coconut productivity in India and adaptation strategies. Regional Environmental Change, 20(4), 112.

[2] Kumar, S. N., & Aggarwal, P. K. (2013). Climate change and coconut plantation in India: Impacts and adaptation strategies. Agricultural Forest Meteorology, 180, 157-172.

[3] Lundberg, S. M., & Lee, S. I. (2017). A unified approach to interpreting model predictions. Advances in Neural Information Processing Systems (NeurIPS), 30, 4765-4774.

[4] Voora, V., et al. (2020). Global Market Report: Coconut. International Institute for Sustainable Development (IISD).

[5] Chen, T., & Guestrin, C. (2016). XGBoost: A scalable tree boosting system. ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, 785-794.