Mathematical Foundations and Computational Techniques for Emerging Technologies
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Mathematical Model For Plant Height Growth And Resource Optimization Under Climate Uncertainty Using Computational Techniques

Dr.M.Archana
Department of Mathematics, SRR Government Arts and Science College(A), Karimnagar, Telanagana, India.

Abstract- Plant growth is a complex biological process influenced by environmental conditions and resource availability. This study develops a mathematical framework to model plant height using linear, exponential, and logistic growth models. A regression model is used to study the effect of water, fertilizer, and sunlight, and a constrained optimization problem is formulated to maximize plant height. To incorporate real-world variability, the model is extended to a stochastic differential equation under climate uncertainty. A case study based on ICAR growth-stage data is used to validate the model. Graphical analysis and optimization results demonstrate that optimal resource allocation significantly improves plant growth. The study highlights the importance of mathematical foundations and computational techniques in emerging technologies such as precision agriculture and smart farming.

Keywords- Plant growth modeling, linear growth model, exponential growth model, logistic growth model, regression analysis, resource optimization, water and fertilizer effects, sunlight influence, constrained optimization, stochastic differential equations, climate uncertainty, ICAR data analysis, precision agriculture, smart farming, computational modeling.

I. INTRODUCTION

Mathematical modelling plays an essential role in understanding biological systems and developing modern technological applications. In agriculture, plant height is an important indicator of growth and productivity.

This study aims to model plant growth mathematically, analyze influencing factors, optimize resource utilization, and incorporate uncertainty due to climate variability.

II. MATHEMATICAL MODELS

Let $h(t)$denote plant height at time t.

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Linear Model: $h(t) = a + bt$
Exponential Model: $h(t) = h_0 e^{rt}$
Logistic Model: $\frac{dh}{dt} = rh\left(1-\frac{h}{H}\right)$

$$h(t) = \frac{H}{1 + Ae^{-rt}}$$

The logistic model best represents plant growth due to saturation.

III. PARAMETER ESTIMATION

Parameters are estimated using least squares:

$$E = \sum(h_i - \hat{h}_i)^2$$

IV. REGRESSION MODEL

$$h = \beta_0 + \beta_1 w + \beta_2 f + \beta_3 s$$

This model shows dependence of plant height on external factors.

V. OPTIMIZATION MODEL

$$\max\ h = f(w, f, s)$$

Subject to:

$$w \leq W, f \leq F, s \leq S$$

VI. STOCHASTIC MODEL (CLIMATE UNCERTAINTY)

$$dh = rh\left(1-\frac{h}{H}\right)dt + \sigma h dW_t$$

This model accounts for environmental randomness such as rainfall and temperature fluctuations.

Discrete form:

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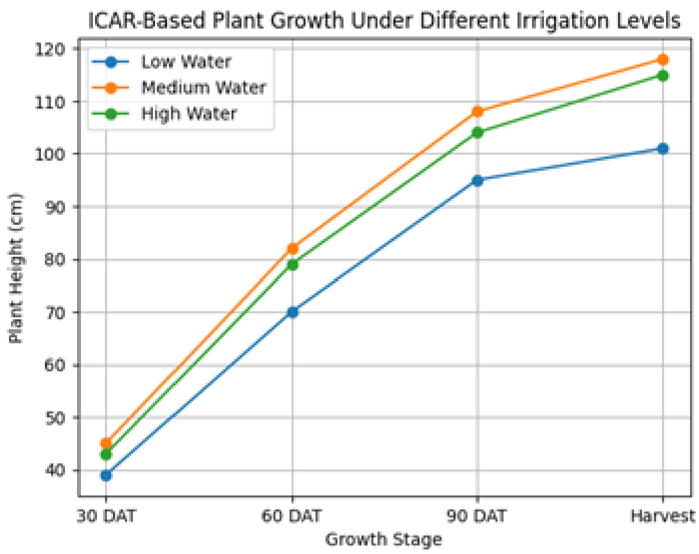
$$h_{t+1} = h_t + rh_t\left(1 - \frac{h_t}{H}\right)\Delta t + \sigma h_t\sqrt{\Delta t}Z$$

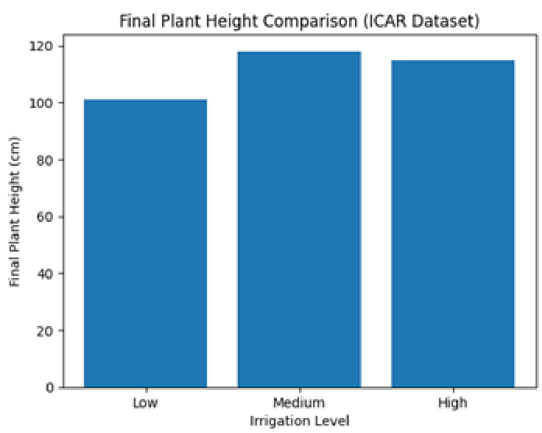
VII. CASE STUDY (ICAR DATA)

Stage	Low	Medium	High
30 DAT	39	45	43
60 DAT	70	82	79
90 DAT	95	108	104
Harvest	101	118	115

Growth Curve



Final Height Comparison



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VII. OPTIMIZATION RESULT

Regression model:

$h(w)=18+0.85w-0.006w^2$

Optimal value:

$w=70.83$

The proposed model finds applications in precision agriculture, smart irrigation systems, AI-based crop prediction, and greenhouse automation, where it supports efficient resource management and enhances plant growth under varying environmental conditions.

VIII. CONCLUSION

This study demonstrates how mathematical modelling and computational techniques can be applied to plant growth analysis. The integration of deterministic and stochastic models provides a realistic framework for agricultural optimization.

This can be extended for Machine learning integration, IoT-based smart farming, Climate-resilient modelling, PDE-based spatial models

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