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# Nonlinear Dynamics of a Soil Nutrient–Plant Biomass Interaction Model for Agricultural Systems

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## INTRODUCTION & AIM

- Soil nutrient dynamics are essential for maintaining the productivity and long-term sustainability of agricultural ecosystems. Many models fail to capture nonlinear feedbacks among nutrients, organic matter, and plant biomass. This study develops a nonlinear model describing these interactions and analyzes its behavior. Objectives:
- Build a dynamic model linking nitrogen, organic matter, and plant biomass.
- Analyze positivity, boundedness, and stability.
- Explore how ecological parameters influence soil fertility.

## METHOD

Model system:

$$dN/dt = \theta + \rho O - \beta NP - \gamma N$$

$$dO/dt = \mu + \omega P - \rho O - \delta O$$

$$dP/dt = \varepsilon\beta NP - \omega P$$

Parameters represent: fertilization ($\theta$), mineralization ($\rho$), nutrient uptake ($\beta$), nitrogen loss ($\gamma$), organic matter input ($\mu$), and plant mortality ($\omega$). Positivity, boundedness, equilibria, and local stability are analyzed using the Jacobian and Routh–Hurwitz criteria

## RESULTS & DISCUSSION

Two equilibria are identified: a plant-free equilibrium (degraded soil) and a positive coexistence equilibrium. Positivity and boundedness ensure biological feasibility. Stability analysis shows plant persistence when nutrient uptake and mineralization rates exceed threshold values. Sensitivity analysis indicates that fertilization ($\theta$) and mineralization ($\rho$) rates most influence long-term fertility. Simulations confirm that high nitrogen loss ($\gamma$) causes soil degradation.

## CONCLUSION

The model captures key ecological feedbacks between soil nutrients and plant biomass. Maintaining an optimal balance between fertilization and mineralization is essential for sustainable soil fertility. This work supports improved nutrient management and precision agriculture strategies.

## FUTURE WORK / REFERENCES

Future Work:

- Include microbial and environmental factors.
- Validate with real field data.
- Develop nutrient control strategies.

1. Kirkby & Smith (2019) Soil Fertility and Plant Growth.
2. Sinha et al. (2022) Mathematical Ecology of Nutrient Cycling.