

Quantifying Nitrogen Biogeochemistry in Diverse Indian Terrestrial Ecosystems: Digitally Innovation

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Abstract

Nitrogen biogeochemistry plays a fundamental role in regulating ecosystem productivity, soil fertility, carbon cycling, and environmental sustainability across diverse terrestrial ecosystems. India contains a wide range of ecosystems, including forests, grasslands, agricultural landscapes, wetlands, and semi-arid regions, each characterized by distinct nitrogen dynamics. This study explores digital innovations for quantifying nitrogen biogeochemistry across these diverse Indian terrestrial ecosystems. Conventional field-based measurements provide valuable information on soil nitrogen pools, mineralization, nitrification, plant uptake, and nitrogen losses; however, integrating these observations with digital technologies can improve the spatial and temporal assessment of nitrogen cycling. Remote sensing, geographic information systems (GIS), Internet of Things (IoT)-based sensors, automated monitoring systems, and data-driven modelling offer new opportunities for collecting and analyzing ecosystem-scale information. Artificial intelligence and machine-learning techniques can be used to identify relationships between environmental variables and nitrogen transformations and to develop predictive models of nitrogen availability and loss. Digital platforms can also integrate field observations, climate datasets, soil properties, vegetation characteristics, and land-use information to provide comprehensive assessments of nitrogen dynamics. Such approaches may support improved understanding of nutrient limitations, fertilizer-use efficiency, greenhouse-gas emissions, and ecosystem responses to environmental change. However, challenges involving data availability, spatial variability, sensor calibration, model uncertainty, and standardization of measurements remain important. The integration of field research with digital technologies can therefore provide a more efficient framework for quantifying nitrogen biogeochemistry and supporting sustainable ecosystem and agricultural management in India.

Keywords: Nitrogen Biogeochemistry, Indian Ecosystems, Digital Innovation, Remote Sensing, GIS, Artificial Intelligence, Machine Learning, Soil Nitrogen, Ecosystem Modelling, Nutrient Cycling.

