Biogeochemical cycling of nitrogen in terrestrial ecosystems of India

A THESIS

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By

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CERTIFICATE

I feel great pleasure in certifying that the thesis entitled "Biogeochemical cycling of nitrogen in terrestrial ecosystems of India" by Ms. Niharika Sharma has been completed under my guidance.
She has completed the following requirements as per Ph.D. regulations of the University:
(a) Completion of the Course Work as per the university rules.
(b) Residential requirements of the university rules.
(c) Regular submission of six monthly progress reports.
(d) Presentation of her work in the Departmental Committee.
(e) Publication of at least one research paper in a referred research journal.

I am satisfied with the analysis of the data, interpretation of the results, and conclusions drawn. I recommend the submission of the thesis.

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DECLARATION

I, Ms. Niharika Sharma, D/o Mr. Amarnath Sharma, resident of A-3, PRL residences, Navrangpura, Ahmedabad - 380009, hereby declare that the research work incorporated in the present thesis entitled "Biogeochemical cycling of nitrogen in terrestrial ecosystems of India" is my own work and is original. This work (in part or in full) has not been submitted to any University or institute for the award of a degree or a diploma.

I have properly acknowledged the material collected from secondary sources wherever required and I have run my entire thesis on the anti-plagiarism software namely "iThenticate".

I solely own the responsibility for the originality of the entire content.

Date: Niharika Sharma

Place: (Author)

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Abstract

Nitrogen is an essential element required to sustain life on this planet. In many ecosystems, nitrogen is a growth limiting nutrient; whereas in other ecosystems, excess amount of nitrogen is causing severe environmental problems. Therefore, in order to ascertain the movement and availability of nitrogen at global scale, studies focussed on understanding nitrogen transformation processes at ecosystem level are desirable. Use of stable isotopes can provide detailed insight into mechanisms of processes involved in nitrogen cycle along with quantification of their rates. To the best of our knowledge, studies focussed on understanding nitrogen transformation processes, particularly their gross rates, using stable isotope approach in soils of the Indian subcontinent are non-existent. In view of this, the aim of present thesis was to quantitatively understand biogeochemical cycling of nitrogen in terrestrial ecosystems of India by measuring gross rates of nitrogen transformation processes in soils of different climatic zones. The ^{15}N isotope dilution technique was employed to estimate rates of nitrogen transformation processes in soils to gain better insights into nitrogen and carbon dynamics.

The experiments conducted in the montane soils of the Himalayas indicated significant increase in gross rates of nitrogen mineralization with increase in temperature. Change in temperature did not show significant change in gross nitrification rates, indicating low sensitivity of nitrifiers towards temperature change.

Study of nitrogen cycling in soils from different land-types present in semi-arid region (Kutch, Gujarat) indicated cumulative effect of vegetation, moisture, and salinity on the soil microbial activity and nitrogen transformations in this region. However, analyses of different factors revealed salinity to be the principal regulator of nitrogen biogeochemistry in the region.

Rates of nitrogen transformation processes were measured in soils of the Western Ghats to understand nitrogen dynamics in tropical humid forest soils. Results indicated higher potential for nutrient consumption than their

production in these forest soils. The potential for consumption of ammonium was higher compared to nitrate indicating active nutrient conservation mechanism in these soils. Despite the higher consumption rates, accumulation of nitrogen was observed in soils of the Western Ghats suggesting significant contribution of external sources of nitrogen, such as atmospheric nitrogen deposition and biological nitrogen fixation, to the soil nitrogen pool of the Western Ghats.

Effect of mono-plantation (rubber plantation) by replacing natural forested ecosystems on soil nitrogen dynamics was studied in soils of Kerala, India. Gross nitrogen mineralization and ammonium consumption were considerably lower in soils of the rubber plantation compared to the managed and unmanaged forests. This was attributed to change in tree species composition from mixed to mono-culture of rubber plants. Longer residence time of ammonium under rubber canopy also supported slow-down in N turnover due to conversion of mixed forest to mono-plantation.

Assessment of stable isotopic compositions of soils collected from different climatic zones of India showed soils from semi-arid climate to be enriched in the heavier isotopes of carbon and nitrogen compared to soils from the humid climate, possibly due to low organic matter content and relatively disproportionate mineralization. Results indicated that change in climatic conditions experienced by soils under different climate has the potential to significantly control the organic matter dynamics.

Overall, soils collected from different locations showed decrease in nitrogen transformation rates with depth indicating lowering in microbial activity in the deeper soils. Mineralization of organic matter was susceptible to change in surrounding conditions, whereas nitrification was relatively unaffected by climatic factors such as temperature and moisture. Ammonium immobilization was the major pathway for ammonium consumption compared to nitrification.

Keywords: Mineralization, Nitrification, Tropical soils, ^{15}N isotope dilution, Terrestrial nitrogen cycle.

Abbreviations

‰	Per mil
$\delta^{13}C$	Isotopic composition of carbon with respect to V-PDB
$\delta^{15}N$	Isotopic composition of nitrogen with respect to Air-N_2
BNF	Biological Nitrogen Fixation
C	Carbon
GWC	Gravimetric Water Content
GWB	Ground Water Board
IAEA	International Atomic Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRMS	Isotope Ratio Mass Spectrometer
N	Nitrogen
P	Phosphorous
SOC	Soil Organic Carbon
TN	Total Nitrogen
TOC	Total Organic Carbon
VOCs	Volatile Organic Compounds
V-PDB	Vienna-Pee Dee Belemnite
WFPS	Water Filled Pore Spaces

Contents

List of Figures

List of Tables

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Publications

Published

1. Lenka, N. K., Lenka, S., Mahapatra, P., **Sharma, N.**, Kumar, S., Aher, S. B., & Yashona, D. S. (2019) The fate of ^{15}N labeled urea in a soybean-wheat cropping sequence under elevated CO_2 and/or temperature. *Agriculture, Ecosystems and Environment*, *282*(1), 23-29. https://doi.org/10.1016/j.agee.2019.04.033

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2. **Sharma, N.**, & Kumar, S. (2019) Change in forest type affects gross nitrogen mineralization in soils of Southern India. *Journal of Forestry Research*.

Under review

3. **Sharma, N.** & Kumar, S. (2019) Gross rates of nitrogen transformations in forest soils of a global biodiversity hotspot (Western Ghats, India). *Journal of Plant Nutrition and Soil Science*
4. **Sharma, N.** & Kumar, S. (2019) Gross nitrogen transformation rates in semi-arid tropical soils: implications for nitrogen cycling under changing climate. *Ecosphere*
5. **Sharma, N.** & Kumar, S. (2019) Gross nitrogen transformation rates in the Himalayan soils at different temperature and elevation conditions. *Geoderma*
6. Kumar, S., **Sharma, N.**, & Kellman, L. (2019) Relative importance of nitrification and denitrification in N_2O emissions from N-amended soils of a managed northern temperate forest chronosequence. *Biogeochemistry*
7. Dutta, M. K., Kumar, S., Bhushan, R., Acharya, A., Sanyal, P., Mukhopadhyay, S. K., Mukherjee, R., & **Sharma, N.** (2019) Diurnal carbon dynamics in a mangrove-dominated tropical estuary (Sundarbans, India). *Estuarine, Coastal and Shelf Science*

Under preparation

8. **Sharma N.**, & Kumar, S. What does stable isotopic composition of soils from of different climatic zones of India tell us?