

How Does Nutrient Mining Affect Crop Productivity?

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Abstract

The dynamics of plant nutrients are vital for sustainable crop production, as nutrient availability in the soil is shaped by factors such as soil properties, environmental conditions, and agricultural practices. Soil organic matter acts as a nutrient reservoir and supplies food for soil microorganisms. However, over time, reliance on straight fertilizers or imbalanced fertilizer applications without incorporating organic matter such as FYM, green manuring or vermicomposting can lead to nutrient mining. In the Indo-Gangetic Plain of India, there is also a significant deficiency of many essential plant nutrients, which impacts crop yield potential and deteriorates soil health. To address these issues, it is important to identify the major causes of nutrient mining and explore sustainable management options. Balancing plant nutrient concentrations in the soil through practices such as the inclusion of organic amendments, precise fertilizer application and crop rotation can enhance soil health and improve crop productivity.

Keywords: Crop residue, Nutrient mining, Plant nutrient, Soil health

Introduction

India is predicted to have 1.67 billion people living there by 2050, which means that food demand will rise significantly and more food will need to be produced from all available sources, including the land and the sea. To do this without jeopardizing the environment, natural resource management must be done in an efficient and scientific manner. It has been observed that the continuous cultivation of high-yielding varieties and multi-cropping systems depletes soil nutrients essential for plant growth. The soil's nutritional status and nutrient supply capacity have been enhanced by using both organic and inorganic fertilizers. During the growing season, management measures have a significant impact on crop yield and also enhance the physico-chemical qualities of the soil. The addition of organic materials, such as FYM, biofertilizer, biochar, pressmud and green manuring have improved the status of organic matter and plant nutrients. This practice also enhances the soil's

mechanical properties and biological processes in most soils. Additionally, the use of pressmud has been found to increase organic-mediated nutrient concentrations in the soil (Dotaniya *et al.*, 2023). Employing balanced fertilizers aligns with sustainable agricultural practices, promoting long-term soil health, responsible nutrient management and reducing the environmental impacts of farming. Effective nutrient management is crucial in agriculture to prevent "nutrient mining," where crops take up necessary nutrients from the soil more quickly than they can be replaced, leading to soil nutrient deficient and leads poor crop yield. Balanced fertilizers supply a combination of essential nutrients in the right proportions, helping to maintain soil fertility and prevent the excessive depletion of nutrients from the soil. Nutrient mining disrupts the balance of nutrient concentrations described by Bharti *et al.* (2017) for sustainable crop production (Table 1). Plants require 17 essential nutrients to achieve optimal crop yields and

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nutrient mining can limit the availability of some of these crucial nutrients.

Table 1: Concentration of nutrients in the mature leaf tissue plant (Tisdale et al., 1997)

Element	Unit	Deficient	Sufficient	Toxic
Nitrogen	%	-	1-5	-
Phosphorus		-	0.1-0.4	-
Potassium		-	1-5	-
Calcium		-	0.2-1	-
Magnesium		-	0.1-0.4	-
Sulphur		-	0.1-0.4	-
Iron	mg kg ⁻¹	<50	100-500	>500
Manganese		15-25	20-300	300-500
Zinc		10-20	27-150	100-400
Copper		2-5	5-30	200-100
Boron		5-30	10-20	50-200
Molybdenum		0.03-0.15	0.1-2.0	>100
Chlorine		<100	100-500	500-1000
Nickel		<0.1	-	-

It has been shown that incorporating organic materials like FYM, biofertilizers, biochar, pressmud, and green manures into the soil boosts organic matter content and directly to the plant nutrients. This practice typically also enhances the soil's bio-chemical activities and physical structure parameters. Furthermore, the use of pressmud specifically has been found to increase the concentration of organically mediated nutrients in the soil (Dotaniya et al., 2023). Utilizing balanced fertilizers aligns with sustainable agriculture practices, supporting long-term soil health, responsible nutrient management and reducing the negative environmental impacts of farming activities. Managing nutrient depletion in agriculture largely depends on the application of balanced fertilizers. Crops that absorb vital minerals from the soil at a rate faster than their natural replenishment cause nutrient mining, which ultimately leads to soil nutrient depletion. Nutrient loss and a decrease in soil organic matter can lead to this poor soil structure problem directly reduce the soil ecological services (Figure 1). Improving agricultural crop management techniques by integrating traditional and scientific knowledge can help address this issue. In water bodies, nutrient runoff can cause pollution and damage aquatic ecosystems, but this can be prevented through the use of balanced fertilizer applications, which help minimize excess nutrient runoff.

Major Factors of Nutrient Mining

In India, nutrient mining is a significant concern due to several factors as mentioned below.

Intensive Agriculture

It is a one of the priority sector of Indian agriculture to grow more crop produce for the growing population. Nutrient imbalances in the soil, however, can result from ongoing

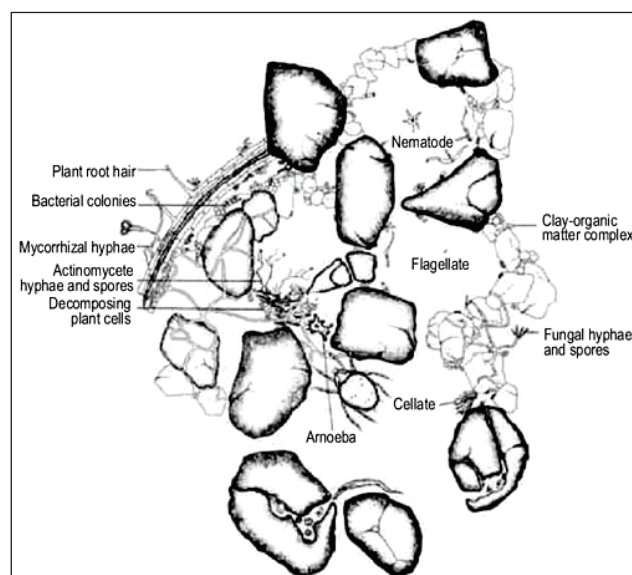


Figure 1: Soil environment (Anonymous, 2024)

cropping and the frequent application of chemical fertilizers without sufficient nutrient replacement. Coastal Andhra Pradesh, West Bengal, Kerala, Tamil Nadu and other states are well-known for their intensive farming practices.

Limited Use of Organic Matter

In many parts of India, the use of organic materials like compost, manure and crop residues is limited. While a soil having lower organic matter leads to nutrient depletion, organic matter is also crucial for retaining soil moisture, improving soil structure and enhancing nutrient availability. According to the National Rainfed Area Authority described that the agricultural sector is concerned about India's declining soil organic carbon (SOC) levels, which have dropped from 1% to 0.3% over the past 70 years.

Imbalanced Fertilizer Use

Indian farmers often prioritize the use of nitrogen, phosphorus and potassium (NPK) fertilizers, frequently overlooking other essential micronutrients. This over-reliance on inorganic fertilizers can lead to deficiencies in the soil's nutrient profile. Ideally, the NPK usage ratio should be around 4:2:1, but the all-India NPK use ratio shifted from 7.7:3.1:1 in 2021-2022 to 11.8:4.6:1 in 2022-2023.

Lack of Soil Testing and Monitoring

Soil testing and monitoring are essential for assessing the soil's nutritional status and making informed decisions about fertilizer application. Unfortunately, these methods are not widely practiced in many parts of India. Nevertheless, the Indian government has focused on promoting fertilizer use based on soil test results.

Subsistence Farming

In certain regions, subsistence farming practices may hinder effective nutrient management and sustainable agriculture, resulting in increased nutrient depletion.

Management Strategies for Minimizing Nutrient Mining

It is imperative to use sustainable agriculture practices to address nutrient mining. The following are some tactics to

control nutrient mining and preserve soil fertility.

Integrated Nutrient Management

To enhance soil health and nutrient availability, it is essential to balance the use of chemical fertilizers with organic amendments such as compost, manure and green manures. Balanced fertilizers supply not only the major nutrients, viz., nitrogen, phosphorus and potassium, but also critical micronutrients, viz., iron, zinc, copper and manganese that crops need for optimal growth (Dotaniya *et al.*, 2021). This approach helps prevent nutrient depletion in the soil and restores the nutrients absorbed by crops.

Crop Rotation

To minimize excessive nutrient extraction, it is important to implement crop rotation methods that involve growing a variety of crops with different nutrient requirements. In addition to reducing the chance of nutrient runoff into water bodies, proper nutrient management with balanced fertilizers also guards against water contamination and preserves aquatic ecosystems.

Cover Cropping

By preserving the soil and improving nutrient cycling with the use of cover crops, nitrogen losses can be decreased. Fast-growing crops were planted, such as cowpea and groundnut, to reduce soil erosion, improve soil fertility and add organic matter to the soil through root decomposition and exudates. It improves soil biological diversity and population of soil organisms over a period (Figure 2).

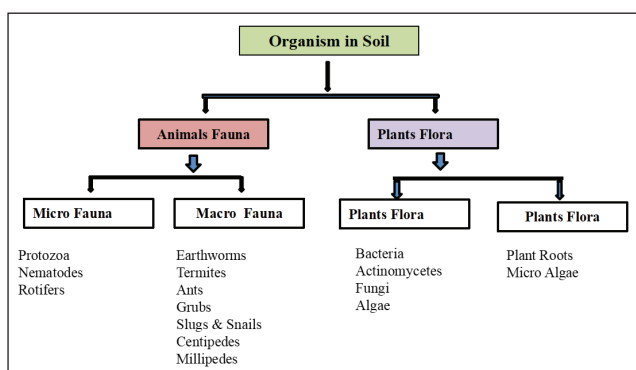


Figure 2: Soil microbial diversity (Bharti *et al.*, 2017)

Conservation Agriculture

Employing conservation agriculture techniques, such as mulching and zero tillage, helps maintain soil nutrient content and structure. These practices improve soil health indicators and contribute to sustainable soil management.

Soil Testing and Precision Farming

Encouraging farmers to adopt precision farming techniques and conduct regular soil tests can ensure that fertilizers are

applied according to specific crop and soil needs. Uneven fertilizer application or continuous cropping may sometimes lead to nutrient deficiencies in the soil. By addressing these deficiencies and correcting nutrient imbalances, balanced fertilizers help improve overall soil fertility.

Nutrient Recycling

Restoring soil nutrients is facilitated by promoting the recycling of agricultural waste, animal dung and crop leftovers. Fertilizers that are balanced and customized to fit the unique nutrient requirements of crops function more effectively to promote ideal plant growth.

Conclusion

By adopting these practices, Indian farmers can minimize the effects of nutrient mining and promote profitable, sustainable agriculture in the future. Balanced fertilizer application is essential for nutrient management, helping to prevent nutrient depletion and maintain soil fertility for productive and sustainable farming. Farmers should consider conducting soil tests and implementing site-specific fertilizer recommendations to tailor nutrient applications to the needs of their crops and the soil's nutritional status. This approach not only ensures effective nutrient use and reduces losses but also enhances long-term agricultural soil health.

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