# Khet Bachao Abhiyan Series: ICAR RCER, Patna

# ICAR-Research Complex for Eastern Region, Patna

## No-5: Environmental Promise of Balanced Fertilization

Fertilizers have been instrumental in enhancing agricultural productivity and ensuring food security, particularly in countries such as India. However, India now consumes more than 60 million tonnes of fertilizers annually, and only 30-40% of the applied nitrogen is effectively utilized by crops. The remainder is lost through leaching, runoff, volatilization, and denitrification, leading to groundwater contamination, eutrophication, soil degradation, and increased greenhouse gas (GHG) emissions. Excessive nitrogen use, coupled with inadequate application of phosphorus, potassium, sulphur, and micronutrients, has further aggravated nutrient imbalances and reduced fertilizer-use efficiency.

Agriculture occupies a unique position in the climate system as both a source and a sink of greenhouse gases. While the sector contributes nearly 14% of India's total GHG emissions, largely through nitrous oxide ($N_2O$) emissions from fertilized soils, it also has significant potential to sequester carbon through improved soil and nutrient management. Balanced fertilization can reduce fertilizer-related emissions by 20–40% and offers a scientifically proven pathway to increase crop productivity, improve soil health, and while supporting food security and Net Zero 2070 goals.

### The Growing Challenge of Nutrient Imbalance

Fertilizer use remains heavily skewed toward nitrogen, with N:P: K ratios in several regions exceeding 10:4:1 compared to the recommended 4:2:1. This imbalance disrupts soil nutrient balance, reduces fertilizer-use efficiency, and has led to widespread deficiencies of phosphorus, potassium, sulfur, and micronutrients. Over time, such practices contribute to declining soil fertility, reduced soil organic carbon, and lower crop responsiveness to fertilizer inputs.

### Environmental Consequences of Imbalanced Fertilization

*Climate Change and Greenhouse Gas Emissions*

Excessive nitrogen fertilization is a major source of nitrous oxide ($N_2O$), a greenhouse gas with a global warming potential approximately 273 times greater than carbon dioxide. Agricultural soils emit $N_2O$ through microbial nitrification and denitrification processes, which are intensified under surplus nitrogen conditions. Consequently, improving nutrient-use efficiency is a key strategy for reducing agriculture's climate footprint.

*Water Pollution and Ecosystem Degradation*

Nutrient lost through leaching and surface runoff transport nitrogen and phosphorus into water bodies, resulting in groundwater contamination and eutrophication. Elevated nutrient concentrations stimulate algal blooms, reduce dissolved oxygen levels, and disrupt aquatic ecosystems. Such nutrient pollution not only threatens water quality and biodiversity but also imposes significant ecological and economic costs on society.

### *Soil Degradation*

Continuous application of nitrogen-dominated fertilizers like Urea without adequate replenishment of other nutrients and neglecting recycling of organic matter accelerates soil degradation. Common consequences include:

- Soil acidification & poor soil physical properties
- Nutrient mining & micronutrient deficiencies
- Decline in soil organic carbon & reduced microbial diversity

Over time, these changes decrease soil productivity and increase dependency on external inputs, creating a vicious cycle of declining nutrient efficiency, poor soil health and rising production costs.

## The Promise of Balance: Benefits for Environment, and Food Security

Balanced fertilizer management represents one of the most effective climate-smart agricultural practices available today.

i. **Reduction in Greenhouse Gas Emissions:** Optimizing nutrient application reduces surplus nitrogen in soils and consequently lowers nitrous oxide emissions. Studies indicate that site-specific nutrient management can reduce fertilizer-related greenhouse gas emissions by 20-40% without compromising crop yields.

ii. **Enhanced Carbon Sequestration:** Balanced nutrition promotes vigorous crop growth and greater biomass production, increasing carbon inputs to soil. Improved root development and organic matter accumulation contribute to long-term soil carbon sequestration and improved soil health.

iii. **Improved Resilience to Climate Stress:** Nutrient-balanced crops exhibit greater tolerance to drought, heat stress, and erratic rainfall. Potassium, for example, improves water-use efficiency and strengthens plant defence mechanisms under adverse environmental conditions.

iv. **Economic Advantages for Farmers:** Reduce fertilizer wastage and thus input costs in farming. Further, increase in fertilizer response efficiency lead to yield improvement and farm profitability

## Challenges in Implementation and the Road Ahead

Transitioning to balanced fertilizer practices is not without obstacles. Small and marginal farmers, who constitute over 85% of India’s farming community, often face limited access to soil testing labs, quality organic inputs, and technical knowledge. In intensively cultivated regions like Punjab, Haryana, and parts of Bihar, decades of heavy urea subsidies have created severe nutrient imbalances (highly skewed N:P:K ratios), groundwater contamination, and stagnating yields. However, successful models—such as Soil Health Card campaign, custom hiring centers for precision equipment, and public-private initiatives promoting neem coated urea, biofertilizers etc. demonstrate that targeted support can overcome these barriers. Integrating digital advisory services, mobile apps, and carbon credit incentives for low-emission farming can make the shift inclusive, economically viable, and scalable across diverse agro-climatic zones.