



## Atlas of Sulphur and Micronutrient Status in Soils of Northeast India



**Indira Sarangthem, Sanjib Kumar Behera, Arvind Kumar Shukla, N. Surbala Devi, Samiron Dutta, Rahul Mishra, Anjali Basumataray, Nivedita Oinam, Vimal Shukla, L. Punilkumar Singh, Akankshya Sikarwar, Yogesh Sikaniya**

**AICRP on Micro- and Secondary Nutrients and Pollutant Elements in Soils and Plants  
ICAR-Indian Institute of Soil Science, Bhopal**

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CENTRAL AGRICULTURAL UNIVERSITY  
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# Atlas of Sulphur and Micronutrient Status in Soils of Northeast India

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**Central Agricultural University, Imphal**

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अजय कुमार भल्ला  
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**Ajay Kumar Bhalla**  
Governor of Manipur

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ꯀꯄꯂꯈ ꯀꯄꯂꯈ ꯀꯄꯂꯈ



सत्यमेव जयते




### MESSAGE

I am glad to know that the All India Coordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (AICRP-MSPE), Central Agricultural University, Imphal Centre, is bringing out an Atlas book titled 'Atlas of Sulphur and Micronutrient Status in Soils of Northeast India'.

This Atlas will be a valuable scientific document that presents region-specific information on soil nutrient status and management strategies for the North Eastern States. It will serve as an important reference for researchers, policymakers, extension agencies and farmers in promoting balanced nutrient management, improving crop productivity and ensuring sustainable use of soil resources.

I commend the efforts of the Central Agricultural University, Imphal, ICAR-Indian Institute of Soil Science (IISS), Bhopal and all the scientists involved in bringing out this significant publication. I am confident that this Atlas will contribute meaningfully to sustainable agriculture, food security and ecological resilience in the region.

  
(Ajay Kumar Bhalla)



डॉ. ए. के. नायक  
**Dr. A. K. Nayak**

FNASc, FNAAS, FISSS, FARRW

उप महानिदेशक (प्राकृतिक संसाधन प्रबंधन)

Deputy Director General (Natural Resource Management)



10.04.2026

### Message

Healthy soil forms the foundation of our food systems, livelihoods, and ecological security. Yet, on a human timescale, it is a non-renewable resource that faces mounting pressure from imbalanced fertilization, monocropping, land degradation, and the imperative to feed a growing population. In this context, the stewardship of soil is not merely an agricultural concern; it is a national priority.

I am pleased to present the atlas book entitled '**Atlas of Sulphur and Micronutrient Status in Soils of Northeast India**' as a timely and authoritative work that bridges rigorous science with practical, field-ready guidance. The Northeast region of India, with its extraordinary ecological diversity and rich organic soils, holds immense promise for sustainable agriculture. This atlas provides a comprehensive, data-driven view of sulphur and micronutrient dynamics across the region's varied landscapes, offering a strong scientific bedrock for informed natural resource management.

More than a compilation of maps, this atlas serves as a strategic manual for action. It affirms a central truth of modern agriculture: crop improvement is inseparable from soil health. By translating soil intelligence into site-specific management strategies, the atlas enables a shift from generalized recommendations to precision-guided, high-efficiency production essential for resilient harvests and sustainable intensification.

I am confident that scientists, farmers, extension professionals and policymakers alike will find this volume invaluable. For governance, it provides the evidence base needed to align agricultural policy with ecological reality. For farmers and practitioners, it offers practical pathways to restore soil fertility, enhance nutrient use efficiency and secure productivity gains without compromising environmental integrity. For policy makers, this atlas is also a call to invest in our most fundamental infrastructure—the soil itself.

I commend the authors and contributors for their dedication and scientific rigor and I am sure that this atlas will help to lead collective action for higher and maintaining good soil health toward a more productive, sustainable and food-secure future for Northeast India.

  
(A.K. Nayak)



**डॉ. एम.एल. जाट**  
**DR. M. L. JAT**

सचिव (डेयर) एवं महानिदेशक (आईसीएआर)  
Secretary (DARE) & Director General (ICAR)

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## FOREWORD

Agriculture in Northeast India is characterized by a high reliance on traditional, subsistence-based farming. Key features include shifting (*Jhum*) cultivation in hilly regions, monsoon dependence, low productivity, and dominance of rice-based cropping systems. The region is a global biodiversity hotspot and a critical biogeographical junction (Indo-Malayan, Indo-Chinese, Indian), hosting over 30% of India's total biodiversity.

*Jhum* is major land use system in North East followed by terrace cultivation. Undulating terrain, poor marketing infrastructure, limited mechanization, vulnerability to natural calamities like floods and landslides are some of the bottlenecks in agricultural development in the region. Further, soil acidity coupled with deficiency of macro and micronutrients, especially in *jhum* intense land use, limits the agricultural production to a great extent.

In this context, Central Agricultural University, Imphal Centre under All India Coordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (AICRP-MSPE) is bringing out the '**Atlas of Sulphur and Micronutrient Status in Soils of Northeast India**'. This publication indicates widespread deficiency of sulphur and micronutrients in the soils of Northeast India.

This atlas, with its diagnostic approach and detailed nutrient mapping across all eight states of the region, will serve as a strategic roadmap for understanding soil fertility constraints and guiding informed decision-making. By integrating scientific insights with practical management options, the atlas has the potential to support sustainable agricultural practices, enhance crop productivity, and improve the livelihoods of farmers while conserving the delicate ecosystem of the North East.

This publication will be useful to the researchers, policymakers, extension workers, and planners. I extend my sincere appreciation to all the scientists and institutions involved in publication of this document.

**Dated the 2<sup>nd</sup> March, 2026**  
**New Delhi**



**(M. L. Jat)**



Dr. Anupam Mishra,  
Vice-Chancellor

# केन्द्रीय कृषि विश्वविद्यालय

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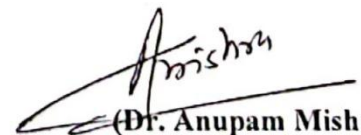
## FOREWORD

I am pleased to share a few of my reflections on this atlas, compiled by the All India Coordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (AICRP-MSPE), Central Agricultural University, Imphal, in collaboration with the Indian Institute of Soil Science (IISS), Bhopal.

The study compiled a scientific and comprehensive soil fertility maps of the studied north east region and characterized the spatial distribution of soil properties in eight states of NE India viz. Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Nagaland, Tripura, Sikkim. The generated fertility maps and spatial distribution patterns will serve as valuable tools for farmers and planners, enabling them to understand the existing soil conditions and to devise judicious strategies for effective soil management aiming at ensuring sustainability and enhancing productivity. These soil maps will contribute to improving crop yields as well as enhancing the nutritional quality of crops, thereby addressing public health concerns such as nutritional deficiencies, while also supporting soil health and environmental sustainability. Furthermore, in the context of North East India, the use of soil maps will greatly assist in the judicious application of fertilizers by taking into account the region's diverse topography, varied soil types, and unique cropping patterns. It is a prerequisite for the economic prosperity of the Northeast farmer and the nutritional security of the nation.

I hope that this atlas book '**Atlas of Sulphur and Micronutrient Status in Soils of Northeast India**' will provide effective learning and research assistance to all learners, educational professionals and farmers leading to optimal academic and agricultural importance.

I wish all the best to the team.

  
(Dr. Anupam Mishra)



Prof. Indira Sarangthem  
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## PREFACE

The North Eastern Region (NER) of India is often described as the country's "green lungs," characterized by high organic matter and lush landscapes. However, beneath this verdant exterior lies a complex nutritional crisis. The book '**Atlas of Sulphur and Micronutrient Status in Soils of Northeast India**' serves as a definitive guide to understanding the diagnostic mapping, providing actionable management frameworks, ameliorative measures to ensure long-term soil resilience.

In the NER, where nearly 91% of the geographical area is occupied by acidic soils, the availability of essential nutrients follows a unique and often detrimental pattern. While nitrogen and potassium are frequently addressed, the "hidden hunger" for sulphur, boron, and zinc remains largely unmanaged. The shift from traditional fertilizers to high-analysis alternatives has left soils depleted of sulphur, critical for the region's oilseed and pulse production. High rainfall leads to severe leaching, making boron deficiency the most significant micronutrient constraint in the NER, directly impacting the "fruit set" of horticultural crops. Restoring the micronutrient balance is not just a scientific endeavour; it is an economic imperative for the millions of farmers in the Northeast. This publication is intended for researchers, policy planners, and extension specialists as a tool to transition from blanket fertilizer recommendations to precision soil health management.

I sincerely thank Dr. Sanjib Kumar Behera, I/c Project Coordinator, AICRP-MSPE, & Head, DSC&F, ICAR-Indian Institute of Soil Science (IISS), Bhopal, without whom, this publication would not be possible. The team, AICRP-MSPE, CAU, Imphal Centre is truly grateful for his guidance, instructions and continuous support in publishing this atlas book.

I acknowledge the cooperation of Dr. A.K. Shukla, Hon'ble Vice-Chancellor, RVSKVV, Gwalior, and former Project Coordinator, AICRP-MSPE, ICAR-ISSS, Bhopal, for his valuable suggestions.

I appreciate the generous support of Indian Institute of Soil Science, Bhopal in all aspects.

I express my sincere gratitude to Dr. Anupam Mishra, Hon'ble Vice-Chancellor, Central Agricultural University, Imphal for his constant inspiration and encouragement throughout the course of this publication.

I firmly believe that this atlas will serve as a valuable source of knowledge for researchers, extension functionaries dedicated to the farming community, policymakers, NGOs, and the academic fraternity.

  
(Prof. Indira Sarangthem)

## PREFACE

The North Eastern Region (NER) of India is widely celebrated as the nation's "*green lungs*"; a landscape of rolling hills, dense forests and rich organic matter that sustains remarkable biodiversity and agricultural potential. Yet, beneath this verdant façade lies a less visible but deeply consequential challenge: a pervasive imbalance of secondary and micronutrients that threatens soil health, crop productivity and farmers' livelihoods. Recognizing and addressing this paradox forms the foundation of the present atlas.

Soils of the NER are predominantly acidic, covering nearly 91% of the geographical area and are shaped by high rainfall, fragile topography and continuous nutrient losses through leaching. While macronutrients such as nitrogen and potassium often receive due attention, deficiencies of sulphur and micronutrients particularly boron and zinc remain largely unrecognized and unmanaged. This "*hidden hunger*" silently constrains crop yields, impairs quality and limits the economic potential of agriculture in the region. The transition from traditional fertilizers to high-analysis fertilizers devoid of sulphur has further aggravated these deficiencies, with serious implications for oilseeds, pulses, cereals and horticultural crops. Among micronutrients, boron deficiency has emerged as the most widespread and critical constraint, directly influencing flowering, fruit set and yield stability under high rainfall conditions.

The atlas book "**Atlas of Sulphur and Micronutrient Status in Soils of Northeast India**" has been conceived as a comprehensive and practical reference to bridge this critical knowledge gap. By integrating large-scale soil diagnostic data with geospatial mapping, this atlas presents a clear picture of the spatial distribution of sulphur and micronutrient deficiencies across the Northeast states. More importantly, it goes beyond diagnosis to offer scientifically sound, location-specific management options and ameliorative measures aimed at restoring nutrient balance and enhancing long-term soil resilience.

Our intent is to facilitate a shift from blanket fertilizer recommendations toward precision-based soil health management, aligned with the principles of sustainable and climate-resilient agriculture. The atlas is designed to serve as a decision-support tool for researchers, extension functionaries, policymakers, planners, NGOs and the academic fraternity who are collectively engaged in improving the productivity and profitability of farming systems in the NER.

We firmly believe that this publication will not only enrich the understanding of sulphur and micronutrient dynamics in acidic soils but also contribute meaningfully to evidence-based policy formulation, targeted nutrient interventions and improved livelihood outcomes for the farming community of Northeast India. It is our hope that this atlas will inspire informed action, foster collaboration and support the stewardship of soil resources for present and future generations.

*The Authors*

# CONTENTS

Sl. No.	Particular	Page No.
1.	North-eastern states at a glance	1-14
2.	Soil sampling and chemical analysis	15
3.	Soil mapping	16
4.	Map of North-East states showing geographical position of the sampling points	17
5.	Maps of Assam state showing status of available sulphur, zinc, iron, copper, manganese and boron	18-24
6.	Sulphur and micro-nutrient deficiency status in soils (% area) of Assam	25-29
7.	Maps of different districts of Assam showing status of available sulphur, zinc, iron, copper, manganese and boron	30-239
8.	Maps of Arunachal Pradesh state showing status of available sulphur, zinc, iron, copper, manganese and boron	240-246
9.	Sulphur and micro-nutrient deficiency status in soils (% area) of Arunachal Pradesh	247-253
10.	Maps of different districts of Arunachal Pradesh showing status of available sulphur, zinc, iron, copper, manganese and boron	254-403
11.	Maps of Manipur state showing status of available sulphur, zinc, iron, copper, manganese and boron	404-410
12.	Sulphur and micro-nutrient deficiency status in soils (% area) of Manipur	411-415
13.	Maps of different districts of Manipur showing status of available sulphur, zinc, iron, copper, manganese and boron	416-511
14.	Maps of Meghalaya state showing status of available sulphur, zinc, iron, copper, manganese and boron	512-518
15.	Sulphur and micro-nutrient deficiency status in soils (% area) of Meghalaya	519-522
16.	Maps of different districts of Meghalaya showing status of available sulphur, zinc, iron, copper, manganese and boron	523-588
17.	Maps of Mizoram state showing status of available sulphur, zinc, iron, copper, manganese and boron	589-595
18.	Sulphur and micro-nutrient deficiency status in soils (% area) of Mizoram	596-599
19.	Maps of different districts of Mizoram showing status of available sulphur, zinc, iron, copper, manganese and boron	560-665

<b>20.</b>	Maps of Nagaland state showing status of available sulphur, zinc, iron, copper, manganese and boron	666-672
<b>21.</b>	Sulphur and micro-nutrient deficiency status in soils (% area) of Nagaland	673-676
<b>22.</b>	Maps of different districts of Nagaland showing status of available sulphur, zinc, iron, copper, manganese and boron	677-760
<b>23.</b>	Maps of Sikkim state showing status of available sulphur, zinc, iron, copper, manganese and boron	761-767
<b>24.</b>	Sulphur and micro-nutrient deficiency status in soils (% area) of Sikkim	768-769
<b>25.</b>	Maps of different districts of Sikkim showing status of available sulphur, zinc, iron, copper, manganese and boron	770-793
<b>26.</b>	Maps of Tripura state showing status of available sulphur, zinc, iron, copper, manganese and boron	794-800
<b>27.</b>	Sulphur and micro-nutrient deficiency status in soils (% area) of Tripura	801-803
<b>28.</b>	Maps of different districts of Tripura showing status of available sulphur, zinc, iron, copper, manganese and boron	804-851
<b>29.</b>	Sulphur and Micronutrient management options in soils and crops	852-875
<b>30.</b>	Crop wise sulphur and micronutrient management for North East states	876-886
<b>31.</b>	Strategy for correction of sulphur and micronutrients in north east states	887-893
<b>32.</b>	References	894-896

# Strategy for Correction of Sulphur and Micronutrients in North East States

## 1. Manipur

### Sulphur

- Use of Gypsum: Applying gypsum can enhance the availability of soluble sulphur in soils, especially in acidic conditions.
- Chemical Extractants: Utilize specific chemical extractants like 0.5M NH<sub>4</sub>OAc, which has shown high correlation with dry matter yield and total plant uptake, making it a promising option for assessing sulphur availability in Manipur's acidic soils.
- Soil Management: Implement soil management practices that consider the physico-chemical properties of soils, such as organic carbon content and clay texture, to optimize sulphur uptake by crops.

### Micronutrients

- Soil Management: Implementing DTPA extraction to determine the availability of micronutrients in the soil and making necessary corrections to improve soil health. This includes maintaining high organic carbon levels through compost, manure, or crop residues, and incorporating crops that can access less available zinc forms.
- Fertilization: Applying zinc sulfate or other zinc-containing fertilizers to soil or as foliar sprays to increase the availability of zinc to crops. Iron (ferrous sulfate) has been shown to significantly increase yield in crops like chickpea, wheat, and paddy.
- Crop Rotation: Rotating crops to ensure a balanced nutrient profile in the soil over time. This helps in maintaining soil fertility and preventing the depletion of essential nutrients.
- Micronutrient Supplementation: Utilizing micronutrient supplements to address deficiencies in specific nutrients. This can be done through foliar sprays or soil application.

## 2. Assam

### Sulphur

- Integrated Sulfur Management: Apply sulfur alongside nitrogen, phosphorus, and potassium (NPK) to enhance crop yields and nutrient uptake.
- Sulfur Fertilization: Use sulfur fertilizers at appropriate rates based on soil tests to ensure efficient use and maximize crop production.

- **Timing of Application:** Apply sulfur at the beginning of the growing season or 20-40 days after planting for optimal results.
- **Soil Properties:** Assess soil pH and organic carbon content, as these factors influence sulfur availability and uptake by crops.
- **Bioinoculum:** Consider using sulfur metabolizing bacteria as bioinoculants to improve sulfur availability in acidic soils.

#### Micronutrients

- **Soil Testing:** Conduct soil tests to assess micronutrient levels and determine deficiencies.
- **Balanced Fertilization:** Apply balanced fertilizers that include essential micronutrients like iron, zinc, and boron to enhance soil fertility.
- **Soil Amendments:** Use organic amendments and compost to improve soil structure and nutrient availability.
- **Precision Agriculture:** Implement precision farming techniques to apply fertilizers and micronutrients at the right time and in the right amounts.
- **Biofortification:** Consider biofortification methods to improve the nutritional quality of crops.

### **3. Meghalaya**

#### Sulphur

- **Terrace or Bun Cultivation:** This system involves constructing bench terraces on hill slopes to retain rainwater and prevent soil erosion. It helps in maintaining water levels and safely disposing of excess runoff.
- **Optimal Sulphur Source Selection:** Trials indicate that gypsum is the most effective source of sulphur for crops like groundnut in acid Alfisols of Meghalaya, followed closely by single superphosphate.
- **Application Rate:** A dosage of 30 kg S/ha or 40 kg S/ha (when used with zinc) is recommended to significantly boost crop yields and improve soil quality.
- **Integrated Nutrient Management:** Combining sulphur with organic manures, such as Farmyard Manure (FYM) at 10 tons/ha, enhances its efficiency, especially in the high-rainfall hilly regions where nutrient leaching is common.
- **Acid Soil Correction:** Applying lime (approx. 400 kg/ha) in combination with sulphur and vermicompost (2.0 t/ha) enhances nutrient uptake by increasing the soil

- Organic Amendments: Using materials like Azolla (1.6 t/ha) or green manure helps manage acidity and improves overall soil fertility in Meghalaya's Inceptisols.
- Timing: To avoid high leaching losses, split application of sulphur is recommended, particularly for long-duration crops

#### Micronutrient

- Soil Testing: Regularly conduct soil tests to assess micronutrient levels and nutrient status, which helps in determining the need for amendments.
- Organic Amendments: Incorporate organic manures and crop residues to improve soil fertility and maintain nutrient balance.
- Precision Fertilization: Apply fertilizers judiciously based on soil test results to avoid overuse and ensure effective nutrient uptake.
- Micronutrient Sprays: Use foliar sprays for micronutrients like Zinc, Manganese, and Boron to enhance crop nutrition and yield.
- Integrated Nutrient Management: Implement Integrated Nutrient Management practices to promote sustainable agricultural productivity and address micronutrient deficiencies.

## **4. Nagaland**

#### Sulphur

- Conservation and Protection: Implement holistic policies and programs to conserve, protect, and restore natural resources, including soil and water.
- Soil Survey and Testing: Strengthen soil survey and testing laboratories to establish an inventory of land resources and monitor soil health.
- Land Use Practices: Change land use practices to improve soil sulfur fractions and bioavailability, such as adopting organic farming methods.
- Sustainable Agriculture: Promote sustainable agricultural practices that enhance soil fertility and reduce erosion risks.
- Monitoring and Awareness: Establish databases and robust monitoring systems to inform stakeholders about soil health and promote awareness of soil conservation.

#### Micronutrients

- Conservation and Protection: The Department emphasizes the importance of conservation and protection of natural resources to address soil degradation and preserve ecosystems.

- **Technological Interventions:** Implementing technological interventions and improving traditional practices on a catchment/watershed basis is crucial for optimizing land capability and enhancing environmental protection.
- **Soil Management:** Strengthening soil survey, soil testing laboratories, and cartography to establish an inventory of land resources is essential for a realistic land use plan.
- **Capacity Building:** Capacity building programs for pre-service, in-service employees, and farmers' training on soil and water conservation technologies are vital for effective soil management.
- **Land Shaping:** Techniques such as bench terrace, half moon terrace, bunding, trenching, and water harvesting ponds are employed to manage surface runoff and improve soil moisture regime.
- **Soil Health:** The Soil Health Card Scheme provides personalized recommendations for nutrient management based on soil test results, aiding in targeted interventions.

## **5. Sikkim**

The strategy for correcting Sulphur and Micronutrient deficiency in Sikkim, a 100% organic state, focuses on sustainable on-farm management, using organic nutrient sources, and increasing microbial activity to mineralize soil nutrients.

### **Sulphur**

- **Application of Organic Fertilizers:** Use balanced organic fertilizers and organic manure to restore soil fertility and improve nutrient availability.
- **Soil Testing:** Conduct soil tests to determine sulphur levels and pH, which can help in identifying the need for amendments.
- **Organic Matter:** Incorporate well-rotted manure, compost, or green manures to enhance sulphur content and improve soil structure.
- These strategies can help restore soil health and improve crop productivity in Sikkim.

### **Micronutrients**

- **Soil Testing:** Conduct soil tests to assess nutrient availability and fertility status, which helps in determining the need for fertilizers and amendments.
- **Organic Matter Management:** Implement organic farming practices to enhance soil organic matter, which can improve nutrient retention and fertility.
- **Soil Amendments:** Apply soil amendments such as compost and green manure to increase nutrient content and improve soil quality.

- Precision Agriculture: Utilize precision farming techniques to apply organic supplements at the right time and in the right amounts to maximize crop yield.

## **6. Arunachal Pradesh**

### **Sulphur**

- Soil Testing: Conduct soil tests to determine the sulfur content and pH levels. This helps in identifying the need for correction and the appropriate method to apply sulfur.
- Organic Matter: Incorporate well-rotted manure, compost, or green manures to enhance sulfur content and improve soil structure and fertility.
- Sulfate Fertilizers: Use ammonium sulfate, potassium sulfate, or magnesium sulfate to provide immediately available sulfur for plants.
- Elemental Sulfur: Apply elemental sulfur, but ensure it is oxidized by soil bacteria before it becomes available to plants. This method is ideal for long-term amendments but may take time to become effective.
- Application Rates: Adjust the application rates based on the soil test results and the specific needs of the crops being grown.
- Continuous Monitoring: Regularly monitor the soil and crop health to ensure that sulfur levels are maintained at optimal levels for sustainable agriculture.

### **Micronutrients**

- Soil Testing: Regular soil testing is essential to assess the micronutrient status and identify deficiencies. This helps in determining the appropriate application of fertilizers.
- Fertilizer Application: The use of balanced fertilizers, particularly those containing zinc and boron, is recommended to address deficiencies. These nutrients are crucial for the growth and yield of crops.
- Agroforestry Practices: Integrating trees with crops can improve soil health by adding organic matter, decomposing nutrients, and reducing soil erosion. This practice can also enhance the availability of micronutrients in the soil.
- Biofortification: Incorporating biofortification strategies, such as applying micronutrients directly to crops or soil, can enhance the micronutrient content in agricultural produce, thereby improving the nutritional quality of food.

- **Policy Support and Capacity Building:** Government policies and capacity building initiatives are necessary to support the implementation of these strategies and ensure their effectiveness.

## **7. Mizoram**

### **Sulphur**

- **Soil & Water Conservation Techniques:** These techniques aim to enhance soil production and improve cash crop programs such as coffee, rubber, and broom. They also focus on checking surface soil erosion and conserving moisture in degraded lands through integrated farming systems.
- **Soil Management Practices:** These practices are crucial for managing soil properties under different land use systems, including rubber plantations, oil palm plantations, bamboo forests, fallow lands, and natural forests.
- **Research and Development:** Ongoing research and development efforts are being made to improve the availability of sulphur in soils and to develop new techniques for soil sulphur fractionation.

### **Micronutrients**

- **Soil Health Card Scheme:** This scheme helps farmers understand their soil condition and the amount of nutrients needed, thereby increasing food productivity.
- **Cover Crop:** This practice involves planting cover crops between rows of crops to improve soil health and fertility.
- **Mulching:** Mulching involves spreading a layer of organic material over the soil surface to improve soil structure and fertility.
- **Conservation Tillage:** This method involves reducing the depth of soil plowing and maintaining soil cover to improve soil health and reduce erosion.
- **Agroforestry:** This approach integrates trees and crops to improve soil fertility, enhance biodiversity, and reduce the risk of soil degradation.

## **8. Tripura**

### **Sulphur**

- **Application of Fertilizers:** Use sulfur-containing fertilizers like gypsum or ammonium thiosulphate to correct deficiency.
- **Organic Amendments:** Incorporate organic matter such as farmyard manure or vermicompost to improve overall soil fertility and sulphur levels.

- Soil Health Card (SHC) Scheme: Utilize the Soil Health Card scheme in Tripura, which provides tailored recommendations for sulfur application based on soil testing.
- Integrated Nutrient Management (INM): Apply sulfur as part of a balanced fertilization approach (N, P, K, and sulphur) to address high acidity and low nutrient status of the soil.
- Crop Rotation: Utilize crop rotation to prevent rapid depletion of sulfur in the soil.

#### Micronutrients

- Soil Amendment (Liming): Since 49.20% of Tripura's soil is strongly acidic (pH 5.1–5.5), applying lime is essential to reduce acidity and increase the bioavailability of essential micronutrients.
- Integrated Nutrient Management (INM): Soil testing is recommended to identify deficiencies, followed by the application of micronutrient fertilizers (e.g., zinc, boron) along with NPK fertilizers, particularly for paddy and horticultural crops.
- Foliar Application: For severe deficiencies, especially in fruit trees (banana, pineapple), foliar sprays are encouraged for rapid absorption, bypassing the acidic soil constraints.
- Organic Matter Addition: Incorporating farmyard manure (FYM), compost, and vermicompost improves soil structure and enhances the availability of micronutrients in acidic soils.
- Bio-fortification & Diversification: Promotion of cultivating and consuming bio-fortified, nutrient-rich crops such as orange-fleshed sweet potato, high-iron pulses, and zinc-enriched maize, particularly for tribal communities to tackle "hidden hunger".