Acid Soils of India

Indian Council of Agricultural Research
New Delhi

Acid Soils of India

2026

Sanjib Kumar Behera
Arvind Kumar Shukla
Rahul Mishra
Monoranjan Mohanty
Amaresh Kumar Nayak

भाकृअनुप
ICAR

Published by

Directorate of Knowledge Management in Agriculture
Indian Council of Agricultural Research
Pusa Campus, New Delhi 110 012

Printed in July 2026

ISBN: 978-81-7164-321-9

Disclaimer

The publisher, authors and editors assume the information in this book was accurate at the time of publication, but they make no express or implied guarantees, and are not liable for any errors or omissions. All sources of information have been duly cited.

Compilation and Technical Editing

Dr Sanjib Kumar Behera
Principal Scientist & Head (Division of Soil Chemistry & Fertility) & Incharge Project Coordinator, All India Coordinated Research Project on Micro- and Secondary Nutrients and Pollutant Elements in Soils and Plants (AICRP-MSPE), ICAR-Indian Institute of Soil Science (ICAR-IISS), Bhopal, Madhya Pradesh

Dr Arvind Kumar Shukla
Vice-Chancellor, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh

Dr Rahul Mishra
Scientist (Soil Sciences & Agricultural Chemistry), Project Coordinator Micronutrient Unit, ICAR-IISS, Bhopal, Madhya Pradesh

Dr Monoranjan Mohanty
Director, ICAR-IISS, Bhopal, Madhya Pradesh

Dr Amaresh Kumar Nayak
Deputy Director General (Natural Resource Management),
Indian Council of Agricultural Research, New Delhi

Citation

Behera S K, Shukla A K, Mishra R, Mohanty M and Nayak A K. 2026.
Acid Soils of India. Indian Council of Agricultural Research, New Delhi, 12 p.

Editing

Dr Anuradha Agrawal
Project Director, Directorate of Knowledge Management in Agriculture (DKMA),
Indian Council of Agricultural Research (ICAR), New Delhi, India

Design & Production

Punit Bhasin
Incharge, Production Unit, ICAR-DKMA, New Delhi, India

Published by Dr Anuradha Agrawal, Project Director, Directorate of Knowledge Management in Agriculture, Indian Council of Agricultural Research, Pusa Campus, New Delhi 110 012, India Lasertypeset and printed at M/s Royal Offset Printers, A-89/1, Naraina Industrial Area, Phase-I, New Delhi 110 028, India.

FOREWORD

Food production in the country is intrinsically linked to healthy soils. It is widely recognized that sustainable food security cannot be achieved without maintaining soil health. Soil acidification, nutrient depletion, erosion, and chemical imbalances adversely affect crop growth, reduce crop yields, and compromise the quality of food, posing serious challenges to meeting the needs of a rapidly growing population.

Acidic soils, particularly those with a pH below 5.5, are of significant concern due to severe nutrient deficiencies and toxic effects of aluminum and iron, which restrict root development and overall crop performance. Soil pH, therefore, serves as a critical indicator for guiding effective soil and nutrient management interventions. The availability of reliable and spatially explicit information on soil acidity is essential for informed planning, efficient resource allocation, and coordinated implementation of soil health programmes.

The Government of India has accorded high priority to soil health management through initiatives such as the Soil Health Card Scheme (SHCS), which promotes soil test–based and location-specific nutrient management across the country. In this context, the present publication developed by ICAR, presenting state-wise soil acidity maps is a timely and valuable contribution. Given that a significant portion of arable land in India is affected by soil acidity, this publication will be instrumental in promoting precise fertilizer and lime application, improving input-use efficiency, enhancing crop productivity and making sound policy decisions. This publication will support evidence-based planning and strengthen the effective implementation of national programmes, including the National Mission for Sustainable Agriculture (NMSA) and *Rashtriya Krishi Vikas Yojana* (RKVY).

(Dr Mangi Lal Jat)
Secretary, Department of Agricultural Research and Education (DARE)
& Director General, Indian Council of Agricultural Research (ICAR)

March 17, 2026
New Delhi

PREFACE

SOIL is a critical natural resource that underpins food and fiber production, water regulation, climate moderation, and biodiversity conservation. Among the soil health indicators, soil pH plays a pivotal role in determining nutrient availability, crop productivity, and the effectiveness of soil management interventions. Reliable and spatially explicit information on soil pH is, therefore, essential for informed policy decisions aimed at sustainable land use and agricultural development.

In India, acid soils are predominantly distributed in high-rainfall regions, where intensive leaching of basic cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) leads to the dominance of H^{+} and Al^{3+} ions on soil exchange sites. This condition adversely affects crop growth through aluminum toxicity, restricted root development, reduced base saturation, and imbalanced nutrient availability. The impacts of soil acidity, if not addressed, limit the ability of farmers (particularly smallholders), from realizing the full yield potential of improved crop varieties and agronomic practices.

Liming and the application of other ameliorants are proven, and cost-effective practices for mitigating soil acidity and enhancing fertilizer-use efficiency by improving soil chemical properties and nutrient uptake. However, blanket recommendations and uniform application, without accounting for spatial variability in soil pH, often result in inefficient input use efficiency and sub-optimal outcomes. Site-specific information on soil pH is, therefore, indispensable for accurate ameliorant requirements and for promoting sustainable and economically viable soil management strategies.

In this context, the present publication provides the latest estimates of agricultural areas with acid soils and presents their state-wise spatial distribution. It draws on data generated under the All India Coordinated Research Project on Micro- and Secondary Nutrients and Pollutant Elements in Soils and Plants (AICRP-MSPE), ICAR-IISS, Bhopal, supplemented with datasets from other agencies such as ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur, and State Agricultural Universities (SAUs). This publication is expected to serve as a decision-support tool for policymakers, planners, and extension agencies in designing targeted interventions for acid soil management and location-specific input recommendations.

The authors gratefully acknowledge the financial support provided by the ICAR, Department of Agricultural Research and Education (DARE), Ministry of Agriculture and Farmers' Welfare, Government of India, New Delhi, for carrying out this study. The institutional support from ICAR-IISS, Bhopal, is sincerely acknowledged. The contributions of Principal Investigators and associated scientists from various centers of AICRP-MSPE, as well as scientists from different SAUs, in supplying state-wise soil pH data along with geographical coordinates, are highly appreciated. The authors also express their gratitude to Dr G.P. Obi Reddy, Principal Scientist and Head, Division of Remote Sensing Applications, ICAR-NBSS&LUP, Nagpur, for providing additional soil pH data for Arunachal Pradesh, and to Dr Vikas Sharma, Professor and Head, Sher-E-Kashmir University of Agricultural Science and Technology (SKUAST), Jammu, for sharing supplementary soil pH data for the erstwhile state of Jammu and Kashmir.

Authors

CONTENTS

CONTENTS

1. Soil Acidity: Extent, Causes, and Implications for Land Degradation and Crop Production

Land degradation due to soil acidity is a major constraint to the optimal utilization of land resources for enhanced crop production worldwide. Acid soils are generally defined as those having a pH of less than 6.5 for most of the year. Approximately one-third of all soils of the world are acidic, and nearly 50% of the world's potentially arable lands fall under this category (von Uexküll and Mutert 1995). The tropics and subtropics alone account for about 60% of these acid soils. In India, nearly 34% of cropped land are estimated to have acid soils (Maji *et al.* 2012). Soil acidity poses a significant challenge to food production across Asia, Africa and Latin America, while also imposing substantial economic burden on farmers in Europe and North America.

Acid soils are associated with multiple toxicities, nutrient deficiencies, and other constraints that limit plant growth. Acidic soil pH adversely affects nutrient availability, increases solubility of toxic heavy metals, alters soil microbial activity, disrupts root cell


integrity, and reduces cation exchange capacity (Bian *et al.* 2013). The chemistry of acid soil is dominated by high concentrations of hydrogen ions (H^+) leading to low pH, increased aluminum (Al) and manganese (Mn) toxicity, and deficiencies in base cations like calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^+). These conditions arise due to proton generation from acids (carbonic, sulphuric and nitric), leaching of bases, and weathering, all of which severely impair nutrient dynamics and microbial activity in soils.

In India, acid soils are predominantly found in high-rainfall regions where heavy precipitation leads to the leaching of significant amounts of exchangeable base cations (like Ca^{2+}, Mg^{2+}, Na^+ and K^+) from the surface soil. This results in the dominance of H^+ and Al^{3+} ions on colloidal exchange sites, which is toxic for plants. Such soils are typically characterized by low base saturation and reduced concentrations of exchangeable Ca^{2+}, Mg^{2+} and K^+ (Behera and Shukla 2015). The detrimental effects of soil acidity on plant growth are related to Al^{3+} toxicity, which inhibits root development, and with imbalances in nutrient availability that vary with soil pH (Fageria and Baligar 2008).

Accurate mapping of acid soils is essential for their effective management, including the judicious application of lime to ensure sustainable crop production and informed policy decisions. Although spatial variability of soil pH has been widely studied across different soils and management systems globally, there remains a need for updated and region-specific information on the distribution of acid soils in India. Such information is critical for designing targeted management strategies and formulating appropriate policy interventions to address land degradation and improve agricultural productivity.

2. Method for Creating Spatial Variability Map of Soil pH

The details of the methodology adopted for preparing spatial variability map of soil pH of the country are depicted in Figure 1.

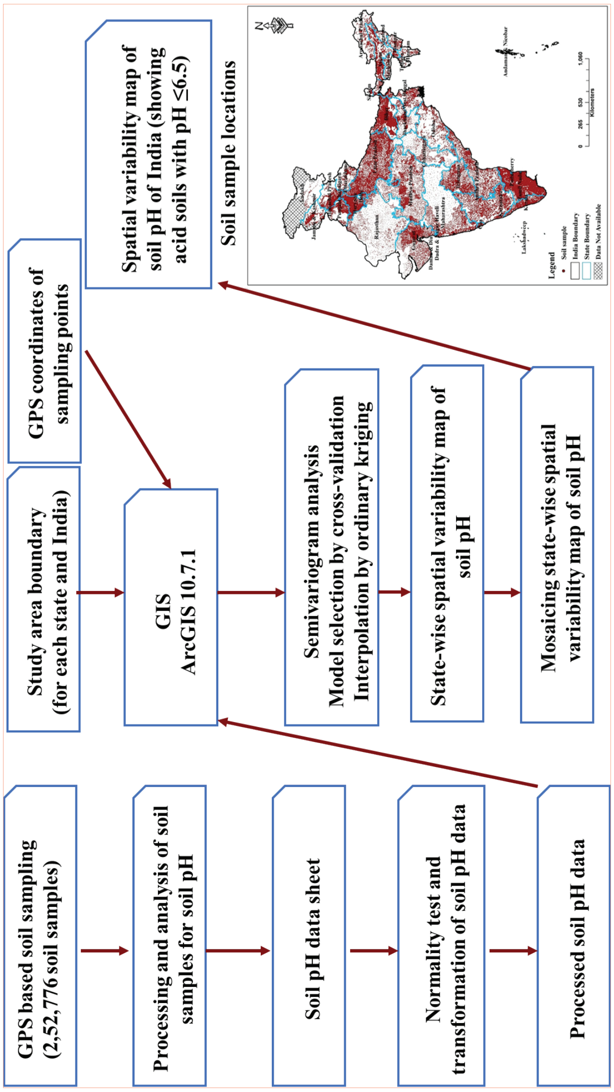


Fig 1. Flowchart for Creating Spatial Variability Map of Acid Soils

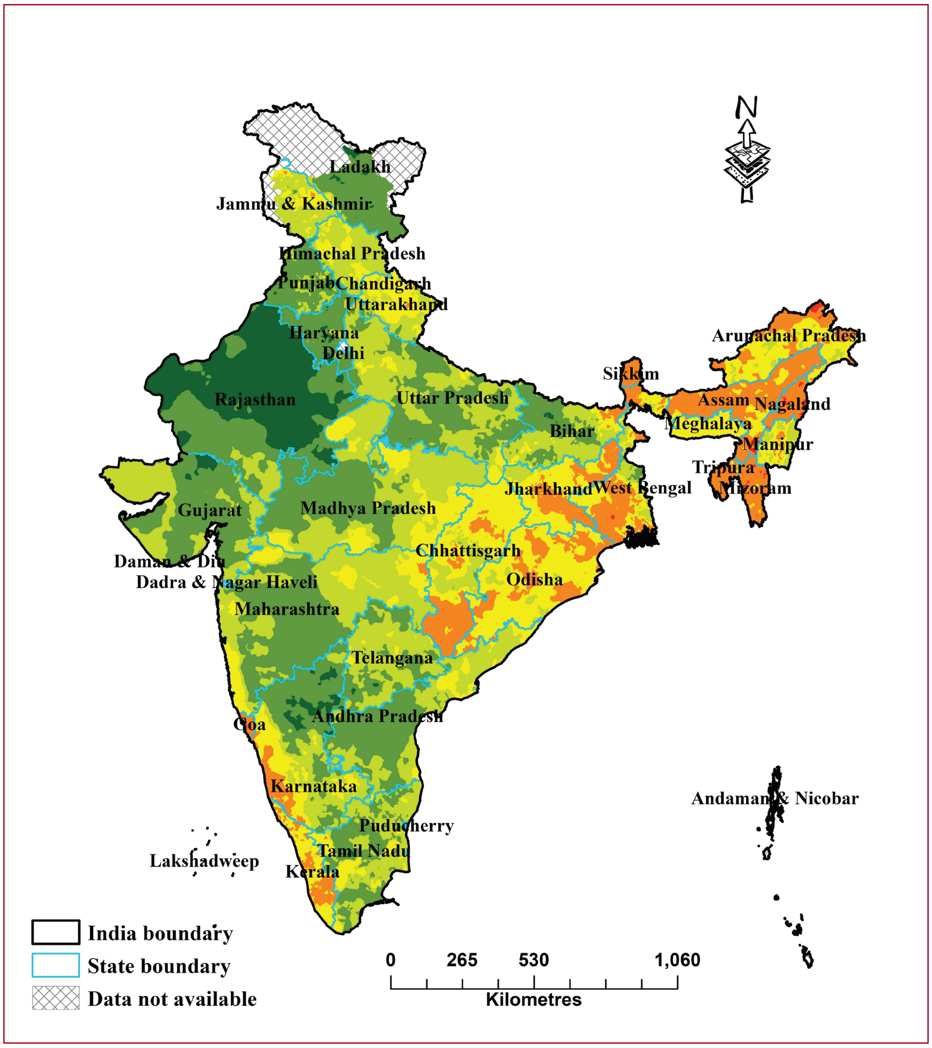
3. State-wise Distribution of Acid Soils

State-wise estimated areas under acid soils is presented in Table 1. The spatial distribution variability maps of soil pH and acid soils are depicted in Figures 2 and 3, respectively.

Table 1. State wise distribution of acid soils in India (Area in million ha)

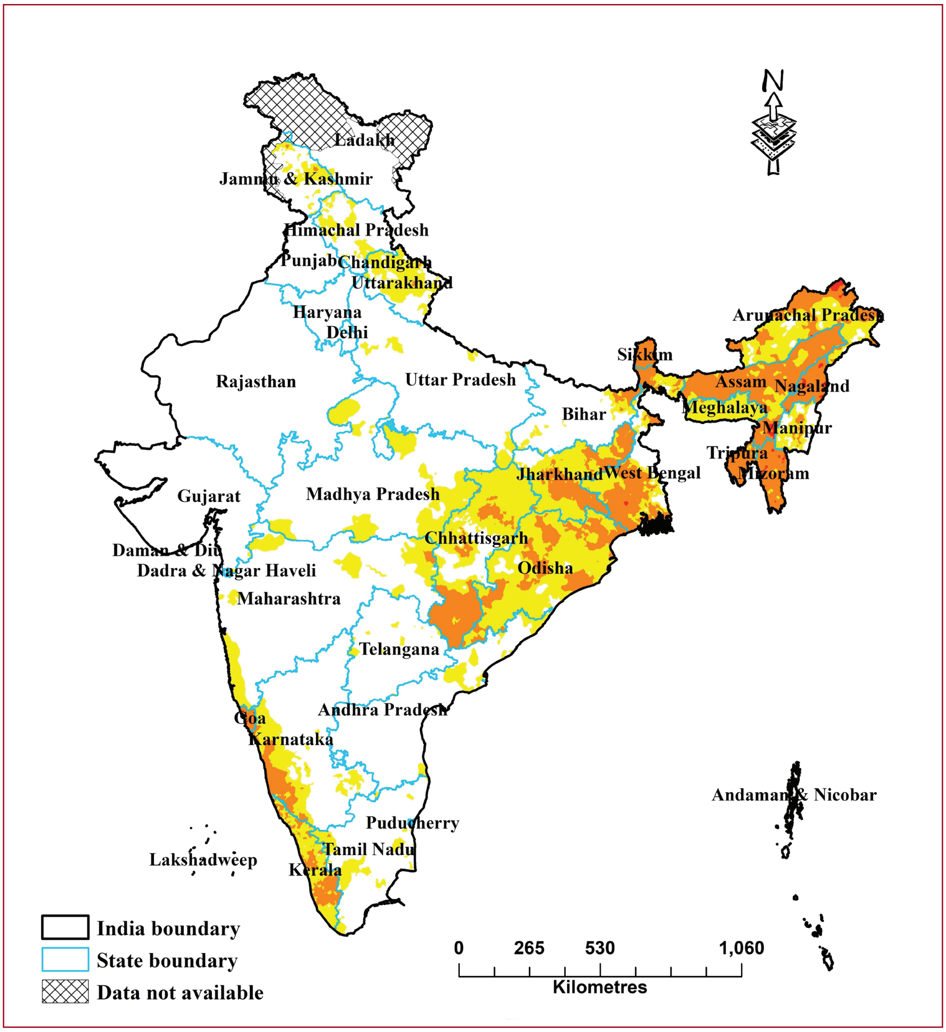
S. No.	State	Strongly acidic (pH ≤ 4.50)	Moderately acidic (pH > 4.50 to ≤ 5.50)	Slightly acidic pH > 5.50 to ≤ 6.50)	Total	Total geographical area (TGA) captured	% of TGA
1	Andhra Pradesh	0.00	0.00	1.65	1.65	16.33	10.11
2	Arunachal Pradesh	0.17	3.14	5.05	8.36	9.01	92.78
3	Assam	0.15	7.15	1.20	8.49	8.49	100
4	Bihar	0.00	0.42	0.75	1.16	9.46	12.30
5	Chhattisgarh	0.00	4.01	7.06	11.08	13.69	80.93
6	Goa	0.02	0.34	0.01	0.37	0.37	100
7	Gujarat	0.00	0.00	0.06	0.06	18.94	0.30
8	Haryana	0.00	0.00	0.00	0.00	4.44	0.00
9	Himachal Pradesh	0.00	0.00	1.31	1.31	5.57	23.52
10	Jammu & Kashmir	0.00	0.05	1.24	1.29	10.88	11.83
11	Jharkhand	0.00	3.42	3.96	7.38	8.03	91.90
12	Karnataka	0.00	1.65	3.42	5.07	19.30	26.26
13	Kerala	0.00	1.64	2.20	3.85	3.88	99.14

S. No.	State	Strongly acidic (pH ≤ 4.50)	Moderately acidic (pH > 4.50 to ≤ 5.50)	Slightly acidic pH > 5.50 to ≤ 6.50)	Total	Total geographical area (TGA) captured	% of TGA
14	Madhya Pradesh	0.00	0.02	6.30	6.32	30.92	20.44
15	Maharashtra	0.00	0.16	4.34	4.50	30.96	14.52
16	Manipur	0.00	0.26	1.19	1.44	2.44	59.14
17	Meghalaya	0.00	0.05	2.25	2.30	2.30	100
18	Mizoram	0.08	2.05	0.06	2.19	2.19	100
19	Nagaland	0.16	1.57	0.00	1.73	1.73	100
20	Odisha	0.00	4.37	10.58	14.95	15.60	95.83
21	Punjab	0.00	0.00	0.01	0.01	5.07	0.14
22	Rajasthan	0.00	0.00	0.00	0.00	34.65	0.00
23	Sikkim	0.01	0.71	0.00	0.72	0.72	100
24	Tamil Nadu	0.00	0.01	1.88	1.89	13.06	14.50
25	Telangana	0.00	0.00	0.33	0.33	11.21	2.90
26	Tripura	0.00	1.04	0.03	1.07	1.07	100
27	Uttar Pradesh	0.00	0.00	1.04	1.04	24.11	4.32
28	Uttarakhand	0.00	0.04	3.09	3.13	5.34	58.60
29	West Bengal	0.03	4.15	2.86	7.04	8.62	81.67
	India	0.61	36.25	61.84	98.71	318.37	31.00
	Area (%)	0.19	11.39	19.42	31.00	100.00	



pH	Area (mha)	% of TGA
≤ 4.50	0.61	0.2
> 4.50 to ≤ 5.50	36.25	11.4
> 5.50 to ≤ 6.50	61.84	19.4
> 6.50 to ≤ 7.50	94.95	29.9
> 7.50 to ≤ 8.50	101.13	31.9
> 8.50	23.59	7.2

Fig 2. Spatial Distribution of Soil pH in India



pH	Area (mha)	% of TGA
Strongly acidic (pH ≤ 4.50)	0.61	0.2
Moderately acidic (pH > 4.50 to ≤ 5.50)	36.25	11.4
Slightly acidic (pH > 5.50 to ≤ 6.50)	61.84	19.4
Neutral to alkaline (pH > 6.50)	219.67	69.0

Fig 3. Distribution of Acid soils of India

4. Trends in Soil Acidity across India's Agroecosystems

Extent and Changing Profile of Acid Soils in India

Approximately 98.71 million hectares (mha) (31% of total geographical area) of India are affected by acid soils (pH ≤6.50) (Fig 2 & Fig 3). Of this, 0.61 mha are strongly acidic (pH ≤ 4.5), 36.25 mha are moderately acidic (pH >4.5 to ≤5.5), and the largest share, 61.84 mha, is slightly acidic (pH >5.5 to ≤6.5). These estimates indicate a notable shift from earlier findings by Maji *et al.* (2012), who reported a lower total acid soil area of 92.80 mha but a significantly larger extent of strongly acidic soils (6.24 mha) and smaller moderately acidic areas (24.41 mha) and a little larger slightly acidic area (62.14 million ha) (Fig 4). This suggests changing soil conditions and the impact of ongoing land management practices.

Distribution of Acid Soils across Indian States

States such as Assam, Goa, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura have area entirely with acid soils, with nearly 100% of their geographical area, falling

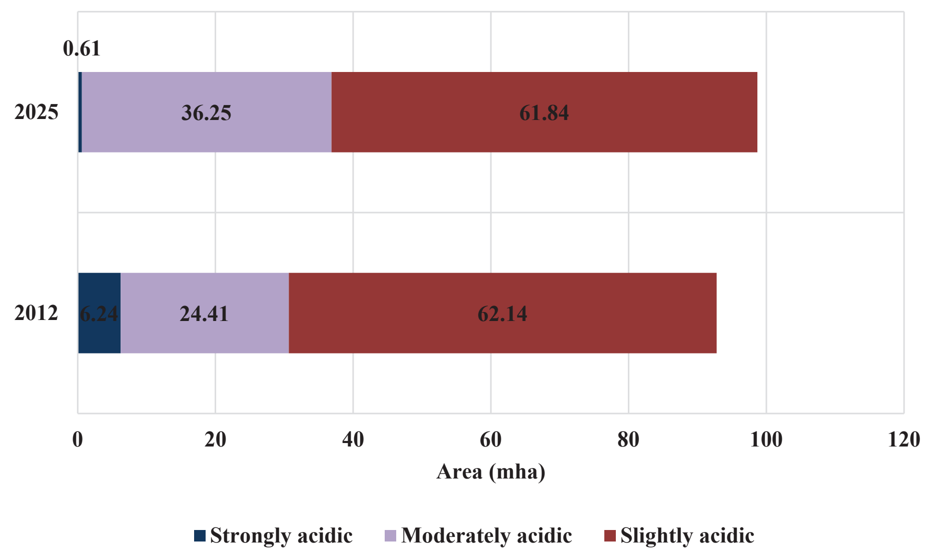


Fig 4. Change in acidic soil profile in India between 2012 and 2025

in this category. A high prevalence (80-90% area) is also observed in Arunachal Pradesh, Chhattisgarh, Jharkhand, Kerala, Odisha, and West Bengal. In contrast, Gujarat, Haryana, Punjab, Rajasthan, Telangana and Uttar Pradesh have very negligible or no areas affected with soil acidity. About 60% area in Manipur and Uttarakhand has acid soils, while Andhra Pradesh, Bihar, Himachal Pradesh, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra and Tamil Nadu have moderate incidence, with acid soils in 10 to 30% area.

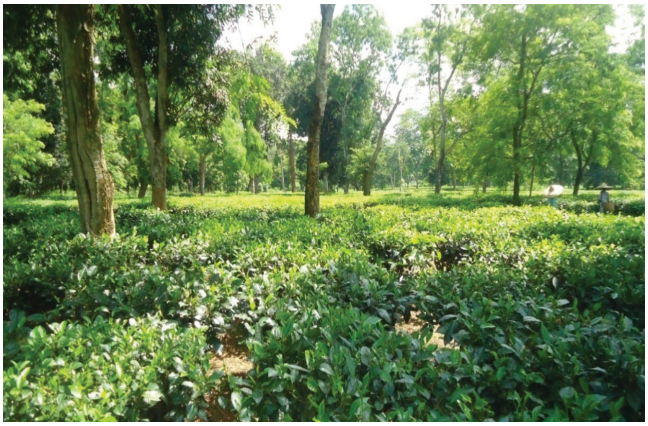
» About 31 % area of the country has soil pH ≤ 6.50.

» Soil pH in different states of India varies from 2.80 to 10.20 with mean value of 6.98 and CV 16.64%.

» 100% area in Assam, Goa, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura has acidc soil.

» In the last 13 years, the area with strongly acidic soils decreased from 6.24 to 0.61 mha, and the area with moderate soil acidity increased from 24.41 to 36.25 mha in india.

The observed expansion of acid-affected soils in India reflects the combined influence of natural processes, human activities, and differences in assessment methodologies. Key natural drivers include the weathering of parent material, high rainfall and humidity, and the rapid decomposition of organic matter in forest and peat land ecosystems, along with the accumulation of acidic leaf litter. Anthropogenic factors have further accelerated soil acidification. These include acid deposition resulting from fossil fuel combustion, prolonged and excessive use of ammonium-based fertilizers, depletion of basic cations due to intensive cropping without adequate replenishment, and localized impacts of mining and industrial pollution. Land-use changes, particularly deforestation and the conversion of grasslands, also contribute significantly to increasing soil acidity. Evidence from other regions supports these findings. For instance, Lu *et al.* (2023) identified nitrogen deposition, precipitation, sulphur inputs, temperature, and vegetation type as major



drivers of soil acidification in China over recent decades (1996–2000 and 2016–2020). However, a notable positive trend is the significant decline in the area under strongly acidic soils in India—from 6.24 million hectares (as reported by Maji *et al.*, 2012) to 0.61 million hectares, as evident in Arunachal Pradesh, Assam, Goa, Kerala, Manipur, Nagaland, Sikkim, Tamil Nadu and Tripura.

The reduction in strongly acidic soils can be largely attributed to the adoption of improved soil management practices. These include the application of lime to neutralize soil acidity, incorporation of organic amendments, implementation of integrated nutrient management, and cultivation of acid-tolerant crop varieties. In addition, supportive policy measures aimed at sustainable land use and environmental protection have played an important role. These measures include promoting the use of low-sulphur fuels, installing emission control technologies such as scrubbers in industries, to remove sulphur from flue gases, employing catalytic converters in vehicles, encouraging a transition towards renewable energy sources (such as wind, solar, and hydro), and improving water and irrigation management practices. At the national level, targeted government initiatives, particularly the Soil Health Card (SHC) Scheme and the Reclamation of Problem Soils (RPS) sub-scheme under the *Rashtriya Krishi Vikas Yojana* (RKVY), have contributed to addressing soil acidity through improved monitoring, farmer awareness, and site-specific soil management interventions.

There is an increase in area with moderate soil acidity from 24.41 (reported by Maji *et al.* 2012) to 36.25 mha in the country. This is attributed to a combination of natural processes and intensified anthropogenic activities, particularly certain agricultural practices, as mentioned above. This highlights the need for intensifying scientific soil management practices and implementation of appropriate policies targeted for sustainable land use and environmental protection.

5. Summary

Understanding spatial distribution of acid soils in the country is important for their effective management, ensuring sustainable crop production and informed policy decisions. The present assessment revealed that about 31 % area (approximately 98.71 mha) of the country has soil pH ≤ 6.50. In the last 13 years, area with strongly acidic soils decreased from 6.24 to 0.61 mha and area with moderate soil acidity increased from 24.41 to 36.25 mha in India. Integrating soil acidity information into policy and practice will enable more efficient, evidence-based decision-making and support sustainable agricultural development. State governments could use spatial maps of soil acidity to identify and prioritize high-risk areas for intervention.

Focused application of lime and other ameliorants can improve soil fertility and optimize the use of public resources. Soil acidity data could guide site-specific fertilizer recommendations. Addressing nutrient deficiencies (e.g., phosphorus, molybdenum) and toxicities (e.g., aluminium, iron, manganese) will support balanced fertilization and enhance crop productivity. Policies should promote the adoption of acid-tolerant crop varieties and cropping systems suited to local soil pH conditions, thereby improving resilience and farm incomes in affected regions. The data could be used by the state agricultural departments to develop location-specific management practices. This includes determining the correct type and amount of amendments needed for different soil types and acidity levels. Soil survey data, including acidity levels, is a crucial input for state planners and stakeholders in preparing strategic sustainable land use plans, watershed development programmes and managing natural resources. Information on acid soil areas could be used in preventing further land degradation and associated environmental issues, such as the leaching of toxic metals (like aluminium) into groundwater, by guiding appropriate management and conservation measures. Research institutions should leverage soil acidity data to develop site-specific technologies, including improved soil conditioners and crop varieties. Strengthened extension systems are essential to ensure effective field-level adoption.

References

Behera S K and Shukla A K. 2015. Spatial distribution of surface soil acidity, electrical conductivity, soil organic carbon content and exchangeable potassium, calcium and magnesium in some cropped acids soils of India. *Land Degradation and Development* **26**: 71–79. https://doi.org/10.1002/ldr.2306

Bian M, Zhou M, Sun D and Li C. 2013. Molecular approaches unravel the mechanism of acid soil tolerance in plants. *The Crop Journal* **1**(2): 91-104. https://doi.org/10.1016/j.cj.2013.08.002

Fageria N K and Baligar V C. 2008. Ameliorating soil acidity of tropical Oxisols by liming for sustainable crop production. *Advances in Agronomy* **99**: 345–399. https://doi.org/10.1016/S0065-2113(08)00407-0

Lu X, Zhang X, Zhan N, Wang Z and Li S. 2023. Factors contributing to soil acidification in the past two decades in China. *Environmental Earth Sciences* **82**: 74. https://doi.org/10.1007/s12665-022-10725-x

Maji A K, Obi Reddy G P and Sarkar D. 2012. *Acid Soils of India – Their Extent and Spatial Distribution*. NBSSLUP Bull. 145, ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur, India 138 p.

von Uexküll H R and Mutert E. 1995. Global extent, development and economic impact of acid soils. *Plant and Soil* **171**: 1-15. https://doi.org/10.1007/BF00009558

भाकृअनुप
ICAR

ISBN:9788171643219

@InAgrisearch | @icarindia | @officialicarindia | www.icar.org.in | @icarindia