22nd Annual Convention and National Conference

Application of Clay and Allied Sciences in Agriculture, Environment and Industry

23-24 September, 2019

ICAR-IARI, New Delhi

SOUVENIR & ABSTRACTS

Organised by

The Clay Minerals Society of India, New Delhi

In collaboration with

ICAR-National Bureau of Soil Survey & Land Use Planning
Regional Centre, Delhi

CSIR - Central Glass & Ceramic Research Institute

196, Raja S C Mullick Road, Kolkata-32, India
Tel.: +91 33 2473 3469/76/77/96, 2483 8079/82
Fax: +91 33 2473 0957; Web: http://www.cgcri.res.in
Email: director@cgcri.res.in

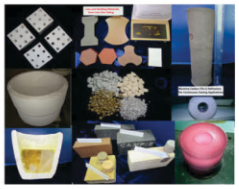
Major Research & Development Activities

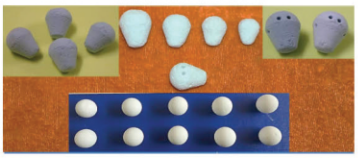
- Fibre Optics & Photonics
- Specialty Glasses
- Sensor & Actuator
- Sol-gel processing
- Whiteware & Rural Pottery
- Engineering Ceramics
- Bioceramics & Coating
- Solid Oxide Fuel Cell & Li-ion Battery
- Ceramic Membrane Filters
- Refractory & Tiles from Industrial Waste
- Nano-structured Coatings
- Nano-structured Materials

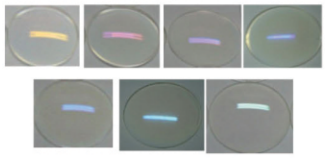
Recently Transferred Technologies

- Ceramic membrane based water purification systems
- Glass nodules for nuclear waste immobilization
- Coated medical implants
- Bioceramics hip & orbital implants
- Optical amplifier for cable TV network
- Glass lining material for reactor

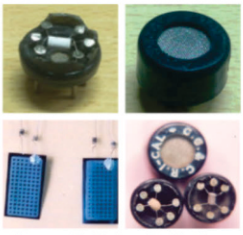
PRODUCTS DEVELOPED BY CSIR-CGCRI

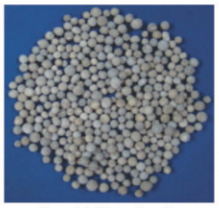

Refractory Products


Orbital Implant


Wavelength Selective AR Coating


Demonstration of Melting of Frits

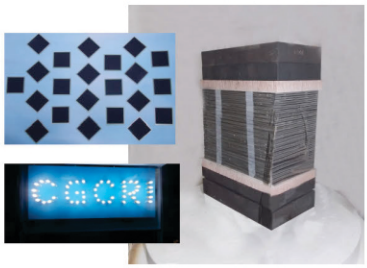

Sensors for Various Applications


Special Glass Beads


Supercontinuum Light Source

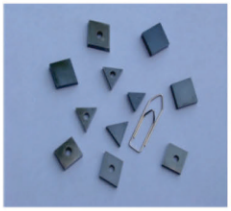


Pilot Plant for Arsenic Removal



500W Class Working SOFC Stack
(Inset: SOFC single cells & illumination by SOFC power)


Glass Blocks


SiAlON Cutting Inserts

CSIR-CGCRI is devoted to achieve excellence and providing leadership in the niche areas of specialty glass, optical fibres, advanced ceramics and nano-structured materials covering frontier science, viable technology and societal empowerment.

Outreach Centres

Naroda Centre
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22nd

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Printed : September, 2019

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(M-9899109778)

सत्यमेव जयते
त्रिलोचन महापात्र, पीएच.डी.
सचिव, एवं महानिदेशक
TRILOCHAN MOHAPATRA, Ph.D.
SECRETARY & DIRECTOR GENERAL



भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001
GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
KRISHI BHAVAN, NEW DELHI 110 001
Tel.: 23382629; 23386711 Fax: 91-11-23384773
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MESSAGE

It is pleasure to note that the Clay Minerals Society of India is organizing its 22nd Annual Convention and National Conference on *"Application of Clay and Allied Sciences in Agriculture, Environment and Industry"* during 23-24 September, 2019 at ICAR-Indian Agricultural Research Institute, New Delhi.

Clay, the most of which are in nano form, is regarded as the most reactive component of the soil. These particles have been considered as soul of soil, which dictate the physical, chemical and biological properties of soil to great extent. Thus, basic and fundamental understanding of clay is very important for proper soil management and land utilisation. Basic and applied clay research would benefit the researchers engaged in contemporary research in the field of nanotechnology, customized and efficient fertilizer products, plant protection formulations, ceramics, pharmaceuticals, soil quality, etc. I am hopeful that deliberation on different aspects of soil clays would bring out practical recommendation for enhancing the input use efficiency in agriculture. In this context, I am confident that two-day symposium will provide an excellent platform for effective and fruitful interaction.

I wish the Conference a grand success.

(T. MOHAPATRA)

Dated the 19th September, 2019
New Delhi

भा.कृ.अ.प. – भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली–110012 (भारत)
ICAR - INDIAN AGRICULTURAL RESEARCH INSTITUTE
(A DEEMED TO BE UNIVERSITY UNDER SECTION 3 OF UGC ACT, 1956)
NEW DELHI - 110012 (INDIA)

डॉ. अशोक कुमार सिंह
उपमहानिदेशक (कृषि प्रसार) एवं
निदेशक, भा.कृ.अ.प.–भा.कृ.अ.सं. (अतिरिक्त प्रभार)

Dr. Ashok Kumar Singh
Deputy Director General (Ag. Extension) &
Director, ICAR-IARI (Additional Charge)

Phones : 011-2584 2367, 2584 3375
Fax : 011-2584 6420
E-mail : director@iari.res.in
Website : www.iari.res.in



MESSAGE

It is a matter of great pleasure that the Clay Minerals Society of India (CMSI) is organizing the 22nd Annual Convention and National Conference on "**Application of Clay and Allied Sciences in Agriculture, Environment and Industry**" during September 23-24, 2019 at Pusa Campus, ICAR-IARI, New Delhi. Clay particles are the most reactive constituent of soil, which help to maintain the quality of the 'soil' *i.e.* the base for every production system. Therefore, knowledge of clay minerals and their properties is essential for understanding the behavior of soils in respect of performing its important functions. Although, excellent work has been carried out on different aspects of clays, a lot more need to be done particularly in the area of developing clay-based fertilizer products, plant protection formulations etc. This symposium may be a unique platform and provide opportunity for the confluence of ideas of imminent researchers from agriculture and allied fields. I trust, the symposium will certainly be of immense value towards generating new information on one hand and critical evaluation of the *hitherto* accrued knowledge on the other.

I welcome all the delegates and extend my best wishes for fruitful deliberations in the symposium. I deeply appreciate the excellent efforts of all the participants and wish all the members of CMSI and participants a grand success in this endeavor.

(AK Singh)

क. अलगुसुन्दरम
उप महानिदेशक (अभियांत्रिकी)
K. Alagusundaram
Deputy Director General (Engineering)



भारतीय कृषि अनुसंधान परिषद
कृषि अनुसंधान भवन–II,
पूसा, नई दिल्ली–110 012
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAVAN-II,
PUSA, NEW DELHI-110 012

19.09.2019

Message

It gives me an immense pleasure to know that the Clay Minerals Society of India (CMSI) is organizing "22nd Annual Convention and National Conference at ICAR-IARI, New Delhi during September 23-24, 2019. I am happy to know that theme of the symposium is "Application of Clay and Allied Sciences in Agriculture, Environment and Industry", which is very much useful for enhancing the use efficiency of inputs in agriculture. In fact, clay particle is the most reactive constituent of the soil, which governs most of the soil properties important to a production system. It plays a vital role in holding plant nutrients, water and sequestering soil organic carbon. The precise role of clay and their effects on soil functions are needed to be defined with its utility and importance in agriculture. The soil clays as nano material have immense use in geology, processing industries, agriculture and environmental remediation. Clay particles can be used as carrier for smart delivery of nutrients and plant protection chemicals.

Participation from agricultural fraternity including researchers, students, industrialists, private sector stakeholders etc. would provide on excellent platform to deliberate and help in understanding various facets of soil clay and its applications.

I convey my best wishes for the smooth conduct of symposium and wish a grand success.

19/9/19

K. ALAGUSUNDARAM

Ph: 91-11-2584 3415, Fax: 91-11-2584 2660; E-mail: ddgengg@icar.org.in

The Clay Minerals Society of India(Regd.)(Estd.1981)
Division of Soil Science and Agricultural Chemistry
ICAR-Indian Agricultural Research Institute
New Delhi



President
Dr Samar Chandra Datta
FCMSI, FISSS
9891119948(M)

Message

The Clay Minerals Society of India (CMSI) is organizing its 22nd Annual Convention and National Conference on " Application of Clay and Allied Sciences in Agriculture, Environment and Industry" in collaboration with ICAR- national Bureau of Soil Survey and Land Use Planning, Regional Centre, New Delhi during 23-24 September, 2019 at ICAR – Indian Agricultural Research Institute. The CMSI is a premier interdisciplinary and professional society registered and founded in 1981 to serve as a nerve centre for Scientists, Industrialists, Technologists and others engaged in the advancement of the frontier of science in the field of application of clay . Clay , the precious gift of nature and most of which are in nano form is the most important reactive component of soil due to its electric charge, high specific surface area and high aspect ratio. By virtue of its unique adsorption property it governs the buffering, filtering and nutrient supplying capacity of soils. It is the component which sequester carbon by making complex with humus in the soil and protects environments from global warming.

Recent study suggests that Clay Paved the Way for Evolution of Complex Animals. Roughly 550 million years ago the first complex animals, such as trilobites, appeared as a result of an increase in the amount of atmospheric oxygen. What might have led to the apparently rapid accumulation of oxygen in the atmosphere was a mystery. Now a team of researchers argues that clay minerals which was formed around 600 million years ago are responsible for trapping the organic carbon that would otherwise bond with highly reactive oxygen and decrease its concentration .

In addition to its role in soil and environment, clay has its immense scope in developing value added product such as efficient fertilizer carrier, such as nanoclay polymer composite (NCPC) , efficient plant protection formulation to protect fruits and vegetables from sunburn and disease, modified clay to remediate heavy metal pollution in soil and water and other industrial products like pharmaceuticals, ceramics and petrochemicals. Recently, unfortunately there is a decline in basic and applied research on clay in soil system and other agriculture sector. I hope two days deliberation will be very helpful in shaping the roadmap of clay research as well as in motivating young researchers to take up the work on various aspects of clay. Our society has also initiated young scientist award and student award for working related to clay science. I wish all a great success in this deliberation. I take this opportunity to extend my sincere thanks to the sponsors of the conference for extending financial assistance . I also place on record my deep sense of appreciation for all the cooperation and support extended to me for organising the conference.

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The Clay Minerals Society of India, New Delhi

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Dr. Tapas Bhattacharya

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Head
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22nd Annual Convention and National Conference on Application of Clay and Allied Sciences in Agriculture, Environment and Industry

September 23-24, 2019

Venue: ICAR-Indian Agricultural Research Institute, New Delhi

Programme

Day-1: September 23, 2019 (Monday)

8.00-9.00 Registration

9.30-10.30 Inaugural Session

11.30-12.30 6th Professor S.K. Mukherjee - CMSI Foundation Lecture
Chair person: Prof. S.K. Ghosh, Former Professor & Head, Div.SSAC, ICAR-IARI, New Delhi
Speaker : Dr. Tapas Bhattacharya, Former VC, BSKKV, Dapoli

12.30-1.30 Lunch

1.30-3.30 Special Session in Collaboration with TIFAC, New Delhi, on "Application Oriented Research on Clay Science"
Chair person: Dr. D.K. Pal, Former Head, Division of SRS, ICAR-NBSS & LUP, Nagpur
Co-Chair person: Dr. Gautam Goswami, Scientist F & Head, TIFAC, DST, New Delhi
Speakers: Dr. D.K. Pal, Dr. Tapas Bhattacharyya, Dr. Siddartha Mukhopadhyay, Dr. Sitendu Mandal, Dr. Sandeep Nagar, Dr. B.N. Srivastava, Dr. Gautam Goswami

3.30-5.30 **Technical Session I: Geoscience and Industrial Application of Clays**
Chair person: Dr. Swapna Mukherjee , Former Director, GSI, Kolkata
Co-Chair Person: Dr. Pankaj Srivastava, Professor, Dept. of Geology, University of Delhi

1. **Pankaj Srivastava and Neha Upreti**
   Red and yellow paleosols formation in response to the latitudinal shift and climatic changes during the evolution of Himalayan Foreland Basin
   Department of Geology, University of Delhi, Delhi 110 007, India

2. **Madhusudhan and P.L. Patil**
   Studies on clay minerals of Kanginhal sub-watershed in Northern dry zone of Karnataka
   Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dharwad-580 005

3. **Abhijit Sarkar, D.R. Biswas, S.C. Datta, K.M. Manjaiah, Trisha Roy**
   Polymer coating of laboratory synthesized phosphatic fertilizer: an effort to enhance phosphorus use efficiency
   Division of Soil Science and Agricultural Chemistry, ICAR-IARI, New Delhi-110012

4. **Siladitya Bandyopadhyay, B.N. Ghosh, K. Das, S. Mukhopadhyay, A.K. Sahoo and S.K. Singh**
   Pedogenesis in some tea growing soils of Terai Region of West Bengal
   ICAR-National Bureau of Soil Survey and Land Use Planning, Kolkata

5. **Chandrakala, M., Srinivasan, R., Anil Kumar K. S., Rajendra Hegde, and S. K. Singh**
   Landform- soil relationship in tropical humid region of Kerala, India- A case study in Elamdesam block
   National Bureau of Soil Survey and Land Use Planning, Hebbal, Bangalore-560 024, Karnataka

6. **P. Kumararaja, K.M. Manjaiah and S.C. Datta**
   Modified bentonite for remediation of industrial effluent irrigated metal contaminated soil
   Division of Soil Science and Agricultural Chemistry, ICAR-Indian Agricultural Research Institute, New Delhi, India

7. **P. Kumararaja, M. Muralidhar, R. Saraswathy, N. Lalitha, S. Suvanaand K.K. Vijayan**
   Biopolymer bentonite composite for the removal of ammonia from aquaculture pond water
   ICAR-Central Institute of Brackish water Aquaculture, Chennai, Tamil Nadu

8. **S. G. Savalia**
   Evaluation of Physico-chemical Characteristics and Clay Mineral Composition in Different Physiographic Units of the Soils of Southern Saurashtra Region of Gujarat (India)
   Department of Agricultural Chemistry and Soil Science, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) – 362 001

9. **Bassel Mhalla, Nayan Ahmed, Debarup Das and S.C. Datta**
   Pedogenesis and Mineralogy of Soils Derived from Different Parent Materials: Case Study from Kumaon Himalayan Region
   ICAR-Indian Agricultural Research Institute, New Delhi

10. **Anjali M C, Manjunatha Hebbara, P. L. Patil and Prathibha, K. S.**
    Mineralogy of selected red soil series of Kavalur sub-watershed
    College of Agriculture, University of Agriculture and Horticultural Sciences, Shimoga-577 204

11. **M. Lalitha, K.S. Anil Kumar, S. Dharumarajan, B. Kalaiselvi, S. Thayalan, Shivanand, Arti Koyal, S. Parvathy, R. Srinivasan, Rajendra Hegde and SK Singh**
    Mineralogical expression in Red and Lateritic soils of Eastern Ghats to East Coastal Plains of Tamil Nadu
    ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore

12. **Ruma Das, T.J. Purakayastha, Debarup Das, Nayan Ahmed, Rahul Kumar, Sunanda Biswas, Shrila Das and S.C. Datta**
    Effect of pre-treatment of soil for identification of clay minerals by XRD analysis in different soil orders
    ICAR-Indian Agricultural Research Institute, New Delhi – 110012, India

13. **Ali R.A. Moursy, Nayan Ahmed, R.N. Sahoo, BasselMhalla and Debarup Das**
    Clay minerals composition in some soils of Southern Plateau Agro-climatic zone of India
    ICAR-Indian Agricultural Research Institute, New Delhi

5.30-7.00 **Technical Session-II: Clay Mineralogy and Nano-Science**

Chair person: Dr. Siddhartha Mukhopadhayay, Former Director, EM&N Lab. & Professor, PAU Ludhiana

Co-Chair person: Dr. K.M. Manjaiah, Division of SS&AC, ICAR-IARI, New Delhi

14. **B. B. Basak**
    Evaluation of low-grade silicate minerals for potassium supplying capacity
    ICAR-Directorate of Medicinal and Aromatic Plants Research, Anand 387310, Gujarat

15. **Ranjan Paul, Karunakaran Karthikeyan, Duraisamy Vasu, Sonalika Sahoo, Pramod Tiwary, Padikkal Chandran, Surendra Kumar Singh**
    Characteristics and edaphological significance of nano size smectites of cracking clay soils (Vertisols) of Tropical India
    ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur

16. **Anshuman Das, D.R. Biswas, Debarup Das, Prasenjit Ray, Ruma Das, Avijit Ghosh**
Release Kinetics of Potassium in Relation to Clay Mineralogy in North-Eastern Himalayan region under Natural and Managed Ecosystems
ICAR-Indian Agricultural Research Institute, New Delhi

17. **Md. Basit Raza, S.P. Datta, M.C. Meena, Ruma Das, Vivek Kr. Trivedi, Debasis Golui and Kapil A Chobhe**
Evaluation of zinc loaded nano clay biopolymer composites for enhancing use efficiency of zinc
ICAR-Indian Agricultural Research Institute, New Delhi

18. **Debarup Das, Mandira Barman, S.P. Datta, B.S. Dwivedi and S.C. Datta**
Effect of potassium depletion from various pools on clay mineralogy of soils
ICAR-Indian Agricultural Research Institute, New Delhi

19. **Nisha Kumari, Nintu Mandal and Rajiv Rakshit**
Changes in clay minerals and potassium release and fixation threshold level under long-term rice-wheat cropping system in a Typic Halustepts
Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Sabour, Bhagalpur, Bihar -813210

20. **Sandeep Nagar**
Study of Clay Minerals using XRD "Aeris"
Philips, Malvern Panalytical Application Specialist Team

7.00-8.00 Annual General Body Meeting (AGM) of the CMSI

8.00 Dinner

Day-2: September 24, 2019 (Tuesday)

10.00-11.00 Presentation of Young Scientist Award and Best Ph.D/M.Sc. Student Travel Grant Award

Chair person : Dr. D.K Pal, Former Head, Div. of SRS, ICAR-NBSS & LUP, Nagpur

11.00-1.00 **Technical Session- III: Soil Health and Environment Quality**

Chair person: Dr. B.S. Dwivedi, Head, Div.SSAC, ICAR-IARI, New Delhi

Co-Chair Person: Dr. S.K. Roy, Head, ICAR-NBSS & LUP, Regional Centre, Jorhat

21. **Ranabir Chakraborty, Vinod Kumar Sharma, Dipak Ranjan Biswas, Mandira Barman, Kapil Chobhe, Debashis Chakraborty**
Impact of long-term nutrient management practices on different phosphorus fractions in an Alfisol under soybean-wheat
Division of Soil Science and Agricultural Chemistry, ICAR-IARI, New Delhi

22. **Sunanda Biswas, Anupama Singh, Priya Singh, G.A. Rajanna, B. S. Dwivedi**
Assessing soil health as influenced by hydrogel application under soybean-wheat cropping system in an Inceptisol of IGP
Division of Soil Science and Agricultural Chemistry, ICAR-IARI, New Delhi-110012

23. **Abir Dey, Brahma S. Dwivedi, Mahesh C. Meena and Narender**
Quantity and quality of soil organic carbon under long-term application of fertilizer and manure
ICAR-Indian Agricultural Research Institute (ICAR-IARI), New Delhi

24. **Shrila Das, R. Bhattacharyya, Ruma Das, and B.S. Dwivedi**
Response of oxidative stability of soil organic carbon and its depth-wise variations to different land use and management practices within north-western Indo Gangetic Plains
ICAR-Indian Agricultural Research Institute (IARI), New Delhi – 110012, India

25. **G. Patra, D. Chatterjee, K.C. Moharana, R. Tripathi, M. Shahid, A.K. Nayak, D.R. Pani and B.B. Panda**
Impact of conservation agriculture on carbon and nitrogen mineralization in soil
ICAR-National Rice Research Institute, Cuttack

26. **Khurshid Alam, Mandira Barman, S.P. Datta, Sarvendra Kumar, K. Annapurna, Livleen Shukla**
Effect of phosphate solubilizing microorganisms on distribution of phosphorus into different fractions and their availability to soybean crop in alluvial soil
Division of Soil Science and Agricultural Chemistry, ICAR-Indian Agricultural Research Institute, New Delhi

27. **Debasis Golui, S.P. Datta, B.S. Dwivedi, M.C. Meena and V.K. Trivedi**
Toxicity characteristics leaching procedure: A technique for assessing metal hazards of polluted soils in relation to human health
Division of Soil Science and Agricultural Chemistry, ICAR-Indian Agricultural Research Institute, New Delhi

28. **K. Modak, D.R. Biswas, R. Bhattacharyya, S. Das and T.K. Das**
Effect of Conservation Agricultural practices on Soil Organic Carbon Pools, C accumulation and soil C sequestration in an Inceptisol
ICAR-Indian Agricultural Research Institute, New Delhi

29. **Suvana Sukumaran and T. J. Purakayastha**
Impact of long-term fertilization and manuring on carbon capacity of two Alfisols with rice-rice cropping system
ICAR-Central Institute of Brackish water Aquaculture, Chennai-600028

30. **Arkaprava Roy, Siba Prasad Datta, Somnath Bhattacharyya, Mandira Barman, Mahesh Chand Meena, Debasis Golui, Vivek Kumar Trivedi, Viswanathan Chinnusamy, Suchitra Pushkar and Kalikinkar Bandyopadhyay**
Exploring relationship of organic acid secreted by roots with arsenic uptake by rice cultivars
ICAR-Indian Agricultural Research Institute, New Delhi

31. **S. Ramachandran, S. Bandyopadhyay, S. K. Reza, Shelton Padua, Bachaspati Das, Dimpi Barpatra,R. K. Jena, P. Ray, K. K. Mauriya, Surabhi Hota**
Soil Macro and Micro nutrient Status of Barpeta District of Assam using GPS and GIS Techniques
ICAR- National Bureau of Soil Survey & Land Use Planning Regional Centre,Jorhat-785004, Assam

32. **B N Srivastava**
Elemental Analysis of Soil byX-ray fluorescence Spectrometry (XRFS)
Malvern Panalytical, India

1.00-2.00 Lunch

2.00-4.00 **Technical Session- IV: Soil Resource Inventory**

Chair person: Dr. S.K. Singh, Director, ICAR-NBSS & LUP, Nagpur

Co-Chair person: Dr. Nayan Ahmed, Division of SS&AC, ICAR-IARI, New Delhi

33. **Jyotirmaya Sahoo, Dinesh Tomar**

Characterization of soils of Jhumpa Kalan watershed of Bhiwani district Haryana, North-west India

Division of Soil Science and Agricultural Chemistry, ICAR-Indian Agricultural Research Institute, New Delhi

34. **K. Das, B N Ghosh, Shreyasi Gupta Chaudhury, S Mukhopadhyay, D C Nayak and S K Singh**
Environmental Influence on Physicochemical Characteristics of Soils in Tangi Block of Khurda district, Odisha
National Bureau of Soil Survey and Land Use Planning (ICAR), Block-DK, Sector II, Salt Lake, Kolkata

35. **Ritu Nagdev, S.K. Mahapatra, R.K. Meena, Vikas, Jaya N. Surya and S.K. Singh**
Study of Agri-environmental characteristics in Rajpura Block of Patiala District in Punjab for Sustainable Productivity
ICAR- NBSS & LUP, Regional Centre, Delhi-110012

36. **Kalaiselvi. B, Dharumarajan. S, Lalitha, M, Srinivasan. R., Anil Kumar. K.S, Rajendra Hegde and S.K. Singh**
Characterization and Classification of Shrink-swell soils developed from Calcic-Gneiss parent material
ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore-560 024, India

37. **S.K. Reza, P. Ray, S. Ramachandran, R.K. Jena, S. Mukhopadhyay, A.K. Sahoo, S.K. Singh and S.K. Ray**
Spatial variability of soil organic carbon fractions as affected by different land uses in Purvanchal range of North- Eastern, India
ICAR-National Bureau of Soil Survey and Land Use Planning, Sector-II, DK-Block, Salt Lake, Kolkata, West Bengal

38. **Shraddha Mohanty, R.M. Karmakar**
Pedogenic characterization of paddy and associated non-paddy soils of Assam
Department of Soil Science, Faculty of Agriculture Assam Agricultural University, Jorhat-785013, Assam

39. **S. Gupta Choudhury, S. Mukhopadhyay, A. K. Sahoo, K. Das, D. C. Nayak[1] and S. K. Singh**
Identification and Characterization of Alfisols in Barind Region of West Bengal
ICAR- NBSS & LUP, Regional Centre, Kolkata-700091

40. **R. Srinivasan, S. K. Singh, D.C. Nayak, Rajendra Hegde and M. Chandrakala**
Effect of climate on seasonal variation of soil salinity and alkalinity in Coastal Odisha for Sustainable crop production
National Bureau of Soil Survey & Land Use Planning (ICAR) Regional Centre, Hebbal, Bangaluru

41. **Nayan Ahmed, T.J. Purakaystha, Ruma Das, Sunanda Biswas and S.C. Datta**
Assessment of clay-humus stability through IR spectroscopy in a long term integrated nutrient management experiment
ICAR-Indian Agricultural Research Institute, New Delhi

42. **S. Hota, R.K. Jena, P. Ray, K.K. Mourya, S. Ramachandran and S.K. Ray**
Impact of land form and land use changes on soil potassium pools in Meghalaya plateau of India
ICAR- National Bureau of Soil Survey and Land Use Planning, Regional Centre, Jorhat, Assam

43. **K.K. Mourya, R.K. Jena1, P. Ray, S. Hota, S. Ramachandran1, S.K. Ray**
Impact of land use on soil organic carbon stocks in Meghalaya Plateu of India
ICAR- National Bureau of Soil Survey and Land Use Planning, Regional Centre, Jorhat, Assam

44. **Achyut Bikash Borah, Prasenjit Ray, S.K. Singh and S.K. Ray**
Boron availability in acid soils of Brahmaputra valley with varying organic carbon content
Department of Chemistry, The Assam Kaziranga University, Jorhat, Assam

45. **Ashok Kumar, S. K. Mahapatra and S.K. Singh**
Role of Clay Particles in Sustainability of Rice-Wheat Cropping System in Indo-Gangetic Plains - a Case Study
ICAR-National Bureau of Soil Survey & Land Use Planning, Regional Centre, IARI Campus, New Delhi-110012

46. **R. P. Sharma and R. Singh**
Classical Cracking pattern in Sodic Vertisols of Gujarat
ICAR-National Bureau of Soil Survey and Land Use Planning, Amravati Road, Nagpur-440033

47. **Abhishek Jangir, R.P. Sharma, G. Tiwari, B. Dash, R.K. Naitam, and S.K. Singh**
Morphological and Physico-Chemical Characteristics of Soils: A Case Study of Bharuch Taluka, Bharuch District of Gujarat
ICAR-National Bureau of Soil Survey and Land Use Planning, Amravati Road, Nagpur-440033

48. **G. Tiwari, A. Jangir, B. Dash, D. Vasu, R.S. Singh and S.K. Singh**
Large-Scale Soil Mapping (1:10,000) using Geospatial Techniques- A Case Study of Gandhidham, Kutch District, Gujarat
ICAR-National Bureau of Soil Survey and Land Use Planning, Amravati Road, Nagpur-440033

4.00-5.00 **Plenary Session**

Chairman: Dr. S.K. Chaudhari, ADG (SWM), NRM Division, ICAR, New Delhi

Penalists: Dr. Swapna, Mukerjee, Dr. D.K. Pal, Dr. S.C. Datta, Dr. Tapas Bhattacharya, Dr. K.M. Manjaiah and Dr. Gautam Goswami

Soil clay minerals and ecosystem services

Tapas Bhattacharyya

Vice-Chancellor (Former), Dr. Balasaheb, Sawant Konkan Krishi, Vidyapeeth, Dapoli, Maharashtra

Extended Summary

I deeply appreciate the honour the Clay Mineral Society of India has done me for delivering the 6th Prof. S.K. Mukherjee CMSI Foundation Lecture. Professor Mukherjee's research forte was Soil Science and Physical Chemistry, but he was at ease from Physics to Philosophy and Social Sciences. During the passage of my research efforts, Prof. Mukherjee's contribution influenced me through deliberations made by my teachers and senior colleagues. As a student of soil science, with my little experience in clay mineralogy, as a part of pedology, I have decided to share some of our research findings, as a tribute to this great scientist.

With the advent of modern technologies, like remote sensing and geographical information system, pedometrics, pedotransfer and taxotransfer rules, soil and clay mineral database storage and retrieval, the subjects of pedology and clay mineralogy have become more incisive. Since all the gamutes of agriculture depend directly on soils, and soil is controlled by the clay, as the reactive substrate, it is appropriate to revisit soil and clay mineralogy and their influence on ecosystem services. It is for this reason, I have decided to flag some examples of soil clay minerals and ecosystem services.

Pedology is the study of soils in their natural environment. Pedology deals with many other branches of science. Among those, soil and clay mineralogy, make an important subject. Four important ecosystem services soil minerals in different size fractions provide are i) provisioning services, ii) regulating services, iii) cultural services, and iv) supporting services. The first one include food, raw materials and water retention, while the regulating services are a) climate, b) water regulation, c) carbon sequestration, d) erosion and flood control. The supporting services include i) weathering/ soil formation, and ii) nutrient recycling. And lastly the cultural services include cultural heritage.

The first step towards providing ecosystem services is perhaps to have more knowledge about the ecosystem. For soil and soil clay minerals the information system needs to be in place. The soil information system, as well as clay mineral information system, developed from the geographic soil information system, are in place. The spatial aspects, and dynamics, of soil properties to

6th Professor Sushil Kumar Mukherjee Foundation Lecture to be delivered at the 22nd Annual Convention of the Clay Minerals Society of India on 23 September, 2019 at New Delhi

ecosystem services, are studied, though mapping or scenario modeling of future changes. Where soil/clay mineral information, is missing, pedotransfer functions or mapping, and modelling exercises may act as a proxy. Ecosystem services, deal with spatial aspects and mapping of resources. Mineral information system in India, other than soil clay mineral,say, zeolites, palygorskite, carbonates and gypsum in soils need a special mention. Taxonomic database, helped to classify, Indian soils *albeit* state wise, to develop, a tentative mineralogy map. At the field level, many soils were wrongly grouped, as mixed mineralogy class which were revised using research data. Both soil clay minerals and other minerals in different size fractions influence ecosystem services in terms of providing foods, fibres, and controlling soil/land degradation.

While making an inventory on the degraded land, land degradation neutrality (LDN) should also be kept in mind. The LDN is achieved, if new degradation is balanced, by reversal of degradation, elsewhere, in the same land type, by restoration or rehabilitation. The recently held meeting during September in India in the United Nations Convention to Combat Desertification, discussed on land degradation. In the fourteenth meeting of the Conference of the Parties (COP14), India has promised to bring many areas under LDN. Two case studies, namely Konkan laterites and horticultural planning, and, Vertisols and semi-arid tropics to predict the soils of tomorrow, may be mentioned as success stories towards LDN since both are related to soil minerals. Knowledge of geology and soil minerals can, therefore, help in LDN, which, reaffirms, the role of mineralogist, in ecosystem services, to combat desertification.

The soil clays are also linked with land use options. The most important thing is that minerals like gypsum and zeolites can maintain soil and biodiversity. The efforts to measure soil and pedo diversity can pave the way to quantify soil mineral diversity which can more precisely help commenting on soil microbial diversity. Soil/clay minerals, have a role to play in understanding climate change signature, so far as, regulation of climate is concerned. Research data indicate that both di-, and trioctahedral smectites can be useful evidence, for climate change. In the Western Ghats, as well as, the red soils, in the southern peninsula, smectite-kaolinite interstratified minerals, are ephemeral, and, therefore, carries signature of climate change. Soils can memorize, past events through soil minerals and, therefore, soil/minerals and cultural heritage are interlinked. Other than minerals, remnants of mineral parts known as bioliths (example, diatoms), could be an interesting areas of study to comment on the age of soils, and the past climate.

Soil scientists and soil mineralogists, appear to be tentative, to use the term 'ecosystem services' even if their research is devoted to linking soils/minerals to ecosystem services. Future soil/mineral ecosystem services' research should focus on exploring soil functional diversity of soil biota and the spatial aspects of soil/mineral properties at the lower level of ecosystem services (e.g., water purification, and climate regulation). Soil scientists and mineralogists should, engage professionals from other disciplines to promote the contribution of soils to ecosystem services delivery and

human well-being. Soil/mineral ecosystem service studies, could be used, in local and national policy development, and in the programmes on natural resource use and management. Little more aggressive, yet, positive attitude, towards what's happening, in the other parts of the globe shall bring the soil and clay mineral scientists, together to show, that they can also contribute to address the global problem.

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Clay minerals' control on factors and of enhancement strategies for carbon sequestration in Indian tropical soils

D.K. Pal

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To feed the global population in the coming centuries by keeping soil health intact is a great challenge for the soil and earth scientists who are making relentless efforts to find suitable ways to maintain, whenever necessary to increase soil organic carbon (SOC) in general and in tropical soils in particular. Both SOC and soil inorganic carbon (SIC as $CaCO_3$)) are the most important components of soil as they determine ecosystem and agro-ecosystem functions by influencing soil fertility, soil water, environment, microbial activity and other soil parameters. Additionally, SOC has a role in the global carbon cycle and in the mitigation of atmospheric levels of greenhouse gases. Both SOC and SIC stock estimates show their important roles for atmospheric CO_2 sequestration. SOC stock (in the first 0–150 cm) of Indian soils is less (29.92 Pg) than that of SIC (33.98 Pg). Impoverishment in SOC in Indian soils is largely due to less accumulation of organic C (< 1%) in soils of the arid and semi-arid and dry sub-humid climatic regions. In contrast, soils of humid tropical (HT) climates have >>1% OC content. Factors responsible for organic carbon sequestration of Indian soils are identified and they are (i) profuse vegetation under HT climate with adequate rainfall (>> 1000 mm) under cooler temperature for a period of a few months, (ii) presence of Ca-zeolites that ensures adequate soil moisture in both HT and semi-arid tropical (SAT) climate by preventing the total transformation of smectite to kaolinite, (iii) active inorganic part of soil as a substrate to build the SOC through clay-organic matter complex formation, and (iv) presence of smectites and vermiculites, which are *hitherto* believed to be capable of accumulating greater amounts of OC than the non-expanding minerals. However, a recent review on the impact of phyllosilicate mineralogy on SOC protection emphasizes that introducing a "phyllosilicate mineralogy" parameter in SOC models appears premature because alongside the phyllosilicates, soil clay fractions do contain short range ordered minerals (SRO), metallic oxides and hydroxides, and carbonates, which are also being considered important for SOC protection, and their possible interaction with phyllosilicates. Indian soils contain a variety of clay minerals of expanding and non-expanding nature and also interstratified or mixed layer ones. Therefore, a revisit is necessary to highlight the nature and properties of crystalline expanding clay minerals, mixed clay minerals and also of associated non-crystalline ones that are likely to influence SOC

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sequestration in major soils of India. This exercise would also explain the ability of these types of minerals in SOC sequestration as eco-system service providers. It is interesting to note that despite being a 0.7 nm mineral interstratified with hydroxy-interlayered smectite or vermiculite, HIS/HIV (kaolin) in HT soils, it shows a remarkable capacity to sequester more organic carbon (OC) than highly smectitic Vertisols of semi-arid tropical (SAT) climate, highlighting a much superior role of interstratified clay minerals such as kaolin than discrete smectite in OC sequestration. This unique example expands the basic knowledge on the role of kaolin in stabilization of SOC. As the formation of kaolin is formed only under acidic pedochemical environment induced by profuse vegetation under HT climate, both acidity and interstratified clay minerals appear to be more important factors in enhancing the OC sequestration in soils. Research also shows an important role of Ca-zeolites in OC sequestration, which they help in forming kaolin by preventing complete transformation of smectite to kaolinite by maintaining relatively high base saturation level in acidic Vertisols, Mollisols and Alfisols. The million years old Inceptisols, Alfisols, Mollisols and Ultisols of HT climate have considerable amount of OC in the 0-30 cm depth that ranges from ~ 1% to 3.1%, which signifies a quasi-equilibrium value under natural forest. Long term experiments (LTEs) in temperate humid region of UK indicated the OC increase > 7‰ yr^{-1} and OC content in the 0-23 cm soil depth increased from ~1 to 2.14%. Such SOC value is comparable to OC content of the HT soils of India, suggesting that for HT soils, there is no immediate need to achieve the "4 per 1000" goal. It however appears necessary in SAT soils as they are expected to release CO_2 under hostile SAT climatic conditions. In the Indian sub-continent, Andisols, Mollisols, Alfisols and Inceptisols of the HT climate, which are mostly dominated by kaolin clay minerals, under forest cover have sequestered maximum amount of OC and thus, such favourable OC enrichment may suggest that introduction of forestry by removing land from agricultural land uses, may lead to large accumulations of SOC. Moderate OC enrichment is also observed even under natural forest in red ferruginous Alfisols and Vertic Inceptisols in Indian SAT climate over a century's time. Alfisols and Vertic Inceptisols could sequester high OC concentration of 1.78% and 0.81% in the 0-30 cm soil depth, respectively. Relatively higher OC accumulation in red ferruginous Alfisols was observed when the soils have dominant amount of kaolin. But the conversion of agricultural lands to forestry has severe limitations if food security goals of the Indian sub-continent are to be met. Few studies on SAT ferruginous Alfisols and Vertisols indicate that horticultural system shows a better quasi-equilibrium value of OC of 0.81% and 0.75% against 0.68% and 0.50% under agriculture system in the first 30 cm soil depth, respectively.

Economic analysis on SOC sequestration in Indian tropical soils reported that in majority of LTEs, the NPK plus FYM (10t ha^{-1}) treatment showed higher SOC and also higher net return than that under NPK treatment, suggesting that application of FYM with NPK is a cost effective, win-win technology for the Indian farmers. Paradoxically, the SOC content (0-30 cm depth) of an LTE of 28 years on SAT Vertisols using sorghum-wheat cropping system with recommended doses of NPK fertilizers plus FYM (10t ha^{-1}) show a value of 0.73% only. Such low accumulation of OC in highly smectitic Vertisols under long term agricultural land use suggests that there is no significant

role of crystalline smectite clay minerals in stabilizing OC. In general, clay smectites of SAT Vertisols are little hydroxy-interlayered, and under slight alkaline pH conditions, hydroxy interlayered materials mostly remain inactive in stabilizing OC, and thus are not supporting SAT smectitic soils to accumulate OC > 1%. On the other hand, small but significant enhancement of OC content under horticultural system as compared to agricultural land uses is observed, which suggests that horticulture is a better option for SOC sequestration if forestry is not feasible in SAT red ferruginous Alfisols and Vertisols.

The agricultural management practices advocated through the national agricultural research system (NARS) for the last several decades did not cause any decline in SOC in the major crop growing zones of the country under SAT climate. The increase in OC in agricultural soils (maximum up to ≤ 1% in 0-30 cm depth) observed in SAT areas through NARS interventions appears enough to provide ecosystem services in growing self-sufficiency in food production and food stock since independence. Such interventions since post-green revolution period helped in moderate OC sequestration in all soil types without leading to increased emissions of greenhouse gases to any alarming proportion. Global scientists however aspire that for better ecosystem services, soils should have at least 2% OC in the upper soil layers. Among other ways to enhance the SOC stock of Indian SAT soils, conversion of soils with low productivity or that are fragile and prone to erosion, from agriculture to forest or grassland may be a good strategy. Sodic soils are impoverished with OC but exhibit good potential to sequester OC when ameliorative management practices are implemented. Through the implementation of specific management practices for Typic Natrustalfs of the Indo-Gangetic Plains and Sodic Haplusterts of southern India, an increase in OC stock was observed for both soil types. Enrichment of OC in sodic soils in the NW part of the IGP is also possible by protecting naturally occurring grassland system over a long period by increasing plant biomass production through biological amelioration. Therefore, to include sodic soils as a potential option for C sequestration, additional financial support through incentives may be a viable option as soil C sequestration has proved to be the most cost-effective option as compared to geological sequestration. Keeping in mind the roles of acidity, interstratified clay minerals like kaolin and non-crystalline clay minerals (SRO) in OC stabilization, it could be envisaged that further enhancement in SOC stock in SAT soils could be possible if the selected agricultural crops with more root volume are engineered by plant breeders. It is possible that greater release of carbonaceous acidic exudates from such crop roots would act as source of carbon. In addition, more soil acidity in the root zone areas would also influence OC sequestration by breaking the crystalline clay structure to form SRO minerals and hydroxy-interlayered clay minerals, which have high carbon sequestering potential.

Acknowledgements

This article is written based on decades of research done by several scientists especially those of the Division of Soil Resource Studies, ICAR-NBSS&LUP, Nagpur and Division of Soil Science and Agricultural Chemistry, ICAR-IARI, New Delhi.

Red and yellow paleosols formation in response to the latitudinal shift and climatic changes during the evolution of Himalayan Foreland Basin

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The northward drift of the Indian Plate, shrinking paratethys, India-Asia collision, and the rise of the Himalaya played a significant role on weathering and genesis of red and yellow paleosols in the foreland. Detailed paleopedological investigation of a 3.1 km succession from Kangra sub-basin of the Himalayan Foreland Basin (HFB) suggests varying intensity of weathering and pedogenesis with formation of the red (10R hue) in the lower 2 km part and the yellow (2.y hue) paleosols in the upper 1.1 km part of the succession. Four pedofacies (A-D types) in the entire succession were identified based paleosol-sediment association and the degree of pedogenic development. Formation of the red paleosols with pedogenic $CaCO_3$ and palustrine carbonates is related to 17ºN to 20ºN palaeolatitudinalposition of the HFB during early Oligocene. This led to the formation of ferruginous paleosols in tropical conditions under incipient seasonality. Whereas, the transition from red to yellow paleosol formation at about 20 Ma is related to increased humidity, rapid aggradation, pronounced uplift, enhanced erosion of the hinterland and possible northward latitudinal shift during paleopedogenesis.

Studies on clay minerals of Kanginhal sub-watershed in Northern dry zone of Karnataka

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Mineralogical studies were carried out for six representative pedons (Ap and Bw horizons) developed on granite gneiss in Kanginhal sub-watershed by XRD analysis. The pedons under study were neutral to moderately alkaline (pH: 7.55 to 8.32) with no salinity (EC: 0.03 to 0.88 dS m^{-1}) and non-sodic (ESP: 0.57 to 4.66). Organic carbon content of soil was low to high (0.28 to 0.90%), CEC was ranged from 42.5 to 50.1 cmol (p^+) kg^{-1} and the clay content was high (45.3 to 69.4%). The mineralogical study by XRD revealed that, smectite was the dominant mineral in clay fraction. It varied from 60.3 to 88.7% in Ap horizon and 55.7 to 74.2% Bw/Bss horizon. Vermiculite was also present in all the soil series identified in the sub watershed except MGR series. Content of vermiculite ranged from 12.6 to 26.8% in surface and 11.2 to 28.4% in Bw/Bss horizon, followed by kaolin and quartz. Vermiculite was absent in MVD and NGT series. Kaolin and quartz varied from 6.0 to 12.8% and 2.7 to 13.6%, respectively in Ap horizon and 5.2 to 13.4% and 3.0 to 8.9%, respectively in Bw/Bss horizon. Among the secondary minerals, smectite dominated over vermiculite and kaolin.

Polymer coating of laboratory synthesized phosphatic fertilizer: an effort to enhance phosphorus use efficiency

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The coating of fertilizers with polymers is an acknowledged strategy for control release of nutrients and their availability in soil. However, its effectiveness in the case of soluble phosphate (P) fertilizers is still uncertain, and information is lacking concerning the chemical properties of nutrient core and structures of such coatings. Here, a nutrient core was synthesized in laboratory after the reaction of liquid ammonia (30%; sp. gr. 0.89) and ortho-phosphoric acid (88%, v/v) in a four necked-reaction vessel on ice-bath. This material was systematically characterized for physico-chemical properties (colour, pH, EC, N and P content), surface morphology (scanning electron microscopy, SEM), particle shape (transmission electron microscopy, TEM) and surface functional groups (Fourier-transform infrared spectroscopy, FTIR). Subsequently, it was coated with poly-vinyl alcohol (PVA), liquid paraffin (LP) and methyl oleate (MO) at the levels of 2 and 3% w/w. Polymer coated products were incubated in a phosphorus deficient sandy loam soil for 120 hours to assess the slow release properties against commercial di-ammonium phosphate (DAP) at 20 and 30 °C. Results revealed that higher rate of P release from MO coated products and resemble DAP, followed by PVA- and LP-coated products. While, 3% coating grade showed better slow release properties than its counterpart at both the temperatures. But, Vant Hoff's Q10 was greater for LP coated products. Based on incubation results, pot-culture experiment with wheat (*Triticum aestivum*) was conducted with PVA and LP coated products only. Significant increase of biomass and economic yield from polymer coated products over DAP and absolute control (without P) was observed. Phosphorus uptake by wheat was at par for PVA and LP coated products, but agronomic use efficiency was significantly higher than DAP. Residual soil P was also higher at polymer coated products treated pots; though PVA treated pots have higher amount of available P in post-harvest soil. Overall, it can be concluded that coating of water-soluble fertilizer materials with bio-degradable organic polymers may enhance the use efficiency of P and also enhance the residual soil fertility over uncoated fertilizers.

Pedogenesis in some tea growing soils of Terai Region of West Bengal

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Soil resource inventory has been conducted in some tea growing soils occurring on piedmont zones of Jalpaiguri district representing the Terai region of West Bengal. These soils were previously reported under Inceptisols order with *Aquic* and *Udic* moisture regimes (sub orders) and under the great groups of *Endoaquepts, Humaquepts, Humudepts, Dystrudepts* and *Eutrudepts.* However, the detailed pedogenic studies revealed that there has been the inception of formation of Alfisols in the region with occurrence of gleyed Argillic horizons (Btg) at lower sub soils. The present investigation unveils that soils (P1-P4) have high fine clay (FC)/ total clay (TC) ratio at sub surface Argillic (Bt) horizons compared to surface with illuviation ratio ranging from 1.21 to 1.24 at sub surface horizons and both the ratios increases with depth of soils. They have texture ranging from sandy loam to silt loam in surface and silty clay loam to clay loam at sub surface with clay fraction ranging from 13.6 to 14.1% at surface and 16.4 to 20.6 at sub surface horizons. The ratio of FC/ TC in all pedons were more than 0.2 with range of 0.23 to 0.31, indicating predominance of fine clay in the finer earth fractions. Among the different particle size ratios, it has been noted that FS/TS and VFS/TS increases with depth of soils, while, silt/clay and sand/silt had opposite trends. These observations go in favour of the process of argillization has been incepted in them in the recent *Holocene* period. Soil-landform relationship has been established in an altitudinal sequence. The results unfold that soils of upper piedmonts (P1-P2) were well drained, sandy loam to loamy at surface and sandy clay loam to clay loam at sub surface horizons, strongly to moderately acidic in reaction with high organic carbon. They have argillization at a very beginning stage with a depth of Argillic horizon (Bt) of less than 35 cm and where classified as *Inceptic Hapludalfs*. Soils on lower piedmonts (P3-P4) were fine loamy, imperfectly drained, silty clay loam to clay loam in texture, moderately to weakly acidic in reaction, high in organic carbon with hue of 2.5 Y to 10 YR and chroma of 2 or less. They were classified as *Umbric Endoaqualfs* (P3) and *Grossarenic Endoaqualfs* (P4), depending up on high OC, darker matrix surface colour in P3 and coarse texture at lower sub surfaces (75-100 cm) in P4. Humid sub-tropical climate with heavy intense rainfall and warm to hot temperature and gentle to moderate slope of the land appear to favour clay illuviation processes indicating that Alfisols have been started to form in the region at juvenile stages.

Landform-soil relationship in tropical humid region of Kerala, India-A case study in Elamdesam block

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Landform is a major factor controlling both hydrological and soil processes at the different landscape scale. This is well-known qualitatively in that topography, along with parent material, climate, biota, and time, is one of the fundamental soil forming factors. The topographic influence is also apparent in the soil catena concept. In this contest case study was attempted Landform-soil relationship in Elamdesam block. The detailed soil survey was carried out in Elamdesam block using IRS satellite (IRS LISS IV) imagery on 1:10,000 scale. The soils were studied in several transects and a soil map was prepared with phases of soil series as mapping units. Study area landforms varied from hills, uplands, midlands, and low lands. Results shown that soils depth is varied from deep (100-150 cm) to very deep (>150 cm) in all the land forms with well drained in hill, upland and midlands and moderately well to poor drained in lowlands. Clay content varies with different landforms position, increasing trend observed with increasing depth. Clay range in different landforms *viz.* hills (15.1 to 41.6%), upland and midland (20.0 to 43.6%) and lowland soils (32.9 to 63.5%), respectively. The wide textural variation might be due to variation in parent material, topography, *in-situ* weathering and translocation of clay by eluviation and age of the soils. The organic carbon, gravels, cation exchange capacity (CEC) and base saturation % ranged from hills (0.36 to 3.39%; 10-40%; 6.91 to 15.12 cmol (p^+) kg^{-1}; 3 to 8%) upland and midland (0.51 to 1.99%; 10-25%; 3 to 3.5 cmol (p^+) kg^{-1}; 4 to 55%) and low land (0.8 to 2.29%; no gravels; 7.14 to 16.14 cmol (p^+) kg^{-1}; 14 to 35%), respectively. Mixed forest and rubber plantation in hilly areas, rubber plantation in upland and midlands and paddy in low lands are the best suitable crops. Soils are classified as Ultisols in hilly areas whereas Ultisols and Inceptisols in upland and midlands and Inceptisols in lowlands.

Modified bentonite for remediation of industrial effluent irrigated metal contaminated soil

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Modified bentonites were assessed for their efficiency in immobilization of heavy metals in a contaminated soil by pot culture experiment. In pot culture experiment, amendment of soil with bentonite (NB), manganese oxide coated bentonite (MnB), and aluminium pillared bentonite (AlB) @ 2.5% significantly reduced DTPA and EDTA extractable Zn, Cu and Ni as well as their uptake by *Amaranthus blitum* and *Beta vulgaris*. Application of AlB, MnB and NB @ 2.5% improved the growth of amaranthus by 62%, 58% and 25%, respectively at first harvest and by 82%, 80% and 51%, respectively at second harvest.The hazard quotient of Zn, Cu and Ni intake through the consumption of leafy vegetables grown on industrial effluent irrigated soil amended with bentonites (@ 2.5%) was significantly lower than unamended soil. The study demonstrated that functionalised bentonites could be potentially used for remediation of heavy metal polluted soils owing to their metal-immobilising ability.

Biopolymer bentonite composite for the removal of ammonia from aquaculture pond water

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Shrimp aquaculture contributed 70% of the Rs. 45,000 crore marine product exports during 2017-18. Under intensive farming with high stocking density, unionised form of total ammoniacal nitrogen (TAN) becomes toxic to aquatic animals. To overcome the higher TAN concentration, farmers used to apply zeolites as an adsorbent. In brackish-water system the efficiency of zeolite in reducing the TAN level is low due to the dominance of competing ions such as Ca^{2+}, Mg^{2+}, Na^{+}, etc. for the adsorption sites. With the objective of developing an adsorbent with enhanced TAN removal capacity, bentonite clay was copolymerised with chitosan biopolymer. Intercalation of chitosan molecule resulted in higher specific surface area and increased *d*-spacing as revealed by the X-ray diffraction of the composite. By batch adsorption study, the efficiency of the composite in TAN removal was evaluated. The removal capacity of the composite was 21.8 mg TAN g^{-1} composite at 0 ppt which reduced to 10.2 mg TAN g^{-1} composite at 30 ppt salinity. These are much higher than the values reported for zeolite (8.60 and 0.04 mg TAN g^{-1} at 0 and 30 ppt, respectively; Boyd, 2010). Treating the low saline shrimp pond water from Orathanadu, Tamil Nadu with the composite for 15 minutes resulted in 77.9% reduction in TAN level. The study revealed that the bentonite chitosan composite could be used for reducing TAN, and ultimately unionised ammoniacal N in shrimp aquaculture.

Evaluation of physico-chemical characteristics and clay mineral composition in different physiographic units of the soils of southern Saurashtra region of Gujarat (India)

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Sixteen typical profiles representing calcareous basaltic soils of different physiographic units of southern Saurashtra region of Gujarat (India) were studied for physico-chemical characteristics and identification of clay minerals by X-ray diffraction analysis. In general, the soils of the study area were clay loam to clay in texture, slight to moderately alkaline in reaction and calcareous in nature. The soils on higher altitude have low pH, EC, $CaCO_3$ and ESP than the soils on lower altitude. The smectite was the predominant clay mineral observed in soils of different physiographic units of southern Saurashtra of Gujarat. The dominant clay minerals identified in hill slope were in sequence of smectite > kaolinite and illite > mixed layer whereas the associated minerals were vermiculite and chlorite. Next to smectite, higher rainfall areas in hill slope showed the dominance of kaolinite, while lower rainfall areas in hill slope had illite as dominant clay mineral. The chlorite was dominant mineral next to smectite in upper piedmont area whereas associated minerals identified were kaolinite, illite, vermiculite and beidellite. The smectite was the dominant mineral in the lower piedmont and piedmont plain areas. The associated minerals identified in the soils of lower piedmont were kaolinite, chlorite, vermiculite, beidellite, mixed layer and illite whereas in the piedmont plain area were kaolinite, chlorite, vermiculite and mixed layer. The dominant clay minerals identified in the coastal plain were in the order of smectite > chlorite whereas the associated minerals were vermiculite, kaolinite, mixed layer, illite and beidellite.

Pedogenesis and mineralogy of soils derived from different parent materials: Case study from Kumaon Himalayan region

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Parent material represents the source of the soil forming mass. Its interaction with climate, vegetation and topography through time will define soil physico-chemical and mineralogical properties. Five soils from Almora district, Kumaon Himalayan region, which derived from mica schist, slate, phyllite, quartzite and alluvial parent materials, were selected to study the effect of parent material on soil genesis and clay minerals composition. Soil development on slates was subject to sever erosion which restrict the soil development resulting in A-C profile that classified as Udorthents. Soils derived from other parent materials showed A-B-C profiles and classified as Udepts. Parent materials were found to be the dominant factor controlling the clay mineralogical compositions while the other soil forming factors has a limited effect. The studied soils were found in the initial stage of weathering as reflected in the ratio of pedogenic iron to total iron in soil (Fed/Fet < 0.3) as well as the chemical index of weathering (CIA < 75). The results revealed that kaolinite and illite were the dominant clay minerals. However, soils derived from mica schist and slate exhibit higher content on kaolinite while other soils were dominated by illite minerals. The distributions of the clay minerals in soil profile suggest that both kaolinite and illite are originated from parent materials. Illite-kaolinite random interstratified minerals were found only in the broad valley soil derived from alluvial parent materials. Illite transformation to vermiculite was limited in all the soils except in the soil developed from mica schist of the hill top terraces. The results showed that the variations in the type of clay minerals and their relative abundance were influenced by parent material and topographical position.

Mineralogy of selected red soil series of Kavalur sub-watershed

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The red soils of Kavalur sub-watershed of Koppal district, Karnataka are inherited from granite-gnesiss under semi-arid climate at an average elevation of 463.27 m above mean sea level. The mineralogical composition of these soils was investigated using X-ray diffraction technique. The soil samples of two depths (Ap and Bt) of two representative pedons covering two different soil series were selected for the study. The silica to alumina molar ratio was higher in Ap horizons than in Bt horizons. Similarly, the silica to sequioxides molar ratio was also higher in Ap horizons than in Bt horizons. In case of clay mineralogy, the kaolin (indicative of mixed mineralogy) was dominant among secondary clay minerals followed by smectite in the Ap horizon. In the Bt horizon, smectite was dominant followed by kaolin. In addition to secondary minerals, clay sized particles also contained primary minerals like mica, quartz and feldspar. Red soil pedons had more kaolin content and its content decreased with depth. In contrast, smectite content was quite low in the Ap and increased with depth. The mineralogical composition of sand fraction of these soils indicated predominance of quartz followed by feldspar, olivines, biotite mica, pyroxenes, ferrihydrides and goethite. The XRD pattern of silt fraction indicated the dominance of primary minerals (>70 %) as compared to secondary minerals. Quartz was the dominant primary mineral found in the silt fraction. Other minerals identified in the silt fraction included mica and feldspar. Silt fraction also contained secondary minerals like smectite, vermiculite and kaolinite.

Mineralogical expression in red and lateritic soils of Eastern Ghats to East Coastal Plains of Tamil Nadu

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Red and lateritic soils are third most important soil group in the world predominantly occupying semiarid to humid tropical climatic areas. In the present study, five soil pedons were selected along a toposequence from the Eastern Ghats to East Coastal Plains of Tamil Nadu for exploring the significance of climate and landform upon the weathering status and clay activity of soil. One profile each representing Kolli hills and Yercaud hills of Eastern Ghats and three profiles representing Inland Plains of Sivagangai and Thiruvarur district were studied. Results indicated that bulk density values are uniform in different horizons of hilly ranges indicating uniform weathering rates with depth whereas in the Inland Plains it increased with increasing depth. Silt to clay ratios are relatively higher (> 0.15) in the surface horizon and decrease with increasing depth indicating that sub-soil horizons are more weathered than surface horizons except in the Inland Plains of Sivagangai where it ranged from 0.08-0.11 (< 0.15) in the subsoil. The soils of hill ranges are slightly acidic in surface and strongly acidic in subsoils. The pH increased with depth from moderately acidic surface soil to neutral subsoil in Sivaganga. The soils are clayey and clay content increased with depth. The soil of Thiruvarur showed neutral pH in surface and slight to moderately acidic pH in subsurface layer. The CEC is low and base saturation is less than 100. The organic carbon content is high in hill ranges whereas it is low in Inland Plains. The CEC/ Clay ratio ranged from 0.1-0.5 and it is high in the hill ranges (semi active) and low in Inland Plains indicating the presence of sub-active kaolinitic clays. The gravel and plinthite are present in the profile except Thiruvarur, which indicate very short dry period and water table fluctuations.

Effect of pre-treatment of soil for identification of clay minerals by XRD analysis in different soil orders

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X-ray diffraction (XRD) analysis of clay is the most commonly employed technique for identification of minerals. A series of chemical pre-treatments is generally given during separation of clay from soil before XRD analysis with the intention to enhance the accuracy of mineral phase identification. However, such pre-treatments are laborious and time-consuming, and may also sometimes adversely affect the expression of peaks of different clay minerals. Keeping this in mind, the effect of pre-treatments on X-ray identification of clay minerals in soils, collected from four ongoing long-term (31 years) experiments situated at Ludhiana (Inceptisol), Jabalpur (Vertisol), Pantnagar (Mollisol) and Ranchi (Alfisol), representing varying mineralogy and carbon content, was studied. The aim was to identify soil conditions where such pre-treatments can be avoided without compromising the accuracy of mineral identification. To get variations within an order, soil (0-15 cm) samples at each site were collected from five treatments with different combinations of organic and inorganic fertilizers. From the soils, clay (with pre-treatment) and colloidal organo-mineral fraction or COMF (without pre-treatment) were isolated and the XRD analyses and semi-quantification of minerals were done following standard procedures. Among the soil orders, Alfisol showed the least deviation in X-ray diffractograms between clay and COMF, whereas highest deviation was found in Vertisol. Irrespective of soil orders, illite and kaolinite peaks were least affected by the presence of organic C or Fe oxide in soils. However, the relative abundance of smectite or smectite rich interstratified minerals (SRM) was higher when it was calculated from clay as compared to COMF. The chlorite mineral was distorted by pre-treatment with very high amount of H_2O_2 for removal of organic matter from soils of Mollisol. On an average, the results indicated that mineral identification and semi-quantification can be done with reasonable accuracy even without chemical pre-treatment, given that SRM is not present in noticeable quantity. However, such findings need further corroboration from a wider array of soil types.

Clay minerals composition in some soils of southern plateau agro-climatic zone of India

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Clays are generally the most important adsorbents for metals and organic substances. Clay minerals play a key role in determining soil properties such as soil structure, cation exchange capacity and water holding capacity. Thus, clay minerals contribute to soil functions and the delivery of soil ecosystem services. This study is a part of ISRO&NASA-JPL science campaign in India which aims to develop a sound soil spectral database of 57 Indian sites using hyperspectral remote sensing. The aim of the current study is to identify the clay minerals in soils of southern plateau agro-climatic zone. The soil samples (*n*=243) were collected from various soil orders, *viz.* Vertisols, Inceptisols and Alfisols from Raichur in Karnataka and Kurnool districts of Andhra Pradesh. Forty spatially distributed soil samples were selected depending on their CEC (ranged from 11.2 to 48.6 cmol (p^+) kg^{-1} and clay content (ranging from 13.4 to 72.0 per cent) to represent the study area. The X-ray diffraction technique was used for identifying the clay minerals composition in these soils. The results obtained from semi-quantitative analysis indicated that montmorillonite was the dominant clay mineral in Raichur soils, followed by vermiculite, kaolinite and illite clay minerals. In Kurnool soils, the dominant clay mineral was kaolinite, followed by vermiculite, montmorillonite and illite. Further studies will be done by using the modern diffuse reflectance spectroscopy technique which will be an effective tool for clay minerals identification and mapping of the large agricultural areas.

Evaluation of low-grade silicate minerals for potassium supplying capacity

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The K supplying capacity of low-grade silicate minerals was evaluated through chemical and biological methods. The silicate mineral samples were collected from different parts of the country. Waste mica was collected from Koderma district of Jharkhand and Nellore district of Andhra Pradesh. Feldspar sample was collected from Gudur, Andhra Pradesh. Two green sand samples were collected from Satna, Madhya Pradesh and Kutch, Gujarat. The details mineralogical compositions of the silicate mineral powder were analyzed by the X-ray fluorescence (XRF) spectroscopic method. The total K (% K_2O) content in the silicate mineral followed the order as: feldspar (14.9%) > waste mica (7.24-9.72%) > greensand (4.56-5.4%). Different chemical extractants, water, neutral 1*N* ammonium acetate, 0.01*N* citric acid and boiling 1*N* nitric acid (HNO_3) were used to study the K release from the low-grade silicate minerals. The K release by different chemical extraction methods showed significant variation. The amount of K release by various extractants followed the order as: water < 0.01*N* citric acid < 1*N* ammonium acetate (NH_4OAc) < 1*N* boiling nitric acid. To study the plant intervention on K release from silicate mineral powder, a greenhouse experiment was conducted using palmarosa (*Cymbopogon martini* var. *motia*) and sudan grass (*Sorghum vulgare* var. *Sudanensis)* in K deficient soil. Results indicated that K recovery from waste mica (39.3 - 42.5%) is quite higher than feldspar (19.7-22.5%) and greensand (5.4-7.5%) irrespective of plant species. So, these low-grade silicate minerals may be identified as a potential K source for agricultural application.

Characteristics and edaphological significance of nano size smectites of cracking clay soils (Vertisols) of Tropical India

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Nano size smectites were isolated from two representative alluvium derived Vertisol developed from the Deccan basalt (DB), occurring in the central and eastern part of India, respectively and characterized for particle size, mineralogy and crystalline behaviour. Soils were clayey (> 60%) in texture, dominant in smectite mineral (60-80% in < 2 μm fraction), alkaline in reaction (pH 7.8-8.5), rich in $CaCO_3$ (6-9%) and contain 0.44-0.54 % organic carbon. Soils contain 40-60 % nano-size clays (<0.1 μm), which are dominantly smectitic (>90%). Apart from smectite, soils also contain hydroxy-interlayered vermiculite (HIV), pedogenic chlorite (PCh), kaolin and mica in the clay fraction. Smectites in the clay fraction are fairly well crystalline and little hydroxy-interlayered (HIS). Hydroxy-interlayering is less pronounced in nano clay smectite than in the clay smectite. The nano size HIS is low charge species and show smaller crystallite size (3.5-5.5 nm) and higher value of strain (15-22%) within its crystal structure. Despite its dominant presence and large surface area for expected favourable physical and chemical reactions, the hydroxy-interlayered minerals of the nano HIS in the present mild alkaline soil reaction, would remain inert. Its participation in stabilizing organic carbon and fixing added phosphorus is possible when hydroxy-interlayered materials remain as positively charged and this can happen in acidic soil reaction. Moreover, it has no K and NH_4 selectivity because of its low charge density. In contrast,small amount of Na^+ ion in the exchange complex (exchangeable sodium percentage,ESP ~ 5) results in swelling and dispersion of large amount of nano sized smectite as they are prone to more swelling than Ca-smectite due to their low charge density. Therefore, the present study hightlights a unique role of nano smectites in some very important aspects of edaphological issues of Vertisols.

Release kinetics of potassium in relation to clay mineralogy in north-eastern Himalayan region under natural and managed ecosystems

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Fertilizer application in Indian agriculture has remained largely skewed towards nitrogen (N) and phosphorus (P), while potassium (K) remained neglected for over last five decades. This has resulted in over dependence on soil native K to support intensive cultivation in the country. For proper management of this precious nutrient, knowledge of K-sorption and desorption behavior in relation to clay mineralogy is very important. Keeping this in view, a study was conducted to assess release, fixation and quantity-intensity relationship of soil K in relation to mineralogy under forest and rice-mustard land use systems in three depths of Inceptisol. The K-fixation capacity had showed significantly positive correlations with clay content, CEC and potential buffering capacity. The illite and illite rich 2:1 interstratified minerals, together, in the clay fraction were noticeably higher in all the three depths under forest system than the rice-mustard system. The soil clays under rice-mustard had the highest centre of gravity (*cg)* values in all the depths which can be linked to the lowest illite contents under this system. As a result, the rate of release of soil K was higher for soils having lower *cg* position of clay minerals. In general, the $mica_{001/002}$ which acts as a potent indicator of amount of di- and tri-octahedral component of mica was positively correlated, while *cg* was negatively correlated with cumulative release of K. Soil clays with lower *cg* and higher $mica_{001/002}$ ratio would have much higher potential for greater K release in due course of time.

Evaluation of zinc loaded nano clay biopolymer composites for enhancing use efficiency of zinc

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Use efficiency of zinc (Zn) applied through conventional sources is very low, hovering around 2%. In view of enhancing use efficiency of applied Zn in crop production, a novel fertilizer product *i.e.* Zn loaded nano clay polymer composite (Zn-NCPC) was recently developed at ICAR-Indian Agricultural Research Institute, New Delhi. In the present study, an attempt has been made to synthesize and evaluate nano clay biopolymer composites (NCBPCs) in order to make these newly developed novel fertilizer products cheaper. The efficacy of Zn loaded polymer composites for enhancing yield and Zn uptake by wheat grown on Zn deficient sodic soil was evaluated under greenhouse condition. Results indicated that Zn applied through NCBPC is 5-6 times more effective in enhancing the yield of wheat as compared to conventional sources *i.e.* $ZnSO_4$. Such positive responses were also reflected in both content and uptake of Zn by wheat. Application of much lower dose of Zn through seed coating with NCBPC could also produce similar biomass yield of wheat as that obtained with the recommended rate of Zn application through $ZnSO_4$.

Effect of potassium depletion from various pools on clay mineralogy of soils

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A study was conducted with five different soils to observe the contribution of various soil potassium (K) pools towards K release and alterations in clay minerals due to K-depletion. Two alluvial soils (Inceptisol) from New Delhi (one low in available K, another high in available K) were leached for 100 times with 0.01 *M* $CaCl_2$, then for 68 times with 1 *M* $CaCl_2$. Separately, one red soil (Alfisol) from Ranchi, one black soil (Vertisol) from Jabalpur and one calcareous soil (Entisol) from Bihar were leached for 61 times with 1 *M* $CaCl_2$. Total K released were 281, 607, 181, 233 and 195 mg kg^{-1} from alluvial (low K), alluvial (high K), red, black and calcareous soils, respectively. Such K depletion caused significant reduction in available K in all five soils, but non-exchangeable K showed significant reduction only in the alluvial soil (high K). In all the soils, highest contribution was recorded from lattice pool towards total K released, except the alluvial soil (high K); and the same varied from 27.5% to 96.4% in different soils. Depletion in K caused noticeable alterations in the distribution of clay minerals. There was clear reduction in illite peak area in both alluvial soils and the calcareous soil owing to K-mining. In the red soil, peak near 1.43 nm disappeared after leaching; while in the black soil, major alterations were observed between 1.43 and 1.80 nm. These findings imply that the actual ill effects of continuous K-mining caused by negligence in K fertilization, a very common phenomenon in Indian agriculture, will go unnoticed even if non-exchangeable K is assessed along with available K.

Changes in clay minerals and potassium release and fixation threshold level under long-term rice-wheat cropping system in a Typic Halustepts

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An attempt has been made to study the effect of long-term application of inorganic and integrated nutrient management options on clay mineral transformation and determine the fixation and release threshold level of potassium (K) in soil under rice-wheat cropping system. The treatments used were as follows: T1: control (no fertilizer), T2: 50% RDF both in rice and wheat , T3: 75% RDF in rice and wheat, T4: 100% RDF in rice and wheat , T5: 50% RDF in rice and wheat + 50% N supplied through FYM, T6: 75% through RDF in rice and wheat and 25% N supplied through FYM, T7: 75% RDF in rice and wheat and 25% N supplied through wheat straw, T8: 75% RDF in rice and wheat and 25% N supplied through green manure and farmer's practices. Dominant clay minerals in treatment under study was Illitic in nature. Formation of interstratified minerals (Illite -Vermiculite/ Illite-Kaolinite) as well as transformation to Vermiculite / Chlorite were also observed through XRD analysis. Si-O stretching (650-900 cm^{-1}) and Al-OH/ Mg-OH/ Fe-OH stretching vibration (3400 cm^{-1}- 3700 cm^{-1}) were invariably observed in all clay samples. Si-O-Al vibration (1030 cm^{-1}) and Al-OH-Si (1400 cm^{-1}) were also observed. Stretching vibration shifted within range indicated changes in functional groups. SEM images further confirmed the clay transformation by showing changes in surface morphologies. Dominantly irregular flakes (Illite), Hexagonal (Kaolinite) and absence of specific surface topologies (indicating interstratification) were also observed. Fixation threshold levels (FTL) varied among the treatments. Maximum FTL was observed in T5 (182 mg kg^{-1}) followed by T7 (178 mg kg^{-1}). Release threshold level (RTLs) varied among treatments. T1 recorded minimum RTLs (35.9 mg kg^{-1}), whereas maximum was observed in T5 (74.8 mg kg^{-1}).

Study of clay minerals using XRD "Aeris"

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Clay minerals have been widely investigated for their significance in environmental, industrial, agricultural and geological sciences. These minerals belong to the phyllosilicate family of minerals, which are characterized by their layered structures composed of sheets of silica tetrahedra attached with octahedral sheets. Mineralogical identification of clays is difficult and usually done with sedimentation separation followed by analytical identification. While the correct identification of clay minerals may involve many different techniques, X-ray diffraction is a non-destructive technique which can quickly reveal the crystal structure of clay minerals. Aeris diffractometer-based investigation will be showcased here. Aeris presents best in class resolution of PIXcel3D detector (256X256 Pixcels being 55 mic°rons sized), superior 2θ linearity ($<\pm 0.02^0$) and good low angle performance (1^0), ease of sample preparation, prefix optics removing the need to align and calibrate as well as 600W working power (no chiller required) makes Aeris an ideal system for clay mineralogist. Using High Score Plus and Robo Riet software, Rietveld quantification model-based analysis can be automated to process large amounts of samples in most time efficient manner. Using artificial intelligence-based algorithms, samples can be classified based on similarity of features for processing further.

Impact of long-term nutrient management practices on different phosphorus fractions in an Alfisol under soybean-wheat

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Phosphorus (P) is the second most important mineral nutrient for crop production after nitrogen. In India, about 50 Mha area is acidic in which Alfisols occupy the major portion. Plants are only able to utilize a small part of applied P-fertilizers, rest is converted to Fe/Al-phosphate in acid soil and Ca-phosphate in alkaline soil, leading to widespread P deficiency. Long-term fertilizer management provides valuable information on residual effect of applied P as transformation and establishment of equilibrium need sufficiently long time. Therefore, an attempt has been made to study the impact of long-term nutrient management practices on different P fractions. The long-term fertilizer experiment was initiated in the year of 1972 at Ranchi, Jharkhand. Eight treatments *viz.* control, 100% N, 100% NP, 50 % NPK, 100% NPK, 150% NPK, 100% NPK+ FYM and 100% NPK + Lime were selected. Soil samples (0–15 and 15–30 cm) were collected after harvest of wheat in April, 2018 for analysis of different P fractions. Results indicated that Fe-P was the most dominant P fraction, whereas soluble and loosely bound P occupied the smallest portion. In general, inorganic P fractions followed the order as: Fe-P > reductant soluble-P > Al-P > Ca-P > soluble and loosely bound-P. Inorganic P, organic P and total P were increased with increasing dose of P fertilizer. Super-optimal dose of P showed maximum accumulation of all inorganic P fractions except Ca-P in both soil depths as compared to others treatments.

Assessing soil health as influenced by hydrogel application under soybean-wheat cropping system in an Inceptisol of IGP

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Soybean-wheat is one of the dominant cropping systems in India and wheat is the second most important cereal crops. The objective of the present investigation was to study the impact of hydrogel application on soil health. Soil samples were collected from soybean-wheat cropping system of ICAR-IARI farm after harvest of wheat. The treatments include three levels of irrigation, two types and rates of gel application at 0-6 cm soil depth. The treatment details were, T1: RF (rainfed)+control, T2: RF + K-Gel 2.5 kg ha^{-1}, T3: RF + K-Gel 5.0 kg ha^{-1}, T4: RF + Pusa-Gel 2.5 kg ha^{-1}, T5: LI (limited irrigation) + control, T6: LI + K-Gel 2.5 kg ha^{-1}, T7: LI + K-Gel 5.0 kg ha^{-1}, T8: LI + Pusa-Gel 2.5 kg ha^{-1}, T9: AI (adequate irrigation) + control, T10: AI + K-Gel 2.5 kg ha^{-1}, T11: AI + K-Gel 5.0 kg ha^{-1}, T12: AI + Pusa-Gel 2.5 kg ha^{-1}. The soil samples were analysed for physical, chemical and biological properties *viz.* pH, organic C, available N, P, K, DTPA-extractable Zn, Cu, Fe, Mn, dehydrogenase and alkaline phosphatase activity. The results of PCA showed that, available Zn, K, S, oxidisable organic C and pH were key soil health indicators. The value of soil health index (SHI) ranges from 0.74 to 0.91 and the highest value of SHI was found in the treatment with LI + Pusa-Gel @2.5 kg ha^{-1} (0.91) and lowest was with RF + control treatment (0.74). Therefore, the application of hydrogel does not adversely affect the overall health of soils.

Quantity and quality of soil organic carbon under long-term application of fertilizer and manure

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Improving soil organic carbon (SOC) in arable soils is one of the important strategies to achieve sustainable crop yields and mitigate climate change. We investigated the changes in SOC under long-term application of balanced and unbalanced doses of manures and fertilizers. The surface soil samples (0-15 cm) were collected from six treatments *viz.*, Control, N, NPK, 150% NPK, NPK+FYM and NPK+S after harvest of wheat in 1996-97, 2001-02, 2006-07, 2010-11 and 2016-17 from an experimental trial under the aegis AICRP–LTFE located at ICAR-IARI, New Delhi since 1972-73. The result showed significantly higher values of total SOC under 150% NPK and NPK+FYM, compared with non-fertilized and imbalance fertilized plots. Irrespective of treatments, mean total SOC significantly increased in 2016-17, as compared with 1996-97. Very labile, labile and less labile SOC increased significantly over the years under 150% NPK and NPK+FYM. On the contrary, treatments control and N registered a decreasing pattern of these SOC pools over the years. Similarly, acid hydrolysable SOC also followed the similar trend. Hot water extractable SOC, which can be termed as the most labile pool of SOC, decreased significantly over the years in all treatment except NPK+FYM. Therefore, application of NPK+FYM improved both the quality and quantity of SOC under the intensive cropping system. The 150% NPK application was also found beneficial, but often failed to maintain more labile pools of SOC, although contributing significantly towards C sequestration.

Response of oxidative stability of soil organic carbon and its depth-wise variations to different land use and management practices in north-western Indo Gangetic Plains

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The soil organic carbon (SOC) in deep soil is assumed to be very stable and recognized to be mineral associated along with biochemical recalcitrance. Therefore, the properties and dynamics of C in deep soils are largely ignored. In addition to this, because of the difficulties of sample collection, the stabilization mechanism of deep soil carbon is poorly understood. In order to address the issues of deep soil C and its role in soil productivity, the present study was undertaken to asses soil carbon pools and depth-wise variation in its stock. Soil samples were collected from seven different land uses and management practices of north-western Indo Gangetic Plains (IGP) region *viz.* agriculture based, horticulture based, grass land, agroforestry, river bed, stabilized dumping site and sewage irrigated soil at four different depths *viz.* 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm in triplicates. Various land use management practices have significant effect on depth wise variation on total carbon (TC) and total organic carbon (TOC) stock and their relative order were as follows: 30-60 cm > 60-90 cm > 0-15 cm > 15-30 cm. Labile and recalcitrant C pools were significantly affected by various land uses and management practices up to 1 m depth and labile C pools decreased with depth (57% to 32%) whereas, recalcitrant C pools increased with depth (67% to 94%). Mean weight diameter (soil aggregation) varied significantly between top most layer and lowermost layer and lowest stability was found in stabilized dumping site throughout the depth. Therefore, it can be visualized that there is large variability in depth wise SOC distribution under different land uses and management practices of north-western IGP region.

Impact of conservation agriculture on carbon and nitrogen mineralization in soil

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Continuous mono-cropping of rice increased the disease and pest incidence in rice crop and declined productivity. Additionally puddling in rice is involved in the destruction of soil structure. To overcome such situation with alternative to conventional practices, introduction of conservation agriculture (CA) serves as an emerging technology to bring sustainability in rice-based cropping system in eastern India. The current research programme was undertaken on soils of an experiment comprising of different components of CA alone and in combinations at Research Farm of ICAR-National Bureau of Plant Genetic Resources, Cuttack. Impact of different components of conservation (minimum soil disturbance/reduce tillage (T), permanent soil cover through crop residues or cover crops (R), and crop rotations (D)) alone and in combination was incorporated for conducting the study. Carbon and nitrogen fractions, mineralization, soil enzymatic activities were estimated using standard methods. Results revealed that higher CO_2-C was found in residue added and diversification (R, RT, RD and RTD) treatments. The carbon mineralization in terms of mean cumulative CO_2-C (mg CO_2-C kg^{-1}) fitted well in first order kinetics (R^2=0.97–0.99) *i.e.* the degradation is dependent on the initial concentration. Potentially mineralizable nitrogen (N_0) content ranged from 191-219 kg ha^{-1}. The lowest potentially mineralizable nitrogen content was recorded in control, while the highest was recorded in D. Among the soil enzymes, the treatment D showed the highest value in dehydrogenase activity and nitrate reductase activity, RD showed the highest value in FDA activity, β-glucosidase, RTD showed the highest value in urease activity in initial stage. It was observed that the treatment D showed the highest value in microbial biomass carbon, ammonium nitrogen, nitrate nitrogen in all growth stages. From this experiment we can conclude that among the different components of conservation agriculture, the effect of diversification was more prominent during the initial year. The residue incorporation was also showing positive impact on carbon and nitrogen mineralization, soil enzymatic activities and carbon and nitrogen fractions. However, the positive effect of residue incorporation was found to be more effective when it was done in combination with diversification.

Effect of phosphate solubilizing microorganisms on distribution of phosphorus into different fractions and their availability to soybean crop in alluvial soil

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A greenhouse pot experiment was conducted to study the effect of phosphate solubilizing microbes on distribution of phosphorus (P) in different soil fractions and its availability to soybean crop (*Glycine max*) grown on alluvial soil of Delhi. Results indicated that P fertilization and phosphate solubilizing bacteria (PSB) **(***Enterobacter* sp.**)** significantly increased the available P in soil over control, which was also reflected in biomass yield of soybean. Available P increased from 10.6 to 13.6 mg kg^{-1} in soil under P application of 50% recommended dose of phosphorus (RDP) over control, while P application of 100% RDP showed available P as 16.4 mg kg^{-1}. The PSB inoculation increased the available P from 13.2 to 14.1 mg kg^{-1} in soil over control. Application of P significantly decreased the alkaline phosphatase activity in soil, while PSB increased the same. Significant increase in distribution P in different inorganic soil fractions was noticed at all levels of P application. Application of PSB increased soluble and loosely bound P and decreased Al, Fe and Ca bound P. The Al, Fe bound, occluded and residual P contributed negatively towards dry matter yield of soybean, while positive contribution was noticed for soluble and loosely bound, reductant soluble and Ca bound fraction of P.

Toxicity characteristics leaching procedure: A technique for assessing metal hazards of polluted soils in relation to human health

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Effectiveness of toxicity characteristics leaching procedure (TCLP) in assessing metal hazards of polluted soils having a long history of receiving pollutant elements was assessed in relation to human health. Total metal content in the soils studied were 1657±2335 mg kg^{-1} for Zn, 351±180 mg kg^{-1} for Cu, 166±79.9 mg kg^{-1} for Ni, 249±269 mg kg^{-1} for Pb and 18.6±23.2 mg kg^{-1} for Cd. The TCLP extractable metal content varied as 177±376 mg kg^{-1} for Zn, 10.9±28.5 mg kg^{-1} for Cu, 23.1±67.2 mg kg^{-1} for Ni, 2.79±10.3 mg kg^{-1} for Pb and 4.92±16.3 mg kg^{-1} for Cd across the experimental soils. In case of spinach, the values of hazard quotient (HQ) varied from 0.055 to 0.972, 0.002 to 0.019, 0.008 to 0.181, 0.066 to 5.489 and 0.044 to 11.32 in respect of Zn, Cu, Ni, Pb and Cd, respectively. There was a considerable variation in hazard quotient (HQ) in different soils. While comparing the effectiveness of assessing metal hazard of TCLP with that assessed in terms of HQ, it was clear that critical value of HQ exceeded in some soil samples for Pb (spinach), whereas TCLP extractable Pb content in those soils were within the safe limit i.e. < 50 mg kg^{-1}. This study underlines the need of upward revision of permissible limits of TCLP extractable metals to protect human and soil health.

Effect of conservation agricultural practices on soil organic carbon pools, carbon accumulation and soil carbon sequestration in an Inceptisol

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Agricultural intensification through intensive tillage practices has deteriorated natural resources like soil. Conservation agriculture (CA) approaches involving soil cover through crop residues and minimum soil disturbance has been successful to achieve higher productivity. An experiment was carried out in a Typic Haplustept at the Research Farm of ICAR-IARI, New Delhi in the year 2008-09 in a split-plot design with two levels of tillage, *viz*. zero tillage (ZT) and conventional tillage (CT) under four levels of residue management, *viz*. no residue (NR), wheat residue (WR), soybean residue (SR) and wheat + soybean residue (WR+SR), respectively. Soil sample was collected from the experiments at 0-5, 5-15, 15-30 and 30-60 cm depths during the year 2016-17 and analyzed for carbon (C) pools, accumulation and sequestration rate of C to study the effect of tillage and residue retention in wheat-based cropping system. Labile C was higher in ZT plots than CT plots across all the plots in the 0-5 cm soil depth. The labile C concentration in WR+SR, SR and WR plots were ~67, 50 and 35% higher, respectively than NR plots. Zero tillage increased labile C within macroaggregates than CT. The labile C increased by 67, 43 and 34% in the WR+SR, SR and WR plots, respectively, over NR plots. The microaggregates of CT had 21% lower labile C than ZT in the 0-5 cm soil depth. Recalcitrant C in WR+SR, SR and WR plots was ~54, 51 and 45% higher than NR plots, respectively in 0-5 cm soil depth. Similar trend was observed in 5-15 cm soil depth. In macroaggregates, the recalcitrant C was ~57, 76 and 63% at 0-5 cm soil depth, and 85, 59 and 40% higher at 5-15 cm soil depth under WR+SR, SR and WR plots over NR, respectively. Similar trend was observed for microaggregate associated recalcitrant C. The soil organic carbon (SOC) accumulation and sequestration rates under residue retained plots were significantly higher than the control plots in top layers (0-15 cm) and deep layers (15-60 cm). Conservation agricultural practices lead to ~40% higher SOC sequestration in top layers. Deep soil layers accounted for ~68% of sequestered C.

Impact of long-term fertilization and manuring on carbon carrying capacity of two Alfisols with rice-rice cropping system

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Carbon (C) sequestration in soil is limited by the maximum C carrying capacity (Cm) and thereof C saturation deficit (Sd) of soil. The Cm and Sd of two Alfisols from India located in Bhubaneswar, Odisha and Pattambi, Kerala, respectively with history of long-term manuring and fertilization under rice-rice cropping system were estimated. The total soil carbon (TSC), soil organic carbon (SOC) and total soil N (TSN) under the rice-rice cropping system in Alfisols of Bhubaneswar and Pattambi increased dramatically with the conjoint application of FYM with 100% NPK and super optimal doses of NPK. There was no significant differences in the C:N ratio under different treatments in soils of Bhubaneswar whereas in case of Pattambi, addition of FYM with 100% NPK increased C:N ratio to 12:1. The estimated return of C (ERC) from different sources as estimated varied across treatments and it was observed highest in 100% NPK + FYM treatment followed by 150% NPK. The humification rate constant (h) as estimated from Jenkinson's two C pool model was marginally higher in Alfisol of Pattambi (0.243) than the Alfisol of Bhubaneswar (0.222). The decay rate constant (k) calculated for Alfisol of Bhubaneswar (0.0033) was three times higher than that of Alfisol of Pattambi (0.001). From the value of k, Ct (SOC content) and change in SOC over time (dCt/dt), the Cm was computed as 56.5 Mg ha^{-1} and 78.5 Mg ha^{-1} at 0-30 cm soil depth in Alfisols of Bhubaneswar and Pattambi, respectively. The saturation deficit (Sd) in Alfisol of Bhubaneswar varied from 0.14 (100% NPK + FYM) to 0.41 (50% NPK) and 0.05 (100% NPK + FYM) to 0.36 (50% NPK) in Alfisol of Pattambi. The Alfisol of Bhubaneswar, Odisha has more carbon sequestration potential (CSP) than the Alfisol of Pattambi, Kerala.

Exploring relationship of organic acid secreted by roots with arsenic uptake by rice cultivars

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Rice, one of the most important staple food crops worldwide, is inherently efficient in accumulation of arsenic (As). Although a few attempts have been made to screen out low As accumulating rice cultivars but the role of rhizosphere environment in such differential As uptake has not been evaluated and understood thoroughly. For this purpose, a solution culture experiment was conducted to assess the effect of As application (@ 0 and 100 μg L^{-1}) on secretion of organic acids by four rice cultivars, *viz.* IR-36, Khitish, Satabdi and Badshabhog. Total weak acid (TWA) and four organic acids (citric, malic, succinic and lactic acid) in the rooting (Hoagland) solution were quantified by conductometric titration and HPLC, respectively. Results indicated that concentration of TWA in Hoagland solution elevated 1.34-fold as a result of increased As concentration in solution. The highest concentration of TWA was secreted by IR-36 (0.82 m*N*), followed by Khitish (0.58 m*N*), Satabdi (0.44 m*N*) and Badshabhog (0.36 m*N*). The concentration of lactic acid varied with rice cultivars; however, such trend was conspicuously absent in case of other acids, *viz.* citric, malic and succinic acid. The highest root to shoot translocation factor was recorded in IR-36 (0.52) and Satabdi (0.42), followed by Badshabhog (0.35) and Khitish (0.31). It is evident that presence of As in Hoagland solution had positive effect on the secretion of total weak acids by different rice cultivars.

Soil macro and micro nutrient status of Barpeta district of Assam using GPS and GIS techniques

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With a view to assess and map the soil fertility status of Barpeta district of Assam, the present investigation was undertaken and analysed in GIS platform. In this study, a systematic set of 1293 georeferenced soil samples were collected at 1 km interval from 718 villages, covering all the 11 community development blocks and 9 revenue circles. The soil samples were analyzed for 9 chemical parameters and the data along with GPS readings were used for the preparation of soil fertility maps using GIS. The soil fertility maps clearly revealed that a major area of the district was acid (53.0% of TGA), slightly to moderately alkaline (13.0% of TGA); low, medium to high in OC (7.6, 24.1 and 42.9% respectively); low, high and medium in available N, P and K, respectively. With regard to available micronutrients, Zn was predominantly deficient (47.2% of TGA) while Fe, Mn and Cu were in sufficient status. As a whole, soil acidity, available K and Zn are the major nutrient constraints in Barpeta district which warrants attention for implementing soil test crop response based nutrient management options.

Elemental analysis of soil by X-ray fluorescence spectrometry (XRFS)

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Survey & elemental analysis of Soils is being done to serve different aspects viz. Geological aspect, environmental aspect & more recently agricultural aspect. XRF as a technique has been a popular choice for elemental analysis due to its ease of sample preparation and speed of analysis. With advancement in X-ray technology, XRFS has gained importance in soil, agriculture and analysis of biological samples due to its ability to analyse nearly all elements in the periodic table at sub-ppm levels.

The advanced software used is capable of classifying samples into different types based on advance statistical methods which is based on the shape of the entire spectrum and not only on the chemical / elemental concentration data.

Critical data on Soils and biological samples using Malvern Panalytical XRF is shown in the paper.

Characterization of soils of Jhumpa Kalan watershed of Bhiwani district Haryana, North-west India

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This study aimed at characterization of soil samples collected from Jhumpa Kalan watershed of Bhiwani district of Haryana in terms of morpho-physical and chemical properties. Visual interpretation of IRS-P6 satellite imagery (FCC) of 1:50,000 was used for the preparation of base map of the area. Eight representative pedons of micro watersheds *viz*., Motipura (P1), Sainiwas (P3), Jhumpa (P5) and Budhsheli (P7) (near to IWMP) and Motipura (P2), Sainiwas (P4), Jhumpa (P6) and Budhsheli (P8) (few kms away from IWMP) were selected. Results indicated that soils of micro watersheds pedons varied in colour from dark brown to dark yellowish brown with sand to loamy sand texture along with higher sand content as compared to silt and clay. These soils were found slightly to moderately alkaline in reaction and non-saline. Bulk density, available water, organic carbon (OC), cation exchange capacity (CEC) and base saturation varied from 1.38 to 1.62 Mg m^{-3}, 2.04 to 13.8%, 0.06 to 0.27%, 2.21 to 7.85 cmol (p^+) kg^{-1} and 88.4 to 98.6%, respectively.

Environmental influence on physicochemical characteristics of soils in Tangi Block of Khurda district, Odisha

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Influence of physiography and land use on soil properties in Tangi block of Khurda district of Odisha covering 34374 ha and constituting 20 G.P's were investigated. The area falls under AESR 12.2 i.e. hot moist sub-humid ESR with medium AWC and LGP of 180-210 days in Eastern Ghat area with mean annual rainfall of 1436 mm. Based on IRS-P6 LISS IV imagery, 7 broad physiographic regions occurring under different elevations varying from 310 m to 1 mm *viz.* Hills, Foothills, Upland, Valleyfill, Alluvial Plains, Coastal Plains, Wetlands were delineated. The land use of the block varies from forest, barren land, cultivated (single/double cropping), fallow land, wastelands and open scrublands and aquaculture. Detailed soil survey of the block was carried out on 1:10,000 scale and nineteen representative soil series were identified. The soils are classified under loamy-skeletal, coarse loamy, fine loamy and fine textural classes under Ustorthents, Haplustepts, Endoaquepts and Rhodustalfs, Haplustalfs and Paleustalfs great groups. Soils were analyzed for different soil hydro-physical and chemical properties, *viz* moisture content at 0.33 bar and 15 bar, available water capacity, soil texture, organic carbon, pH, exchangeable bases etc using standard methods. Perusal of the data reveals that the Kusumi soils with clay loam texture under paddy plus moong cultivation in the very gently sloping alluvial plains recorded the highest mean organic carbon (0.67%), while the Brusbandha soils on similar landform and Kharif paddy land use showed highest AWC values (219 mm m^{-1}).The Gayabandh and Damanbhuin soils with sandy loam texture under forest plantation and degraded pasture lands showed the lowest AWC values (26.9 mm m^{-1}) and organic carbon (0.17 %), respectively. The mean clay content and CEC content of the soils varies from 6.10–69.9 % and 2.20–27.2 cmol (p+) kg^{-1} soils, respectively. The soils are strongly acidic to slightly alkaline with the surface soils (0-20 cm) showing values ranging from 4.5-7.2, while the subsurface values ranged from 4.8-8.4. The correlations study reveals that AWC content of the soils are positively correlated with the clay ($r=0.58^{**}$; $p<0.01$) and CEC values ($r=0.52^{**}$; $p<0.01$) and with the sand ($r= - 0.65^{**}$ $p<0.01$) and organic carbon % content ($r=- 0.26^{*}$; $p<0.05$) of the soils.

Study of Agri-environmental characteristics in Rajpura block of Patiala district in Punjab for sustainable productivity

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The knowledge of agri-environmental factors of an area are requisite for developing any sustainable agricultural land use plan. A study was undertaken in Rajpura block of Patiala district in Punjab state to identify the climatic variability, characteristics of soil resources, availability of irrigation water and yield pattern for evolving sustainable land use and better crop productivity. The total geographical area of the block is 28315 ha spread over 116 villages. Primary and secondary data were collected in respect of different agri-environmental parameters and interpreted. The block is facing environmental related issues like fluctuating climate, decline in water table, nutrients deficiency in soil, contamination of pollutants affecting soil health and crop productivity. From the land resource inventory of the block on 1:10,000 scale, ten soil series have been identified covering different types of physiographical units. Soils are very deep, moderately well to imperfectly drained, sandy loam, loam, silt loam, silty clay loam in texture and affected by salinity in some patches. They are classified under mostly *Inceptisols* along with *Entisols* in some areas. The climatic data reveals fluctuation in maximum and minimum temperatures. The mean maximum annual temperature ranges from 30.80 to 33.60 °C, whereas, the mean minimum annual temperature ranges from 24.0 to 26.4 °C. The annual rainfall is showing continuous fluctuation in last fifty years varying from 506 to 836 mm, whereas, in last 10 years it declined from 691 to 506 mm. The status of ground water in different soil series area indicates drastic decline in water table due to its over exploitation for irrigation purpose. The farmers of Urdan, Gopalpur, Aluna, Akar, Takhtu Majra soil series are facing acute scarcity of irrigation water as the ground water table has gone down as well as to 250, 245, 225 and 200 feet, respectively. Besides, the farmers of Lehlan, Jansui and Shamdo soil series are using contaminated water of sewage nala (Chandigarh Drain) for irrigation purposes which is affecting the soil health, quality of food produces and agricultural sustainability. The yield pattern of two dominant crops *viz*., rice and wheat in the last 3 decades indicate year wise variation depending upon rainfall, availability of irrigation water and other inputs. It reveals that in case of rice it was 31.08 q/ha (1987-1996), decreased to 29.17q/ha during 1996-2006 and increased to 33.19 q/ha during 2007-2016 at the cost of inputs *viz*. high doses of fertilizers and over exploitation of ground water. However, indiscriminate use of fertilizers and pesticides along with contaminated irrigation water are deteriorating the agri-environment. Besides, small farmers are facing hardship for food quality and other inputs. Therefore, judicious use of irrigation water, water harvesting and proper fertilization as per soil resources are highly essential for maintaining soil health and sustainable productivity.

Characterisation and classification of shrink-swell soils developed from calcic-gneiss parent material

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Nature and characteristics of shrink-swell soils developed from calcic-gneiss parent material were studied in Palani block of Dindugal District, Tamil Nadu. These soils are deep to very deep (100- >150 cm), very dark brown (10 YR 2/2) to very dark grayish brown (10 YR 3/2), poorly drained, moderately alkaline (7.8-8.6) with low to medium in organic carbon (<0.5-0.75%). The cracking nature of the soils is due to its clay texture with 55 to 66 % clay and it is increasing with increasing depth. The soils are having high cation exchange capacity (46-65 c mol(+)kg^{-1}) with maximum base saturation. Availability of phosphorus is very low (<11 kg ha^{-1}) and potassium is high in surface soils and decreases with depth. Cation exchange capacity to clay ratio ranged between 0.8 and 1.02. Calcium carbonate equivalent and exchangeable sodium percentage are increasing with depth from 3.6 to 9.0 and 0.6 to 13.9 per cent, respectively. The sulphur content of the sub-surface soils is tremendously high (>900 ppm), which might be due to the accumulation of gypsic material over the calcic-gneiss parent material beneath the soil layers. The presence of gypsic properties of the soil shows the resilience characteristics towards degradation and offer high land quality. These soils are taxonomically classified into fine, smectitic iso-hyperthermic family of Typic Haplusterts.

Spatial variability of soil organic carbon fractions as affected by different land uses in Purvanchal range of north-eastern India

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An attempt was made to assess the spatial distribution of soil organic carbon (SOC) fractions and its relation to different land use systems in north-eastern India. For this purpose, topsoil samples (0–25 cm) from 284 georeferenced points at 500 m grid interval in four major land use systems (forest, mixed, rubber plantation and cultivated) of Charilam block, Sepahijala district, Tripura of north-eastern India were collected. The values of total SOC (C_{tot}), very labile SOC (C_{VL}), labile SOC (C_L), less labile SOC (C_{LL}), non-labile SOC (C_{NL}) and lability index (LI) varied from 2.36 to 44.67 g kg^{-1}, 0.30 to 5.70 g kg^{-1}, 3.00 to 3.90 g kg^{-1}, 0.10 to 5.30 g kg^{-1}, 1.46 to 30.47 g kg^{-1} and 0.40 to 1.15, respectively. The coefficient of variation was highest for C_L (52.1%) and lowest for LI (15.1%). Gaussian model was found to be the best fit for C_{tot}, C_{VL} and C_{NL}, while exponential model was the best fit for C_L, C_{LL} and LI. The nugget/sill ratio indicated that all C fractions were moderately spatially dependent (25–57%). Spatial distribution maps of C_{tot} and its fractions were prepared by ordinary kriging. It was observed that the use of geostatistical method could accurately generate the spatial variability maps of soil variables. The amount of oxidizable organic C (OC) varied among the land uses studied. On average, its amount was highest in forest followed by rubber plantation, mixed and cultivated at 0–25 cm depth of soil, respectively. There was a statistically significant difference ($P< 0.05$) between the different pools of SOC among the land uses. The value of LI under different land uses decreased as cultivated > mixed > rubber > forest. Low LI under forest and rubber plantation might be due to lower amount of easily decomposable compounds present in the leaf litter and less churning of soils (tillage operation). The information generated from this study would allow the development and implementation of appropriate strategies for maintenance of SOC, the most important soil health parameter, for sustainable crop production.

Pedogenic characterization of paddy and associated non-paddy soils of Assam

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An investigation was carried out to study the morphological, physical, chemical characteristics as well as clay-organic carbon complexes and pedogenic distribution of Fe, Mn, Al in clay fraction of paddy and associated non-paddy soils of Jorhat (P1, NP1), Golaghat (P2, NP2), Sivasagar (P3, NP3) and Dibrugarh (P4, NP4) districts of Assam using standard procedures. Soil colour varied from dark grey (10YR 4/1) to brownish yellow (10YR 6/8) with textures from loamy sand to clay. Most of the paddy soils exhibited aquic characteristics leading to the process of gleization. Low amount of sand (11.3-49.0%) and high amount of clay (26.2-56.98%) in paddy soils as compared to non-paddy soils (23.3-65.4% and 14.4-44.4%, respectively) indicated more weathering in paddy soils. Higher amount of soil organic C (SOC) was observed in paddy soils (2.0-12.0 g kg^{-1}) as compared to non-paddy soils (0.5-10.0 g kg^{-1}). Higher amounts of SOC, exchangeable Al^{3+} and exchangeable H^{+} led to enhanced biochemical and pedochemical weathering in paddy soils. Cation exchange capacity of the soils was low (7.5-14.1 and 5.1-12.7 cmol (p+) kg^{-1} in paddy and non-paddy soils, respectively). Soils were classified as: *Typic Epiaqualfs* (P1), *Aeric Epiaqualfs* (NP1, P2, P3, NP3, P4), *Ultic Hapludalfs* (NP2), and *Typic Dystrudepts* (NP4). Organic carbon content in clay fractions (OC_{clay}) varied from 2.41-15.5 g kg^{-1} in paddy and 0.71-13.8 g kg^{-1} in non-paddy soils. The OC_{clay} constituted 37.2-65.6% of SOC in paddy and 31.6-54.6% of SOC in non-paddy soils. Appreciable amounts of humus and humin C were associated with clay fraction forming clay-organic complexes. Dominance of fulvic acid C was observed in the clay-organic complex. Less amounts of dithionite Fe and more amounts of oxalate Fe were associated with clay in the paddy soils. In general, different forms of Fe, Mn and Al in the clay fraction followed the sequence: dithionite extractable > oxalate extractable > pyrophosphate extractable.

Identification and characterization of Alfisols in Barind region of West Bengal

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Barind region is the largest physiographic unit in the Bengal Basin developed in Pleistocene era. This tract is largely distributed in the eastern part of Maldah district of West Bengal. This area is dominated by older alluvium and has a very well developed soil. A detailed study of land resource inventory at 1:10,000 scale was conducted in four blocks (Gazole, Bamangola, Habibpur and Old Maldah) mostly situated in the Barind region of West Bengal. *Kharif* rice is the dominant crop of this region followed by mustard/ wheat/ potato/ fallow depending on the availability of irrigation water in *Rabi* season. It has been observed that, in the gently and very gently sloping old alluvial plain, there is a formation of Alfisols, which has not been reported in the earlier soil resource inventory and mapping by any of the National Institutes. The formation of Alfisols in these four blocks have been influenced by comparatively higher elevation than the adjacent areas, non-occurrence of flood, stable landform characteristics, which subsequently promoted clay illuviation and enrichment in sub-soil region. Soils are slightly acidic to neutral in reaction (pH ranges from 4.7 to 7.5) with low to medium soil organic carbon content, low CEC, low to medium nitrogen and potash, low phosphorus and sufficient micronutrient levels. The distribution of Alfisols have taxonomically been defined and demarcated at 1:10,000 scale map.

Effect of climate on seasonal variation of soil salinity and alkalinity in coastal Odisha for sustainable crop production

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Soil salinity is a major environmental constraint to crop production, affecting about 45 million hectares of irrigated land and is expected to increase due to global climate changes. Excess presence of salt disperses soil structure, reduces permeability and accelerates the soil degradation. In coastal Odisha, majority of rainfall occurs during Mid-June to 1st week of October leaving rest of the period almost dry. Salinity increases with the progress of such dry period. Soil salinity in coastal Odisha is mainly due to sea and brackish lake water intrusion and reverse flowing of sea water from river during summer. Development of salinity, sodicity and toxicity problems in soils not only reduces crop productivity but also limits the choice of crops. In this region, pH varied from moderately acidic to slightly alkaline (5.4 to 8.1) and ECe from slight to very severe (1.37 to 16.86 dS m^{-1}). The ECe value increased with increasing depth of soils. Exchangeable bases were in the order of $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ on the exchange complex and exchangeable sodium percentage (ESP) values were low in surface soils which gradually increased with the soil depths, ranging from 9.3 to 22.9%. The high salt content in subsurface layer may be due to lower topographic position, that receives salts periodically through runoff and seepage movement. Also, high water table and secondary salinization were responsible for increasing sub-surface salinity in coastal Odisha during dry period. Therefore, appropriate land and soil managements promoting diversification is needed for higher agricultural crop production.

Assessment of clay-humus stability through IR spectroscopy in a long term integrated nutrient management experiment

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An attempt has been made in assessing the stability of clay-humus in five long term treatments under rice-wheat cropping system of Integrated Farming System (IFS) research experiment, GBPUA&T, Pantnagar. The treatments used were as follows: T_1= control (no fertilizer), T_2= 100% recommended dose of NPK by chemical fertilizer, T_3= 50% recommended dose of NPK by chemical fertilizer+ 50% N by FYM, T_4= 50% recommended dose of NPK by chemical fertilizer+ 50% by N through straw, T_5= 50% recommended dose of NPK by chemical fertilizer+ 50% by N through green manure. The clay, clay-humus and humic acid fraction have been isolated from the surface soils (0-15 cm depth). All the fractions were subjected to FTIR study for characterization of clay, clay-humus and humic acid. The FTIR spectra of clay, humic acid and clay-humus showed that in clay humus complex structural OH at 3621 cm^{-1} and 2918 cm^{-1} (aliphatic C-H stretching) region of the clay was shifted towards 3417 cm^{-1}, which is indicative that when organic input was added the adsorbed humus had more retention of adsorbed water that produced strong absorption band of water-OH group around 3400 cm^{-1}. The clay humus bonding through inorganic cations led to strong water absorption band of these complexes that reduced and shifted to lower peak after complexation. FTIR adsorption bands at 1713 cm^{-1} (C=O stretching of COOH and ketonic C=O), 1609 cm^{-1} (aromatic C=C), and 1217 cm^{-1} (C-O stretching and OH deformation of COOH groups) were observed in humic acid. However, the reactive functional groups at 1713 cm^{-1} and 1609 cm^{-1} and 1217 cm^{-1} were reduced in clay–humus complex due to polymerization between clay and humus which shifted towards a broad absorption band at 1026 cm^{-1}. This alteration of humic acid peak in clay humus complex indicated the involvement of ketones, carboxyl and amide moieties in complexation with octahedral OH of the clay minerals leading to stabilizing of carbon in humic acid through clay-humus bonding.

Impact of land form and land use changes on soil potassium pools in Meghalaya Plateau of India

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Meghalaya plateau consists of a major part of the state of Meghalaya. A detailed soil survey at 1: 10000 scale using geo-spatial techniques was carried out in Jirang block of Ri-Bhoi district of Meghalaya. Soil samples were collected from different landforms under different land uses. Soils from four different landforms and three different land uses, viz. denundational hill under forest vegetation, highly dissected plateau under shifting cultivation, lowly dissected plateau and valley plain under paddy cultivation were tested for K fractions. The K fractions include available K, exchangeable K, non-exchangeable K, mineral K and total K. The ranges of different K fractions varied according to landform and land use. Highest available K (124.2 to 389.6 kg ha^{-1}) was found in highly dissected plateau under shifting cultivation in the surface soil layers. A strong positive correlation was found between available K and exchangeable K in all the landforms. A weak positive correlation was found between available K and non-exchangeable K in denundational hill under forest vegetation (0.57), highly dissected plateau under shifting cultivation (0.59) and lowly dissected plateau under paddy cultivation (0.52) while a weak negative correlation (-0.067) was found between these two pools in valley plain under paddy land use system, including samples from all the layers of soil profile. Highest exchangeable K was detected in highly dissected plateau under shifting cultivation (104.8 to 322.4 kg ha^{-1}) in the surface soil layers. The soils were also analyzed for non-exchangeable K which was found to be highest (261.8 to 3073.06 kg ha^{-1}) in valley plain. The mineral K (8824.7 to 67183.9 kg ha^{-1}) and total K (9072.0 to 67872.0 kg ha^{-1}) was found to be highest in highly dissected plateau under shifting cultivation in the surface soil layers. Hence, the study shows that the changes in landform and land use highly impact the soil potassium pools.

Impact of land use on soil organic carbon stocks in Meghalaya Plateu of India

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Soil organic carbon (SOC) constitutes a significant proportion of the terrestrial carbon pool and its management becomes very important to sustain agricultural productivity. Understanding SOC dynamics in the hilly areas is a challenge due to its varying physiographic position and accelerated soil erosion. Here, we attempted to determine the SOC pools for land use planning. The study area comprised of Jirang block, Ri-Bhoi district, Meghalaya, India (Agro-Ecological Sub-Regions 15.2 and 17.1), where a detailed soil survey had been conducted for soil resource mapping. Horizon wise soils sample were collected up to a depth of 150 cm from four different landforms and three different land uses, viz. denudational hill under forest vegetation, highly dissected plateau under shifting cultivation, lowly dissected plateau and valley plain under paddy cultivation. The SOC chemical pools of very labile (VLC), labile (LC), less labile (LLC) and non-labile (NLC) were determined. In different land-use systems VLC, LC, LLC, and NLC varied from 14-22, 2-16, 4-21 and 29-45 % of total soil organic carbon respectively in 0-30 cm soil depth. The SOC stocks vary from 31- 80 Mg ha^1 and highest was under paddy cultivation in the upper valley plain and lowest under forest in denudational hills in 0-30 cm soil depth. The cumulative SOC stock (0-150 cm) ranged from 88- 234 Mg ha^1 and followed the same order as in 0-30 cm. Active carbon stocks ranged from 12-20 Mg ha^1 while passive carbon stocks range from 17-63 Mg ha^1 under the different land-use system in 0-30 cm whereas cumulative active and passive carbon stocks ranged from 32-60 Mg ha^1 and 41 -173 Mg ha^1 respectively. A strong positive correlation (0.95) was found between the passive pool and total soil organic carbon and very weak positive correlation was found between clay and active pool (0.001), clay and passive pool (0.067). The study shows that different land use and landform has a great effect on different pools of SOC and its stocks.

Boron availability in acid soils of Brahmaputra valley with varying organic carbon content

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Boron (B) is one of the essential micronutrients for plant growth and development. In general, the availability of boron in soil is governed by various soil physical and chemical properties. Soil pH and organic carbon are widely discussed in literature as important soil properties to control boron availability in soil. It is also reported that the boron deficiency in acid soils of humid to per-humid regions is quite common. Further, non application of boron containing fertilizers into these soils aggravates boron deficiency. Maintenance of boron at proper level in such acid soils is of immense importance as far as plant growth and productivity are concerned. Understanding boron availability in different fractions and their relationship with other soil properties is imperative in the context of acid soils of humid to per- humid regions. In the present study, an attempt has been made to assess boron content in different fractions in acid soils of varying land use systems with differential organic carbon content. Interactive effect of land use system and soil depth on different boron fractions were also assessed for studying the relationship between boron content in different fractions and important soil properties including soil organic carbon content. Soil samples were collected from three different land use systems namely, tea, sugarcane and rice fallow systems in Jorhat and Golaghat district of Assam. Soil samples were collected from five different locations under each land use system at three different depth namely, 0-15, 15-30 and 30-60cm. Results indicated that soil pH under tea land use system was extremely acidic. Whereas, soil pH was very strongly acidic under sugarcane land use system and soils of rice-fallow land use system were strongly acidic in reaction. On an average, the availability of readily soluble and specifically adsorbed boron were higher in tea growing soils than that in sugarcane and rice growing soils. As far as the availability of other boron fractions are concerned, oxide bound and organically bound boron contents were significantly higher in tea and sugarcane growing soils than that in rice growing soil. However, no significant difference in residual and total boron content was recorded in soils of different land use systems. In general, readily soluble, specifically adsorbed, oxide bound, organically bound and total boron content decreased significantly with soil depth. Correlation analysis indicated significant negative correlation between soil pH and different boron fractions, excepts residual boron. Whereas, CBD-extractable Fe and

organic carbon content were positively correlated with boron content in different fractions. Significant higher positive correlation between readily soluble boron and organic carbon content as determined using 12N H_2SO_4 indicates that boron availability in soil solution in highly governed by the fraction of organic carbon oxidized with 12N H_2SO_4. Similarly, the results indicate that specifically adsorbed boron is also governed by the organic carbon fractions oxidized with 12N and 18N H_2SO_4. Further, the results of the present study indicate that specifically adsorbed and organically bound boron predominantly governed boron availability in readily soluble fraction. The study indicates that soil pH, CBD-extractable Fe and organic carbon content are the most important parameters governing boron availability in acid soils of Brahmaputra valley region of Assam. The information generated in the present study would be useful in devising appropriate strategy for management of boron in acid soils of humid to per- humid region.

Role of clay particles in sustainability of rice-wheat cropping system in Indo-Gangetic Plains - a case study

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India is endowed with one of the most fertile and densely populated plains of the world, popularly known as Indo-Gangetic Plains (IGP). In India, it covers several states of northern, central and eastern parts *i.e.,* major parts of Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal. IGP produces about 50 percent of the total food grains and able to feed about 40% population of the country. Thus, soil resources of this region need to be utilized according to their suitability and capability for various land uses besides their good health. In the past few decades, the quality of soil resources of IGP has been suffered due to several constraints including soil salinity, waterlogging and erosion, which decreases or the sustainability of rice-wheat cropping systems. Stagnation in production capacity of rice-wheat system in IGP region poses great challenge before scientific community, planners and policy makers. In light of this, a case study was undertaken in *Chhata tehsil* of Mathura district of Uttar Pradesh to evaluate the soil resources for their suitability to sustainable crop production. The extent of study area is between 27° 33' to 27° 56' N latitudes and 77° 17' to 77 ° 42' E longitudes, and spreads over an area of1063.5 km^2. It is comprised of alluvium of sand, silt and clay as well as their mixture in varying proportions besides hillocks of Aravalli Mountains. The area has been surveyed on 1:50000 scale to collect the soil samples from different horizons in each interpreted physiographic units. Soil samples have been processed for physico-chemical properties using standard procedures. Soil suitability of rice and wheat crops has been evaluated as per FAO framework for land evaluation.

In the study area, wheat occupied highest area (52.3%) followed by rice (24.8%) indicating the dominance of rice-wheat cropping system. In Chhata tehsil, total nine soil series *viz., Simri, Garhsauli, Tarauli, Chhatikara, Chhata, Ladpur, Neri, Bechhawan Bihari* and *Barsana* have been identified. Soil series characterization indicated that soil texture, primarily the clay content plays a crucial role in evaluating soil suitability for crops due to its controls over water and nutrients retention and release behavior. Results revealed that *Simri* soil series with very deep, moderately to imperfectly drained, loam to clay loam, calcareous soils (lime concretion below 50 cm) and sodicity problem, grouped under marginally suitable class (S3) for rice and wheat crops, recorded the yield of 56.3 and 46.3 q ha$^{-1,}$ respectively. *Garhsauli* series with very deep, moderately well drained,

loam to clay loam, calcareous soils having few lime nodules below 75 cm, classified S3 for wheat while, moderately suitable (S2) for rice, and produced 47.5 and 62.5 q $ha^{-1,}$ respectively. *Neri* series with very deep, well drained to moderately well drained, sandy loam, calcareous soils with lime concretion below 75 cm (hard pan) evaluated as S2 for rice and wheat crop, and produced 60.0 and 48.8 q $ha^{-1,}$ respectively. *Bechhawan Bihari* series characterized as very deep, somewhat excessively drained, loamy sand over sandy and subjected to annual flooding, assessed to be marginally suitable (S3) for both rice and wheat crops, which produced 55.0 and 50.0 q $ha^{-1,}$ respectively. *Barsana* series is shallow, excessively drained, gravelly sandy loam soils on 15-30% slopes, and occupies only very small portion of the study area, and qualified under presently not suitable class (N1) for agricultural and horticultural crops. Based on soil resources characterization, it can be concluded that finer particles (clay content) had greater influence on soil suitability and crop yield of both rice and wheat due to their role in controlling nutrient uptake and release besides water retention. Thus, clay particles assumes greater role in soil suitability for sustaining the productivity of rice-wheat cropping system in the IGP region of India.

Classical cracking pattern in Sodic Vertisols of Gujarat

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Vertisols have unique morphology and the capacity to change volume with changes in water content. Shape, size and depth of cracks, gilgai, slickensides, pressure faces etc. are the typical features of shrink–swell soils. Cracking patterns are not merely the response of the soil material to dehydration, but rather the differential moisture status of the soil at different depths. Such soil moisture dynamics plays a role in determining the size, shape, and frequency of the cracks. A classical cracking pattern was observed in Sodic Haplusterts of Gujarat. Study area is situated in west coast, near the Sabarmati river of Dholka block, Ahmedabad. The sampling field was ploughed after draining out the surface water filled during monsoon. The ploughing was done at 60 cm interval using tractor operated cultivator cum seed driller. Sorghum seeds were sown in the rows at 60 cm intervals. Seed germination was very low due to salt and moisture stress. The crop was failed within two months from the date of showing due to water shortage. A profile was dug in field during the month of December. While observing the profile, there was soft friable layer of soil on the surface. The upper 6 cm soil layer was removed very carefully. It was observed that soils were cracked in a very systematic pattern underneath the soft friable layer. Approximately, 2-3 cm wide and 50-60 cm deep cracks were observed in the row where sorghum seeds were sown. The field was appearing just like the sweet pieces were cut in very decorative manners. The primary reason might be the removal of moisture by plant roots was faster in soils nearby the plant roots which created more negative water potential and developed the point of weakness. These soils were clayey in texture, Alkaline (pH 8.7-9.5) in reaction, calcareous ($CaCO_3$12-22%) with high exchangeable sodium percentage (33-80).

Morphological and physico-chemical characteristics of soils: A case study of Bharuch Taluka, Bharuch district of Gujarat

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Studies on natural resources are a prerequisite for execution of any community development programme at village, taluka, district or state level. Soil resources are the major component for sustainable agricultural developments. The soils of west coast of Gujarat are under tremendous pressure due to intensive industrial and agricultural uses. Therefore, detailed soil survey (1:10000 scale) of Bharuch taluka of Bharuch district, Gujarat was carried out using IRS-P6 LISS IV and Cartosat-1 images to characterize and classify the soils. Typifying pedons representing major landforms of the area *viz.* old and recent alluvial plains developed from basaltic parent material were characterized and classified. The soils were very deep, clay to loamy in texture, well to moderately well drained, very dark gray (10YR3/1) to dark yellowish brown (10YR4/4), subangular blocky structure, neutral to slightly alkaline in reaction having low to medium organic carbon, low to high calcium carbonate (1.88 to 16.48%) with high base saturation (>50%). The clay content of the soils varied from 23.3 to 66.6% and decreased with soil depth. The sand and silt content of the soils varied from 7.8 to 27.7% and 24.2 to 49.3%, respectively. Based on morphological and physico-chemical characterization soils were classified as Typic Haplusterts, Vertic Haplustepts and Typic Haplustepts and a detailed soil map was prepared for sustainable agricultural land use planning.

Large-scale soil mapping (1:10,000) using geospatial techniques- A case study of Gandhidham, Kutch district, Gujarat

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Large scale (1:10000) soil mapping serves as a major source of information for planners and executives to use soil information for enhancing agricultural productivity. Gandhidham is the part of Kuchchh Peninsula sub physiography which belongs to Gujarat coastal plain. Gandhidham known as economic capital of Kutch and it is a fast developing city in Gujarat state. Cotton, castor and pigeon pea were the major crops, mango and papaya were the major fruits growing area in Gandhidham block. Based on landform, slope class and land use four land ecological units (LEUs) were delineated to characterize the land resources. These LEUs are associated with the two major landform i.e., piedmont plain and pediment. Three soil series namely Kidana and Shinay were identified in piedmont plain while soils of Antarjal series are in pediment area. Kidana soils are very deep, sandy clay loam, strongly alkaline (pH >8.5), non-saline (EC 0.16 to 0.40 dS m^{-1}) having low organic carbon content (OC < 0.5%), medium to high calcium carbonate (10.31 to 18.13%) with high CEC [58.50 to 71.50 cmol (p^+) kg^{-1}]. Exchangeable complex was dominated by Ca^{2+} followed by Mg^{2+}, Na^+ and K^+ cations with high (36.93 to 61.13%) base saturation with moderate erosion whereas Shinay soils are moderately deep sandy loam to sandy clay loam, moderately alkaline (pH <8.5), non-saline (EC < 2 dS m^{-1}) having low organic carbon content (OC < 0.5%), medium to high calcium carbonate (14.38 to 19.06 %), high CEC [58.50 to 71.50 cmol (p^+) kg^{-1}]. Exchangeable complex was dominated by Ca^{2+} followed by Mg^{2+}, Na^+ and K^+ cations with high (49 to 52 %) base saturation. Antarjal soil series was shallow, sandy clay loam moderately alkaline, non-saline having moderate organic carbon content (OC 0.75%), high calcium carbonate (> 15%), medium CEC [22.75 to 30.88 cmol (p^+) kg^{-1}] and high (64 to 71%) base saturation. The soil map was prepared with five phases of soil series with detailed information can be used for better agricultural planning.

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